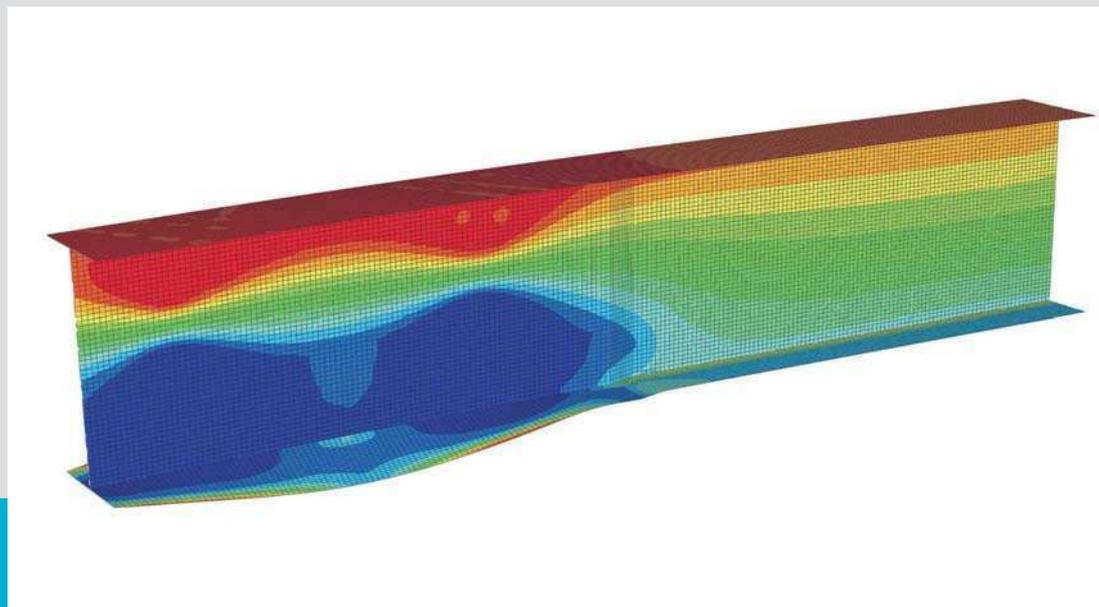


Stabilitätstragverhalten von gedrückten Stahlträgerunter- gurten veränderlicher Dicke

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Masterarbeit

Thema

STABILITÄTSTRAGVERHALTEN VON GEDRÜCKTEN STAHLTRÄGERUNTERGURTEN VERÄNDERLICHER DICKE

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Graz, Juni 2010

ERKLÄRUNG

Hiermit erkläre ich an Eides Statt, dass ich die vorliegende Masterarbeit selbständig und ohne fremde Hilfe verfasst habe, andere als die angegebenen Quellen nicht benutzt und die, den benutzten Quellen wörtlich und inhaltlich entnommenen Stellen, als solche erkenntlich gemacht habe.

Graz, Juni 2010

Michael Tillian

KURZFASSUNG

In dieser Masterarbeit wird das Stabilitätstragverhalten (Lokales Beulen) von gedrückten Stahlträgeruntergurten veränderlicher Dicke mittels Finite Element Berechnung untersucht. Es soll gezeigt werden, ob bei Untergurtdickensprüngen eine Steife anzuordnen ist, oder ob auf diese verzichtet werden kann.

Um ein entsprechendes Ergebnis zu erzielen, wird mittels eines Finite-Element-Programms anhand von zwei verschiedenen I-Profil Trägern mit unterschiedlicher Bauhöhe, zuerst eine Lineare Analyse zur Systemkontrolle durchgeführt. Danach werden an den beiden Trägern und zusätzlich als Referenz an dreiseitig gelagerten Platten lineare Beulanalysen erstellt, um Imperfektionsformen, geeignete Elementtypen und Randbedingungen, sowie das kritische Tragverhalten zu ermitteln.

Anschließend werden anhand der zwei symmetrischen I-Profil Träger mit den unterschiedlichen Bauhöhen geometrisch und materiell nichtlineare Berechnungen unter Berücksichtigung von geometrischen und strukturellen Imperfektionen durchgeführt. Einerseits werden geometrische Imperfektionen aus den zuvor berechneten Eigenformen für den Grundfall ohne Dickensprung und auch neu generierte Imperfektionen für die Berechnungen mit Dickensprung am gedrückten Untergurt aufgebracht. Weiters wird der Effekt von Schweißeigenstressungen am Gurt untersucht. Die Untersuchungen werden bei einem konstanten Normalspannungsverlauf im Gurt über die Trägerlänge sowie mit einer Spannungsgradienten, welche am Dickensprung die Streckgrenze erreicht, durchgeführt. Durch die Anordnung von Quersteifen am Gurtdickensprung wird die aussteifende Wirkung der Steife im Vergleich zur Berechnung ohne Steife dargestellt.

ABSTRACT

In this master thesis the stability behaviour (local buckling behaviour) of flange thickness transitions of welded I-section steel beams is analyzed by means of the Finite-Element method. The aim is to work out a thorough understanding of the mechanical behaviour and to investigate the effect of additional vertical stiffeners at the position of flange thickness transitions as specified by the present design standards.

In order to achieve adequate result, in a first step a linear analysis is performed. Thereby two different I-section steel beams are investigated by the Finite-Element program ABAQUS and system checks are done. Then linear buckling analyses are performed for these two sections. The buckling analyses are used to provide imperfection shapes, to find out appropriate mesh and boundary conditions and to investigate the critical buckling behaviour. For reasons of comparison, these analyses also are performed on equivalent three-sided supported plates including thickness transitions.

As the main topic of this thesis, a parametric study applying geometrically and materially nonlinear Finite-Element analyses including geometrical and structural imperfections is accomplished for double-symmetric I-section steel girders with two different sizes. Separate local buckling imperfection shapes at the flange thickness transitions are also developed. The effects of welding residual stresses are investigated in detail. In the nonlinear investigations, constant as well as linear variable bending moment distributions which reach the elastic stress limit at the thickness transitions are analysed. Since all of these analyses are performed for sections with and without additional vertical stiffeners at the transition zone, the beneficial effect of vertical stiffeners is illustrated.

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Verwendete Formelzeichen und Kürzel

| | | |
|----------------------|-----|---|
| f_y | ... | Streckgrenze |
| E | ... | E-Modul |
| ν | ... | Querdehnungszahl |
| σ_x | ... | Normalspannung in Längsrichtung |
| σ_y | ... | Querspannung |
| τ_{xy} | ... | Schubspannung |
| u_x | ... | Verschiebung in globaler x-Richtung |
| u_y | ... | Verschiebung in globaler y-Richtung |
| u_z | ... | Verschiebung in globaler z-Richtung |
| k_σ | ... | Beulwert |
| α | ... | Längenverhältnis zu Breiter der Platte a/b |
| ρ | ... | Koeffizient |
| q | ... | Koeffizient |
| m | ... | Wellenlänge |
| Δ | ... | Abweichung zweier Werte zueinander |
| s_{11} | ... | Normalspannung ABAQUS in x-Richtung |
| N_x | ... | Normalkraft in x-Richtung |
| M_y | ... | Moment um die y-Achse |
| σ_{crit} | ... | kritische Beulspannung |
| σ_e | ... | Euler'sche Bezugsspannung |
| $\sigma_{crit, ABQ}$ | ... | aus ABAQUS rückgerechnete kritische Beulspannung |
| σ_{mittel} | ... | mittlere Normalspannung im Gurt |
| EV1, 2, 3 | ... | Eigenwerte aus ABAQUS |
| LA | ... | Lineare Analyse |
| LBA | ... | Lineare Beulanalyse |
| GMNIA | ... | Geometrisch und materiell nichtlineare Analyse mit Imperfektionen |
| a.L. | ... | analytische Lösung |
| OB | ... | oben bündige Anordnung bei Gurt dickensprung am UG |
| UB | ... | unten bündige Anordnung bei Gurt dickensprung am UG |
| Z | ... | zentrische Anordnung bei Gurt dickensprung am UG |

1. Aufgabenstellung

1.1. Allgemeines

Laut Eurocode 3 [4] sollen geschweißte Bleche unterschiedlicher Blechdicken bei Stahlträger in der Nähe von Quersteifen ausgeführt werden, damit die an der Unstetigkeitsstelle auftretenden Exzentrizitätseffekte in der Bemessung unberücksichtigt bleiben dürfen. Andernfalls sind diese zu berücksichtigen. Nun stellt sich die Frage, ob sich bei einem hinreichend großen Unterschied in den Wanddicken der beiden Bleche, dem Verhältnis t_1 zu t_2 , die Anordnung von Steifen nicht erübrigen könnte. Da angenommen werden kann, dass sich eine Einspannwirkung der dünneren Platte in die dickere Platte einstellen, und somit eine aussteifende Wirkung der dünneren Platte ergeben wird. Im Gegensatz dazu treten die Exzentrizitätseffekte und Normalkraftunterschiede am Gurt dickensprung auf.

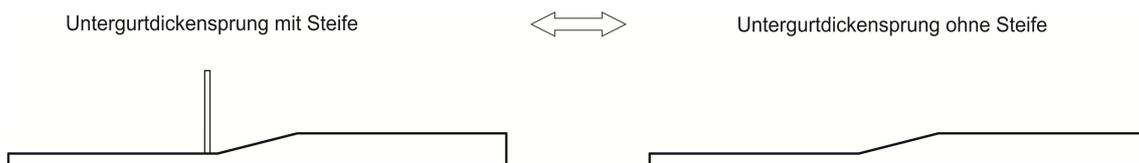


Abbildung 1: Veranschaulichung Untergurtdickensprung mit/ohne Steife

Anhand dieser Masterarbeit soll untersucht werden, wie das tatsächliche, nichtlineare Tragverhalten von Trägern mit Gurt dickensprung aussieht.

Im ersten Teil dieser Arbeit steht die FE-mäßige Ermittlung kritischer Beulspannungen von Platten und Trägern, mit und ohne Gurt dickensprung und deren Vergleich soweit möglich mit entsprechenden analytischen Lösungen. Anschließend wird eine umfangreiche Parameterstudie mittels nichtlinearer Finite-Element-Berechnungen der Platten und Träger, mit und ohne Dickensprung, durchgeführt. Bei diesen Berechnungen werden die lokalen Imperfektionsformen gemäß EN 1090-2 [5] bzw. EN 1993-1-5 [4] angesetzt.

Anhand der Ergebnisse dieser Parameterstudie soll ein späterer Bemessungsvorschlag, mit oder ohne Steife, bei Untergurtdickensprüngen ermöglicht werden. Der Schwerpunkt dieser Arbeit liegt in der FE-mäßig basierenden Untersuchung von einer Vielzahl an Parametern und deren Dokumentation.

1.2. Vorgehensweise in dieser Masterarbeit

Zunächst soll in einer Systemmodellierung, mit einer für die Berechnung im Finite Element Programm ABAQUS [1] geeigneten Netzteilung, passende Elemente und allgemein eine sehr realistische Modellierung der Platte und des Trägers gefunden werden. Diese soll anhand einer analytischen Lösung der kritischen Beulspannungen nach [9] und einer Berechnung mit dem Finite-Streifen-Programm CUFSM [2] überprüft und verfeinert werden.

Anschließend werden kritische Beulspannungen von Platten und Trägern mit und ohne Untergurtdickensprüngen ermittelt und miteinander verglichen. Der Vergleich der Einzelergebnisse erfolgt über den Beulwert k_{σ} .

Im Anschluss werden geometrisch und materiell nichtlineare Berechnungen (GMNIA) mit dem Ansatz von geometrischen und strukturellen Imperfektionen durchgeführt. Diese Ergebnisse werden für den Stahlträgeruntergurt mit Dickensprung, mit oder ohne Steife, sowie für den Bezugsfall der dreiseitig gelenkig gelagerten Platte verglichen und in Form von Diagrammen und Tabellen gut ersichtlich dargestellt.

2. Systemmodellierung

2.1. Allgemeines

Um ein möglichst realistisches Finite Element Modell (FE-Modell) zu erhalten, waren vorab einige Vergleichsrechnungen mit verschiedenen Lagerbedingungen und Elementtypen erforderlich.

Die Vergleichsrechnungen erfolgten anhand zweier geschweißter I-Profil Träger mit unterschiedlichen Steghöhen sowie getrennt für den Grundfall der dreiseitig gelenkig gelagerten Rechteckplatte. Die Berechnungen wurden grundsätzlich mit dem Finite Element Programm ABAQUS [1] durchgeführt. Als Vergleich wurden die klassischen analytischen Lösungen basierend auf der Kirchhoff'schen Plattentheorie der dreiseitig gelagerten Platte nach [9] als Referenzwerte herangezogen. Zusätzlich wurden die so ermittelten Beuleigenwerte der dreiseitigen Platte mittels dem Finite Streifen Programm CUFSM [2] überprüft.

Untersucht wurden jeweils die erste Beuleigenform und der zugehörige Beuleigenwert der unterschiedlichen Bauteile. Zur Berechnung des Beulwertes k_{σ} , welcher als Vergleichswert dient, wurde jeweils die per Handvergleichsrechnung ermittelte Membranspannung (mittlere Druckspannung) herangezogen.

2.2. Material

Die gesamten Berechnungen wurden mit einem Stahl der Güte S355

Streckgrenze $f_y=355 \text{ N/mm}^2$

E-Modul $E=210000 \text{ N/mm}^2$

Querdehnungszahl $\nu=0.3$

durchgeführt.

2.3. Belastung

Bei den Untersuchungen am Träger erfolgte die Belastung mit einer konstanten Drucknormalkraft in den Platten bzw. in den Untergurten. Als Belastung der Träger wurde, wie in Abbildung 5 und Abbildung 7 dargestellt, von einem konstanten Biegemomentenverlauf ausgegangen. Die Belastung für die Vergleichsrechnungen an der dreiseitig gelagerten Platte wiederum wurden äquivalent zur konstanten Momentenbeanspruchung über eine konstante Normalkraftbeanspruchung, wie in Abbildung 11 dargestellt, belastet. Aus Gründen der Modellierung wurde diese konstante Normalkraftbeanspruchung mittels einer Einzellast am Plattenende erzeugt, welche auf den Plattenrand gleichmäßig verteilt eingeleitet werden konnte. Durch geeignete Koppelungsbedingungen wurde dies ermöglicht.

Die im Träger durch den Dickensprung auftretenden Spannungen σ_y und τ_{xy} wurden in den Vergleichsrechnungen an der Platte vernachlässigt.

Die Beanspruchung erfolgte mit konstanter Normalspannung σ_x . Querspannungen σ_y und Schubspannungen τ_{xy} wurden hier nicht untersucht und daher gleich Null gesetzt. Der Einfluss des veränderlichen Normalspannungsverlaufes in Längsrichtung wurde nur, soweit erforderlich, untersucht.

2.4. Geometrie

2.4.1. Trägergeometrie

Die Träger wurden mit den Bauteilabmessungen L/B/H modelliert (siehe Abbildung 2).

L ... Gesamtlänge der Trägers

B ... Gesamtbreite des gedrückten Untergurtes

H ... Höhe des Trägers

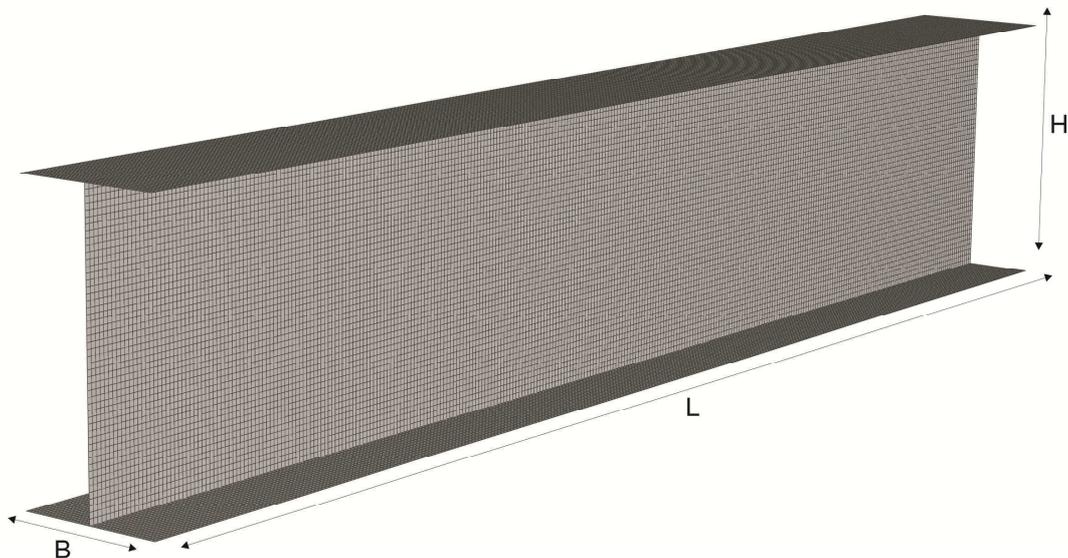


Abbildung 2: Trägerabmessungen des Referenzträgers

Als Querschnitte wurden geschweißte einfach- bzw. doppelsymmetrische I-Profile behandelt, siehe Abbildung 3. Als Trägerlängen wurden ganzzahlige Vielfache der halben Untergurtbreite mit Werten von $\alpha_{\min} = 1$ bis $\alpha_{\max} = 70$ untersucht, siehe Tabelle 1. Der Wert α beschreibt das Plattenverhältnis a/b (Plattenlänge / Plattenbreite). Der Einfluss von Schubverformungen wurde an breiten Scheibengurten nur in der Beulanalyse der dreiseitig gelagerten Platte untersucht.

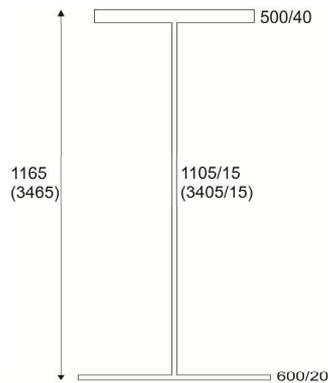


Abbildung 3: Verwendete Querschnitte

| α | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 15 | 20 | 25 | 30 | 40 | 50 | 60 | 70 |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|------|------|------|
| L | 114 | 171 | 228 | 342 | 456 | 570 | 684 | 798 | 912 | 1026 | 1140 | 1710 | 2280 | 2850 | 3420 | 4560 | 5700 | 6840 | 7980 |

Tabelle 1: Verwendete Längen bezogen auf das Längenverhältnis α , Referenz UG-Breite $B_{UG}=600\text{mm}$

Ziel der Untersuchung ist das nichtlineare Tragverhalten von gedrückten Stahlträgeruntergurten in der Nähe von Gurtdickensprüngen zu analysieren. Um lediglich den Grundfall des reinen UG Beulens ohne Einfluss des Stegs bei I-Trägern zu untersuchen, wurde bei der Trägermodellierung einerseits das lokale Beulen des Stegbleches durch seitliche Halterungen ausgeschlossen, und andererseits auf die Einspannwirkung des Gurtbleches in den Steg durch gelenkige Koppelungsbedingungen verzichtet. In Längsrichtung ist die Schubübertragung über die Stegkehlnähte möglich. Weiters ist der Obergurt durch zusätzliche Halterungen gegen Verdrehung gesichert.

Der Trägeruntergurt ist gegen seitliches Ausknicken gesichert. Lokale Beulverformungen (Drillknicken) des Untergurtes sind frei möglich.

Diese Modellierungsannahmen gelten für den ganzen Teil dieser Arbeit. Überlagerungen von Stegeinflüssen bei Gurtdickensprüngen sind nicht Teil dieser Arbeit.

Diese Modellierungsannahmen sollen den Einfluss der Dickensprünge möglichst klar herausstellen, da hier ein Stegeinfluss auf die Beulform nicht gegeben ist. Die Auswirkungen der Schubkraftkoppelung auf die lokale Beultragfähigkeit im Bereich des Gurtdickensprungs im Vergleich zur idealen dreiseitig gelagerten Platte wurden rechnerisch ermittelt und im hinteren Teil dieser Arbeit ausgewiesen.

Der Obergurt und der Steg des Trägers wurden mit S4 Schalen-Elementen modelliert. Der Untergurt wurde einerseits ebenfalls mit S4 Elementen, andererseits mit C3D8 Volums-Elementen gestaltet.

Um eine konstante Lasteinleitung über die Breite der Einzelplatte zu gewährleisten, wurde an jedem Ende des Trägers ein starrer Querschnitt (siehe Abbildung 9) mittels Connector-Elementen erzeugt, welcher das aufgebrachte Moment bzw. die aufgebrachte Normalkraft (Platte) gleichmäßig in den Trägerquerschnitt einleitet.

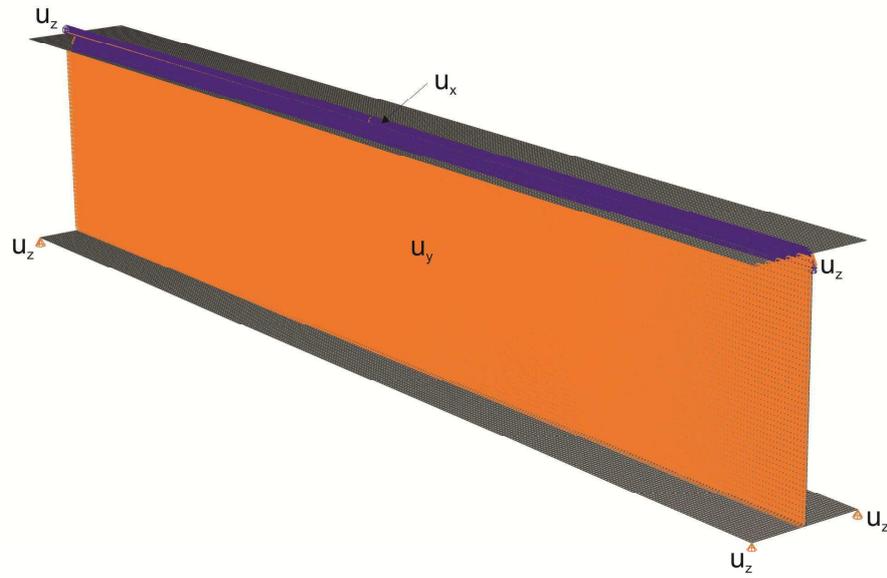


Abbildung 4: Lagerung des Trägers

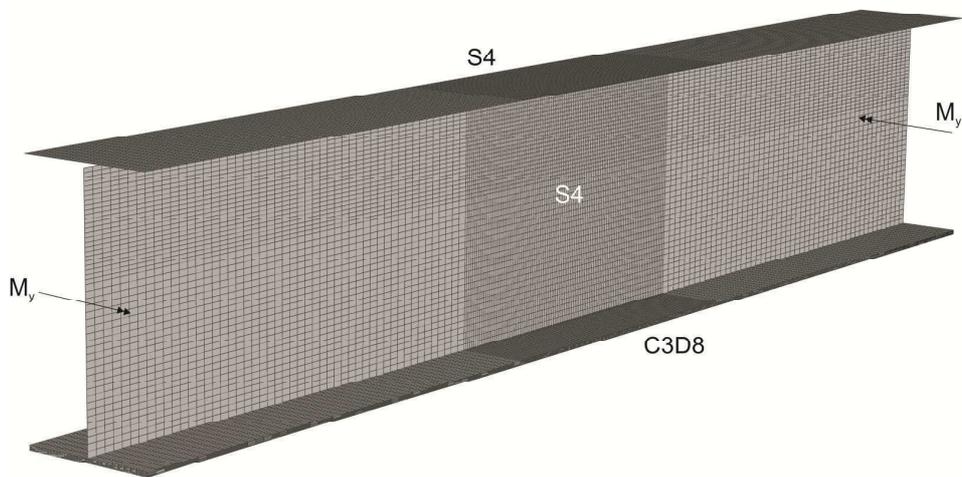


Abbildung 5: Darstellung I-Träger mit Volumselementen und Momentenbelastung

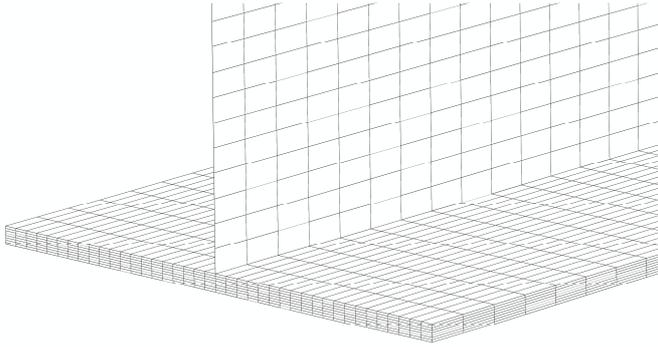


Abbildung 6: Detailansicht Volumselemente C3D8

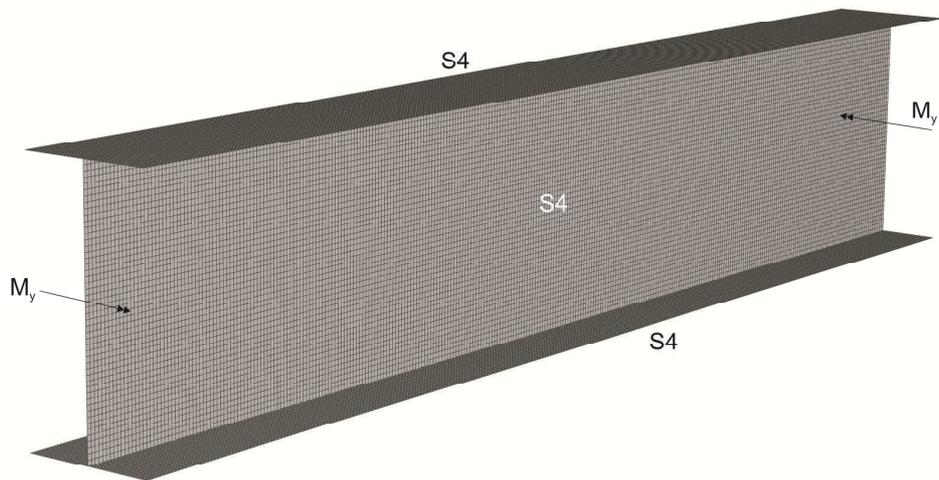


Abbildung 7: Darstellung I-Träger mit Schalenelementen und Momentenbelastung

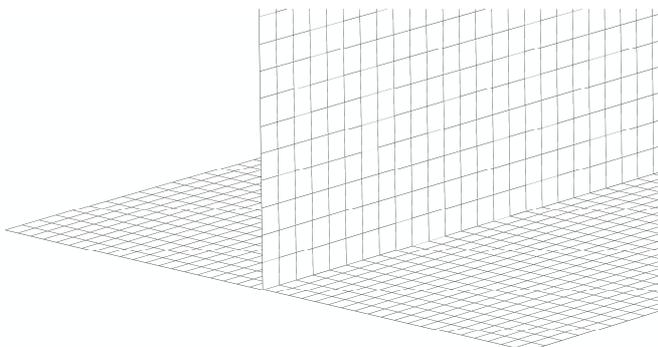


Abbildung 8: Detailansicht Schalenelemente S4

Generierte Elementanzahl:

| # | Träger mit C3D8 im UG | | | Träger mit S4 im UG | | |
|-------------|-----------------------|-----|---|---------------------|-----|---|
| | L | B | H | L | B | H |
| OG | 210 | 40 | - | 300 | 40 | - |
| STEG | 210 | 40 | - | 300 | 40 | - |
| UG | 210 | 40 | 8 | 300 | 40 | - |
| Summe | 630 | 120 | 8 | 900 | 120 | - |
| Gesamtsumme | 758 | | | 1020 | | |

Tabelle 2: Zusammenstellung der generierten Elementanzahl

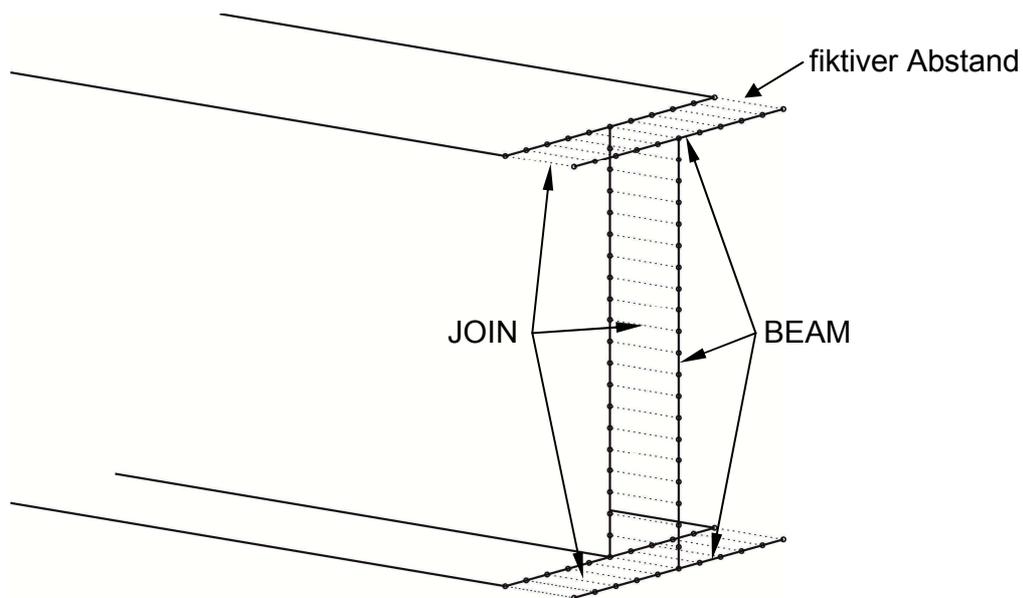


Abbildung 9: Connector Elemente JOIN und BEAM

2.4.2. Plattengeometrie

Die Platte, welche im Folgenden für Vergleichszwecke untersucht und herangezogen wurde, wurde mittels S4 Shell(Schalen)-Elementen modelliert.

Die Lasteinleitung erfolgte, wie beim Träger bereits beschrieben, über Connector Elemente und Einzellastbeanspruchung am Ende, siehe Abbildung 11.

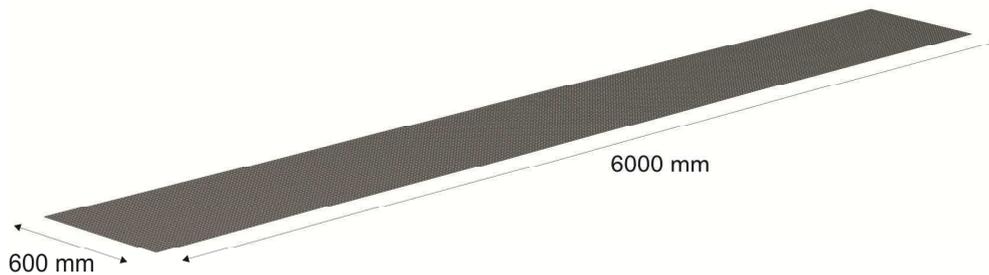


Abbildung 10: Plattenabmessung

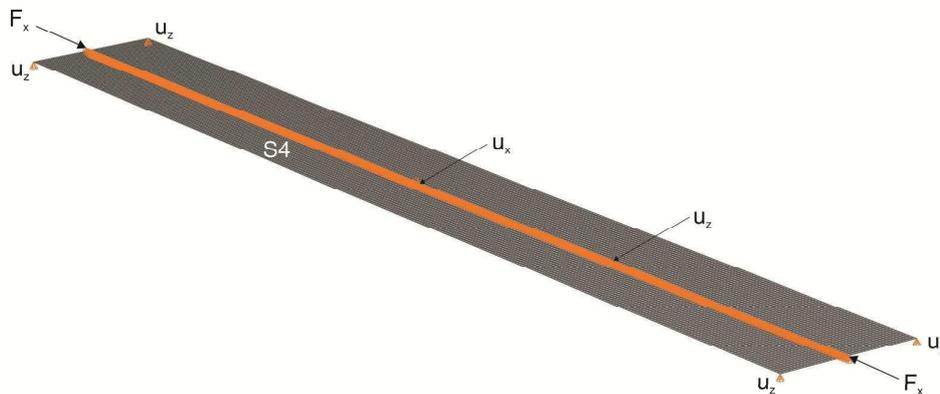


Abbildung 11: Plattenlagerung und Belastung

2.4.3. Verwendete Schalen- und Volumselementtypen

Das Finite Element Programm ABAQUS besitzt eine breite Palette an Elementtypen für Schalenelemente (Shell Elements) und Volumselemente (Solid Elements).

Ursprünglich wurden die Volumselemente in Betracht gezogen. Es wurde vermutet, dass sich dieses Knotendetail des Gurt dickensprunges mit schräg verlaufender Übergangszone zwischen den beiden Blechdickenbereichen besser modellieren lässt. Bei diesen Elementen wurden die Breite sowie die Dicke des Untergurtes vollständig modelliert.

Bei den Schalenelementen wurde, im Gegensatz zu den Volumselementen, nur die Mittelebene in ihrer Breite und Länge modelliert. ABAQUS modelliert die Elemente über die Höhe selbst. Somit ist der Steg des Trägers um die halbe Untergurtdicke in den Untergurt eingebunden. Dieser Umstand ist bei weiteren Querschnittsberechnungen zu berücksichtigen.

Hier nun eine kurze Beschreibung der verwendeten Elementtypen mit Skizzen aus dem ABAQUS User's Manual.

- S4 – Shell Element

4-Knoten, 6 Freiheitsgrade, lineare Randverformung, doppelt gekrümmter Verformungsansatz mit linearen Erzeugenden (HP Schalen), Mehrzweck Schale, endliche Membranspannungen, 4 Integrationspunkte, "dickes" Schalenelement - Schubverformungen werden berücksichtigt, vorzugsweise für plastische Berechnungen zu verwenden

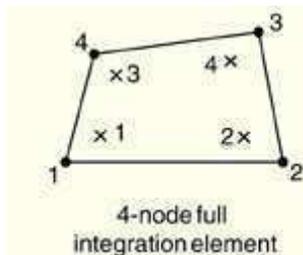


Abbildung 12: Darstellung S4 Element

- B31 – Beam Element

2 Knoten, 1 Integrationspunkt, linearer Verformungsansatz

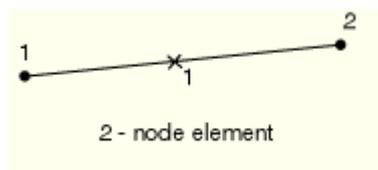


Abbildung 13: Darstellung B31 Element

- C3D8 – Continuums Element

8-Knoten, lineares Element, 3 Freiheitsgrade, 4 Integrationspunkte je Fläche, Brick-Element

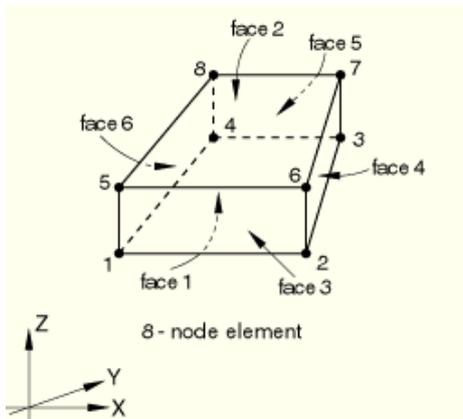


Abbildung 14: Darstellung C3D8 Element

- Conn3D2 - Connector Element

3 - dimensionales Element mit 2 Knoten, 6 Freiheitsgrade

2 verwendete Typen: JOIN und BEAM

JOIN – verbindet Node a mit Node b ohne die Verdrehung zu sperren (=Gelenk)



Abbildung 15: Darstellung Connector JOIN

BEAM – Verbindet Node a mit Node b, sperrt jedoch alle Freiheitsgrade (starre Kopplung aller sechs Freiheitsgrade)

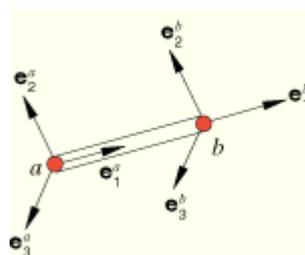


Abbildung 16: Darstellung Connector BEAM

2.5. CUFSM – Modellierung

Als Vergleichsrechnung wurde nicht nur eine analytische Berechnung, welche unter Pkt. 2.6 näher behandelt wird, verwendet. Zusätzlich wurde auch mit dem Finite Streifen Programm CUFSM [2] eine Gegenrechnung zur Beulanalyse soweit möglich durchgeführt.

Da die Modellierung des Trägers mit gelenkigen Anschlüssen der Gurte in diesem Programm nicht möglich war, beschränkte sich die Vergleichsrechnung auf die dreiseitig gelagerte Platte. Von der Berechnungsleistung her beschränkt sich CUFSM in der verfügbaren Form momentan auf die Kirchhoff'sche Plattentheorie für dünnwandige Platten. Dies begründet auch den Unterschied welcher, speziell bei etwas dickeren Platten, beim Vergleich mit den Abaqus-Ergebnissen für bestimmte Plattenabmessungen zu sehen ist, siehe Abschnitt 4.

2.6. Analytische Berechnung

Die analytische Berechnung erfolgte nach den allgemein bekannten Lösungen für die 3-seitig gelenkig gelagerten Platten aus Kollbrunner & Meister [9].

$$k_{\sigma} = p + q \cdot \left(\frac{\alpha}{m}\right)^2 + \left(\frac{m}{\alpha}\right)^2$$

$$p = 0.425$$

$q = 0 \dots$ für 3-seitig gelenkig gelagerte Platten

$m = 1, 2, 3, \dots$ Wellenlänge

(1)

$\alpha = \frac{a}{b} \dots$ Verhältnis Länge zu Breite

$$\alpha = \frac{6000}{300} = 20$$

$$k_{\sigma} = 0.425 + 0 \cdot \left(\frac{20}{1}\right)^2 + \left(\frac{1}{20}\right)^2 = 0.428$$

Als Vergleichswert wird in weiterer Folge der Beulwert k_{σ} herangezogen.

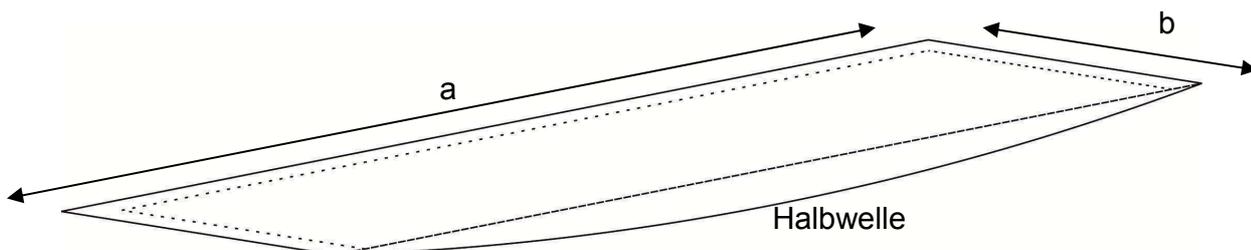


Abbildung 17: Darstellung 3-seitig gelenkig gelagerte Platte

2.7. Wahl des Systems

In Tabelle 3 werden für die Längenverhältnisse $\alpha = 8, 10, 15, 20$ die rückgerechneten Beulwerte k_σ der einzelnen untersuchten Platten und Träger (unterschiedlicher Elementmodellierung) dargestellt. Durch den Prozentwert Δ wird die Abweichung der einzelnen Beulwerte zur zugehörigen analytischen Lösung ausgewiesen.

| α | analytische Lösung | CUFSM | Träger h=1165 C3D8 | Träger h=3465 C3D8 | Träger h=1165 S4 | Träger h=3465 S4 | Platte S4 |
|----------|--------------------|-------|--------------------|--------------------|------------------|------------------|-----------|
| 8 | 0.441 | 0.441 | 0.498 | 0.499 | 0.427 | 0.427 | 0.431 |
| Δ | - | 0 % | +11 % | +12 % | -3 % | -3 % | -2 % |
| 10 | 0.435 | 0.435 | 0.475 | 0.476 | 0.423 | 0.423 | 0.427 |
| Δ | - | 0 % | +8 % | +9 % | -3 % | -3 % | -2 % |
| 15 | 0.429 | 0.429 | 0.437 | 0.438 | 0.419 | 0.419 | 0.423 |
| Δ | - | 0 % | +2 % | +2 % | -2 % | -2 % | -1 % |
| 20 | 0.428 | 0.428 | 0.422 | 0.424 | 0.418 | 0.418 | 0.422 |
| Δ | - | 0 % | -1 % | -1 % | -2 % | -2 % | -1 % |

Tabelle 3: Rückgerechnete k_σ - Werte als Vergleich der unterschiedlichen Berechnungsvarianten

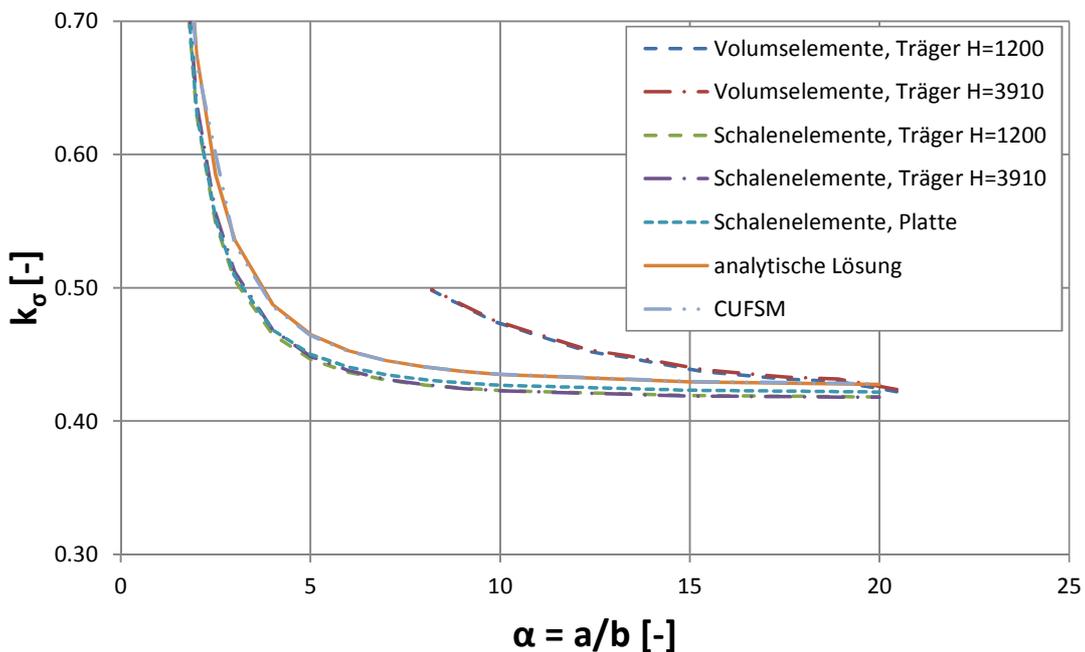


Abbildung 18: Darstellung der k_σ Verläufe

Es zeigt sich, dass die CUFSM Rechnung exakt mit der analytischen Rechnung übereinstimmt. Der Grund hierfür ist, dass, sowohl die klassische Lösung als auch die CUFSM-Berechnung, auf der Kirchhoff'schen Plattentheorie aufbauen.

Weiters zeigt sich, dass sich die Volums-Element Berechnung erheblich weiter von der analytischen Lösung entfernt als die Berechnung mit Schalen-Elementen. Dies ist auch deutlich in Abbildung 18 ersichtlich. Bei einem Längenverhältnis von $\alpha=10$ ergibt sich eine +8%-ige Abweichung der Volumselemente gegenüber einer -3%-igen Abweichung der Schalen-Elemente zur analytischen Lösung.

Dieses Ergebnis führte für diese Arbeit zur Entscheidung, dass alle weiteren Beulberechnungen und auch die nichtlinearen Berechnungen mit Shell(Schalen)-Elementen im Finite Element Programm ABAQUS [1] durchgeführt wurden.

2.8. Überprüfung der Spannungsverläufe

Um eine zusätzliche Kontrolle der Randbedingungen und der Lasteinleitung zu erhalten, wurde eine lineare Analyse des Trägers und der Platte durchgeführt. Die Ergebnisse wurden mit der Handrechnung verglichen.

2.8.1. Lineare Analyse des Trägers

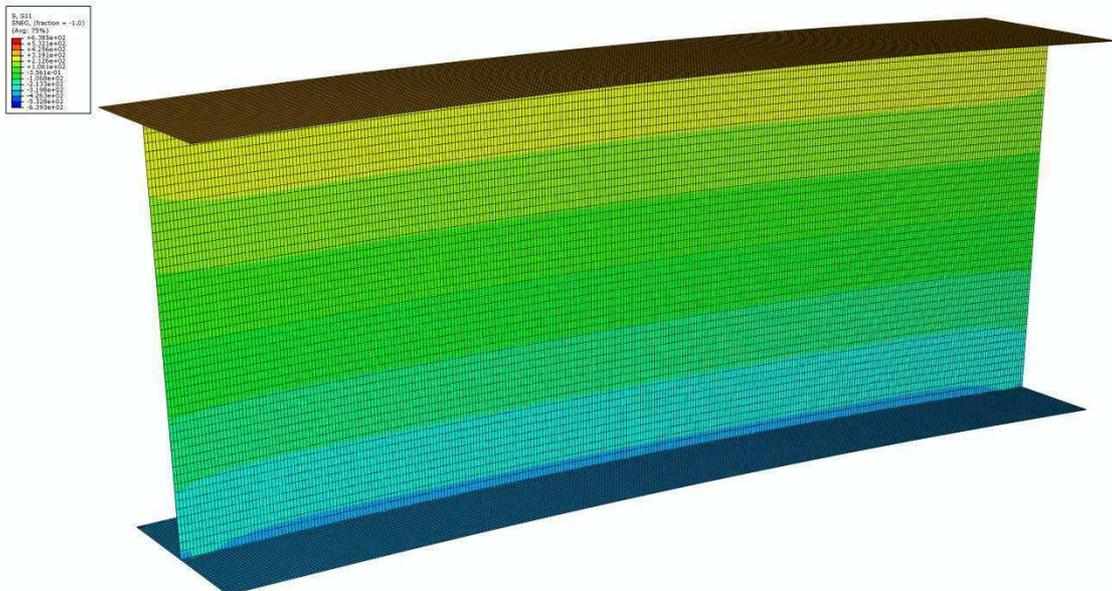


Abbildung 19: Spannungsverlauf s_{11} des Trägerquerschnittes $H=1200$ mm

Es zeigt sich ein gleichmäßiger Spannungsverlauf über den gesamten Träger mit einer konstanten Druckkraft im Untergurt. Das Ergebnis der Untergurtspannung s_{11} deckt sich mit dem berechneten Ergebnis laut Anhang A.

2.8.2. Lineare Analyse der Platte



Abbildung 20: Spannungsverlauf s_{11} der Platte $B=600\text{ mm}$

Auch hier zeigt sich, wie beim Träger zuvor, ein konstanter Druckspannungsverlauf über die gesamte Platte. Die unter Anhang A berechnete mittlere Plattenspannung deckt sich ebenfalls mit den ABAQUS Ergebnissen.

3. Grundsätzliche Beanspruchung des Biegeträgers an Gurtdickensprüngen

Die Beanspruchung von Biegeträgern mit Gurtdickensprüngen werden sowohl bei Stahlträgern als auch bei Verbundträgern zu Festlegung des Längsverlaufes der Gurte in der Regel sorgfältig verfolgt. Nach der technischen Biegetheorie werden die Randnormalspannungen der Gurte sowie die Schubspannungen der Stegbleche für die jeweiligen Bereiche mit konstanter Ausbildung der Trägerquerschnitte aus den maßgebenden Schnittkräften berechnet.

Abbildung 21 zeigt die geläufigen Spannungslinien für die Gurtnormalspannungen $\sigma_{x,u}$ und für die Schubspannungen in Stegunterkante $\tau_{w,u}$ mit den typischen Spannungssprüngen an den Gurtdickensprüngen. Es sind auch die Schubkräfte ΔN an den Gurtdickensprüngen und das Gurtbiegemoment ΔM angeführt, welche als Folge der exzentrischen Wirkungslinie der Gurtkräfte entstehen.

Weiters wird in Abbildung 22 der exakte Verlauf der Untergurtkraft N_{fl} und die zugehörige Schubbeanspruchung im Stegblech für einen Untergurtdickensprung dargestellt. Diese Werte stammen aus einer linear elastischen Schalenrechnung ohne Imperfektionen.

Weitere Betrachtungen sind [6] zu entnehmen.

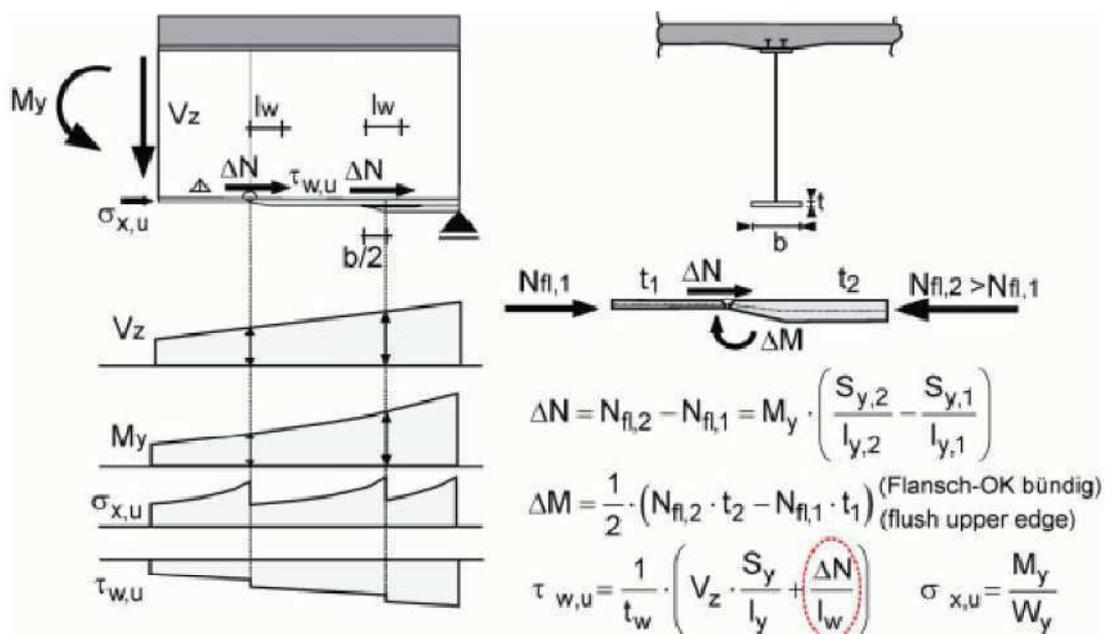


Abbildung 21: Grundsätzliches Tragverhalten und Spannungsverteilung nach der technischen Biegetheorie

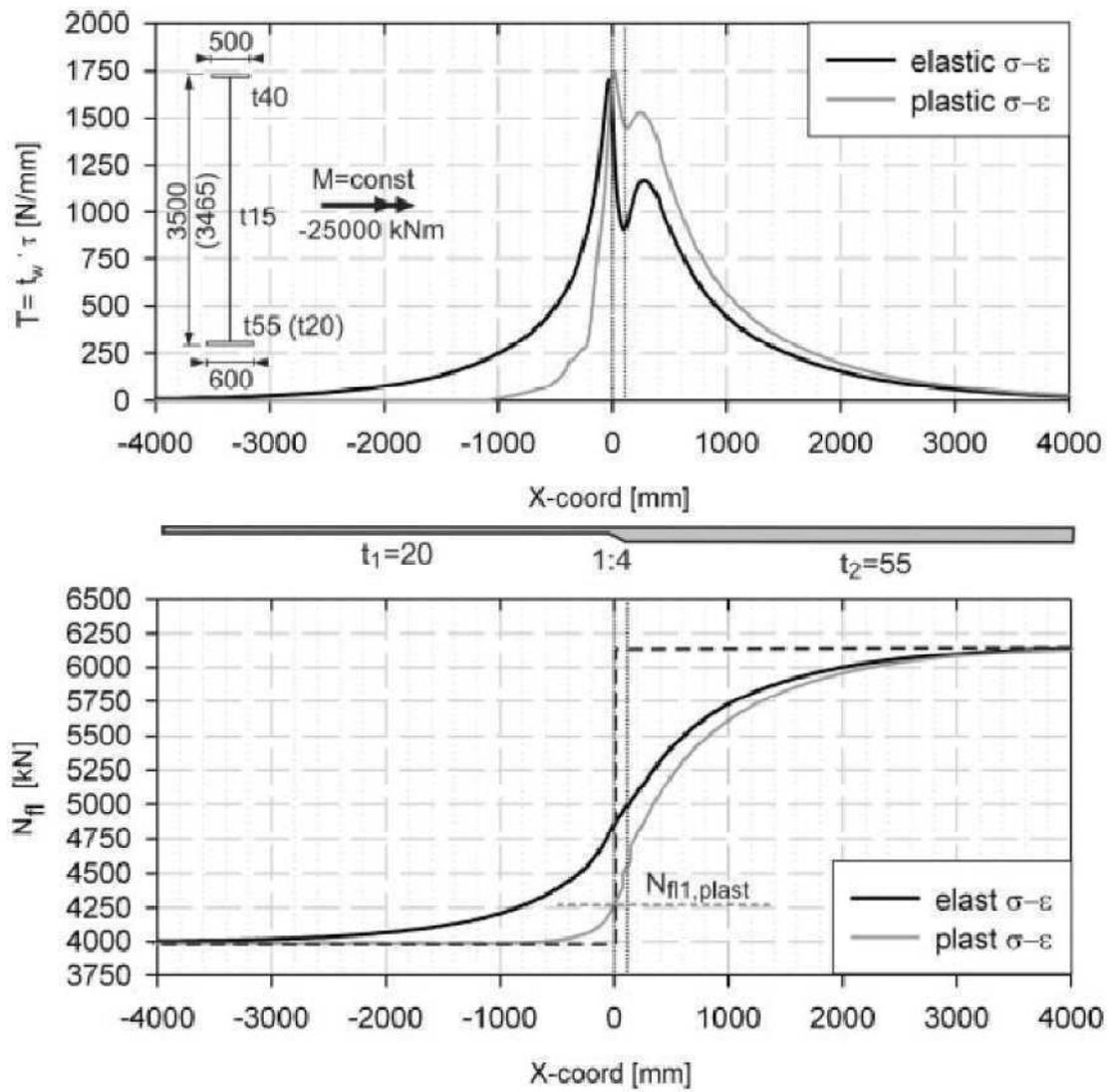


Abbildung 22: Schubkraft T in Stegunterkante und Gurtnormalkräfte N_{fl} aus FEM

4. Beuluntersuchung Platte

4.1. Allgemeines

Bevor die Untersuchung der Träger begann, wurde die Beulrechnung an der dreiseitig gelenkig gelagerten Rechteckplatte durchgeführt. Dies diente zur besseren Vergleichbarkeit mit den schon bekannten analytischen Lösungen (siehe Pkt. 2.6).

Randbedingungen wurden entsprechend Abbildung 11 aufgebracht (Linienlagerung längs in Plattenmitte).

Vorab wurde die Platte ohne Dickensprung ($t_1=t_2$) berechnet, was der analytischen Lösung entspricht. Danach wurden drei unterschiedliche Varianten des Dickensprunges mit unterschiedlichen Verhältnissen t_1/t_2 betrachtet.

Alle Beulrechnungen an der Platte wurden sowohl mit dem Finiten Element Programm ABAQUS [1], als auch mit CUFSM [2] durchgeführt.

4.2. Beulanalyse ohne Dickensprung

Zur Berechnung der Eigenform, des Eigenwertes und Beulwertes k_σ wurde die Platte mit einer gleichmäßigen Normalkraft belastet. Die Modellierung der Platte erfolgte mittels Schalen-Elementen des Typs S4 (siehe Pkt. 2.4.3). Die Einzellasteinleitung wurde mit Connector Elementen zur gleichmäßigen Lastverteilung durchgeführt, siehe Abbildung 9.

Die Belastung orientierte sich an der Trägerbelastung. Das bedeutet, dass die im Träger durch das Moment von $M_y=6000\text{kNm}$ entstandene Untergurtmittelspannung in eine Normalkraft N_x umgerechnet und dann als Einzellast auf die Platte aufgebracht wurde. Somit konnten die ermittelten Eigenwerte von Träger und Platte direkt miteinander verglichen werden.

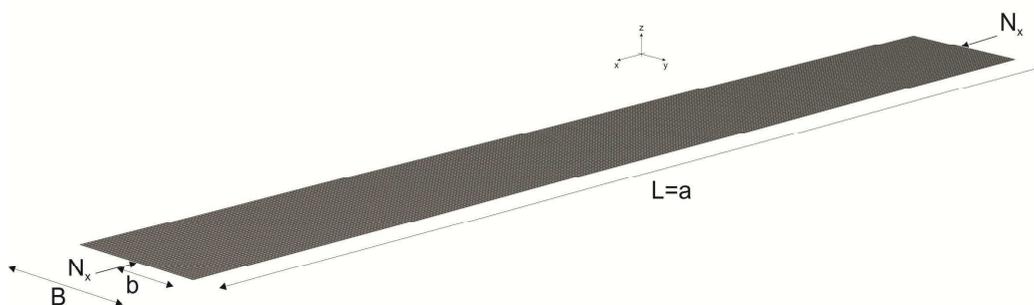


Abbildung 23: Darstellung der Belastung, Abmessungen

Aus Gründen der einfacheren Modellierung (Knoten- und Elementdefinition), wurden die FE-Modelle bei Platten konstanter Dicke gleich definiert, wie für Platten mit Dickensprung. Die Rechenleistung stellte keine Grenzen hinsichtlich der Modellierung dar.

Die Breite B entspricht somit der gesamten Untergurtbreite der Platte, also $B = 2 \cdot b$ der dreiseitigen Platte.

Die Ermittlung der Querschnittswerte, welche anhand des Trägers für die Normalkraftbelastung der Platte durchgeführt wurden, sind dem Anhang A zu entnehmen.

Um neben einer Überprüfung der FE-Modelle auch noch einen etwaigen Einfluss des Verhältnisses der Plattendicke zu -breite (b/t) zu untersuchen, erfolgte diese Plattenstudie an Platten verschiedener Breite, allerdings konstanter Dicke. Die Längen orientierten sich am Plattenverhältnis $\alpha = a/b$.

Im Detail erfolgte die Untersuchung der Platte an drei verschiedenen Plattenbreiten B und an unterschiedlichen Längen des Plattenfeldes. Die Breiten wurden mit 228 mm, 600 mm und 2000 mm festgelegt. Die zugehörigen c/t -Werte würden vergleichsweise bei 7.04 / 18.5 / 61.7 liegen. Die Länge L der Platte wurde über das Verhältnis $\alpha = a/b$ bestimmt. Wobei a die Plattenlänge und b die Plattenbreite der dreiseitig gelagerten Platte darstellt (siehe Abbildung 23).

Die α -Werte bewegten sich von 1 bis 70, welche sehr lange Platten und breite Platten darstellen sollen. Die Variation der B -Werte (b -Werte) diente zur Untersuchung des Effektes der Beulschlankheit b/t , die Dicke der Platte t wurde konstant mit $t=20$ mm angenommen.

Nachstehend soll für den Fall $B=600$ mm und $\alpha=10$, bei einer Plattenlänge von $L=3000$ mm, die erste Eigenform exemplarisch dargestellt werden. Weitere Eigenformen sind dem Anhang B Pkt. a zu entnehmen.

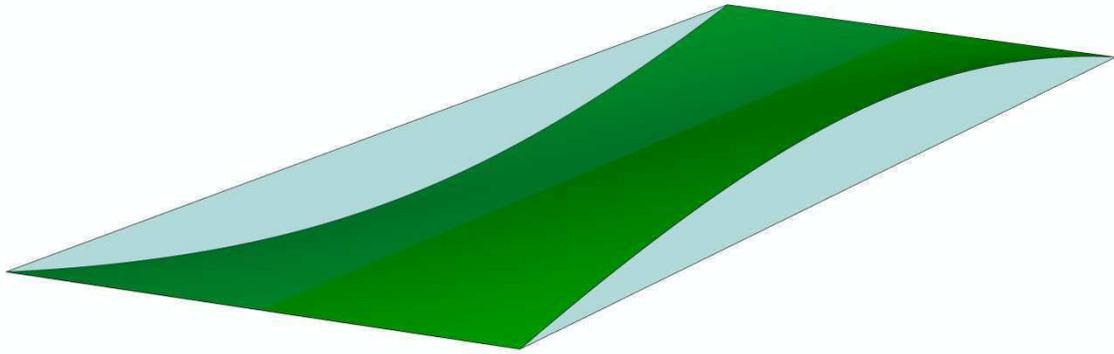


Abbildung 24: Platte $B=600$, $\alpha=10$, 1.Eigenform, $EV1=1.055$, $k_\sigma=0.427$, $\sigma_{crit}=360.16N/mm^2$

Abbildung 24 zeigt, dass sich die erste Eigenform in einer Halbwelle ausbildet, wie dies auch die analytische Lösung nach 2.6 ergeben hat. Dies ermöglicht einen Vergleich der Ergebnisse.

Die Beulwerte k_σ errechnen sich aus der berechneten Mittelspannung im Untergurt σ_{mittel} und der idealen Beulspannung.

Die ideale Beulspannung σ_{ki} berechnet sich nach

$$\sigma_{ki} = \sigma_{crit} = k_\sigma \cdot \sigma_e \left[N / mm^2 \right] \quad (2)$$

mit der Euler'schen Bezugsspannung

$$\sigma_e = \frac{\pi^2 \cdot E}{12 \cdot (1 - \mu^2)} \cdot \left(\frac{t}{b} \right)^2 = 189800 \cdot \left(\frac{t}{b} \right)^2 \left[N / mm^2 \right] \quad (3)$$

Berechnung von σ_{crit} für die ABAQUS Plattenrechnung

$$\sigma_{crit,ABQ} = EV1 \cdot \sigma_{mittel} \quad (4)$$

daraus folgt der Beulwert k_σ

$$k_{\sigma,EV1} = \frac{\sigma_{crit}}{\sigma_e} \quad (5)$$

Nun soll für alle obigen Variationen der Plattenschlankheit b/t und des Längenverhältnisses α der Beulwert k_σ berechnet werden und mit der analytischen Lösung nach 2.6 und der CUFSM Berechnung nach 2.5 verglichen werden.

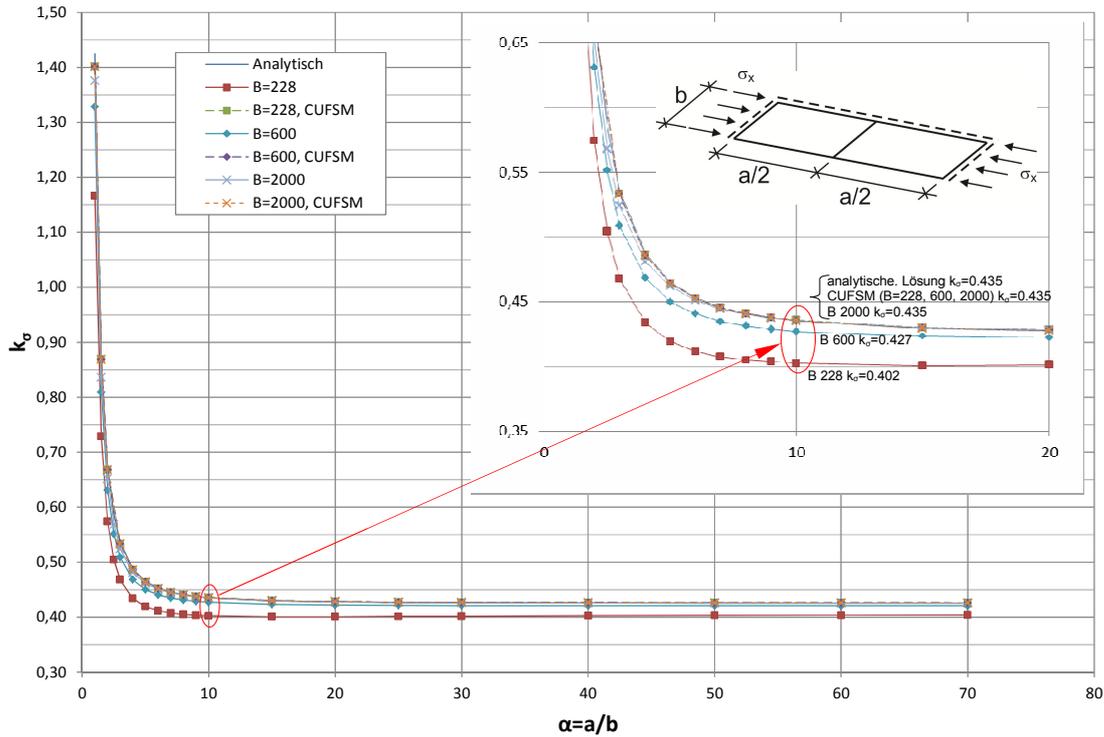


Abbildung 25: Darstellung der unterschiedlichen Vergleichsvarianten

Wie in Abbildung 25 zu erkennen ist, ist die analytische Lösung (Kirchhoff-Theorie) mit der Berechnung mit dem Finite-Streifen Programm CUFSM ident. Damit ist nachgewiesen, dass CUFSM die Kirchhoff-Lösung exakt implementiert. Die Abaqusberechnungen mit den Breiten $B=600$ mm und $B=2000$ mm liegen sehr nahe an der analytischen Lösung. Die Berechnungen mit der Breite $B=228$ mm ($b/t = 114/(20 \cdot \epsilon_s = 0,81) = 7,04$) weisen für alle α -Werte kontinuierlich geringere k_σ aus.

Aufgrund der Vergleiche (Abbildung 25) werden Modellierung und entsprechende Netzteilung für in Ordnung befunden, nachdem die Rückrechnungen der Plattenbeulwerte über einen sehr großen Parameterbereich - auch Breiten- zu Dickenbereich - zu nahezu identen Lösungen geführt haben.

Ein Effekt der dicken Platte ist für $B=228$ mm zu sehen. Es ist anzunehmen, dass der Einfluss der Schubnachgiebigkeit hier geringere kritische Beulspannungen bei gleichem α -Verhältnis über den ganzen Parameterbereich führte. Die Kirchhoff Lösung gilt streng genommen nur für dünne Platten. Nachdem die Platte $B=228$ mm gemäß EN 1993 nicht beulgefährdet ist (Klasse 1), ist dieser Unterschied für die weiteren Analysen nicht signifikant. Somit ist gerechtfertigt, dass der I-Träger mit Untergurt $B/t = 600/20$ einen guten Referenzquerschnitt für die folgenden Studien darstellt.

4.3. Beulanalyse mit Dickensprung

Unter 4.2 wurde die Platte ohne Dickensprung untersucht um zu zeigen, ob sich die analytische Lösung mit der ABAQUS Rechnung und CUFSM Lösung deckt.

Daraufhin wurde die Platte mit drei unterschiedlichen Arten des Dickensprungs (oben bündig OB, unten bündig UB, zentrisch Z) untersucht. Diese Berechnungen sollen den Einfluss des Dickensprungs auf den Beulwert k_σ im Vergleich zur Platte mit konstanter Dicke zeigen. Auch dienen diese Rechnungen als Vergleichswerte zu den später behandelten Dickensprüngen in Untergurten geschweißter I-Träger.

Es wurden folgende drei Arten des Dickensprungs untersucht:

- Oben Bündig (OB)

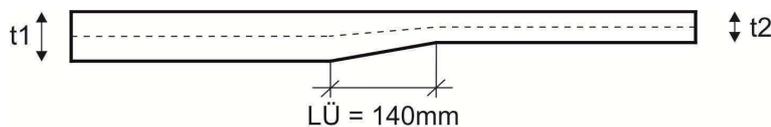


Abbildung 26: Dickensprung OB

- Unten Bündig (UB)

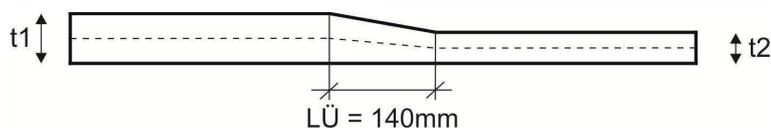


Abbildung 27: Dickensprung UB

- Zentrischer Dickensprung (Z)

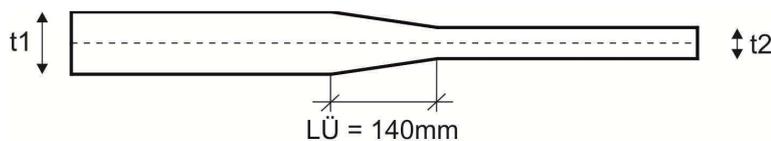


Abbildung 28: Dickensprung Z

Die Lagerung der Platte erfolgte in der Mittelebene, dadurch wurde die Lagerung in der Belastungsebene hergestellt.

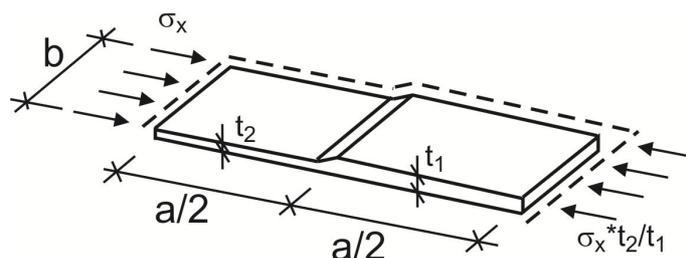


Abbildung 29: Dickensprung

Die Variation der Plattenbreite und des Verhältnisses α wird gleich gehandhabt wie unter Pkt. 4.2. Zusätzlich wurde nun noch eine Variation der Größe des Dickensprungs über das Verhältnis große Plattendicke zu kleiner Plattendicke (t_1/t_2) durchgeführt. Die Berechnungen erfolgten für jede Art des Dickensprungs (OB, UB, Z) mit den Verhältnissen t_1/t_2 von 1.25, 1.50, 3.00 und 6.00. Die Überlagerung der Dickensprünge beträgt vereinfacht $LÜ = 140\text{mm}$.

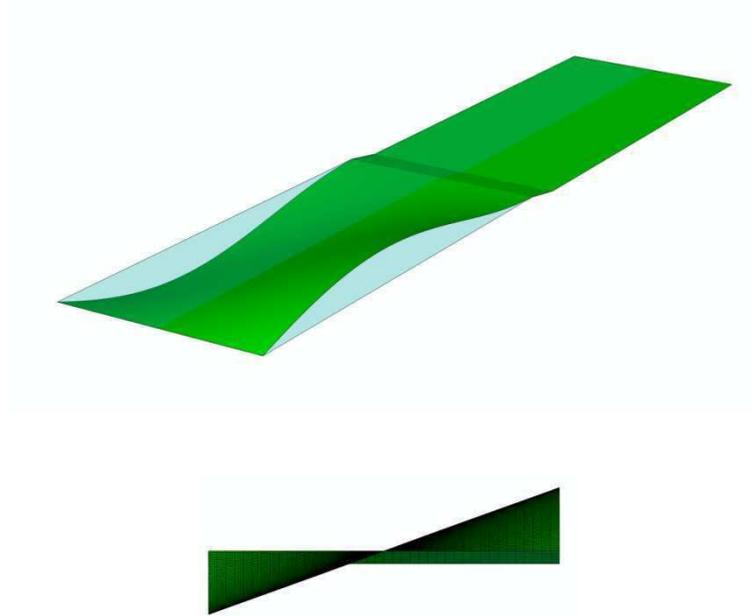


Abbildung 30: Platte $B=600$, OB, $t_1/t_2=3.0$, $\alpha=10$, $EVI=1.2201$, $k_\sigma=0.494$, $\sigma_{crit,ABQ}=416.52\text{ N/mm}^2$

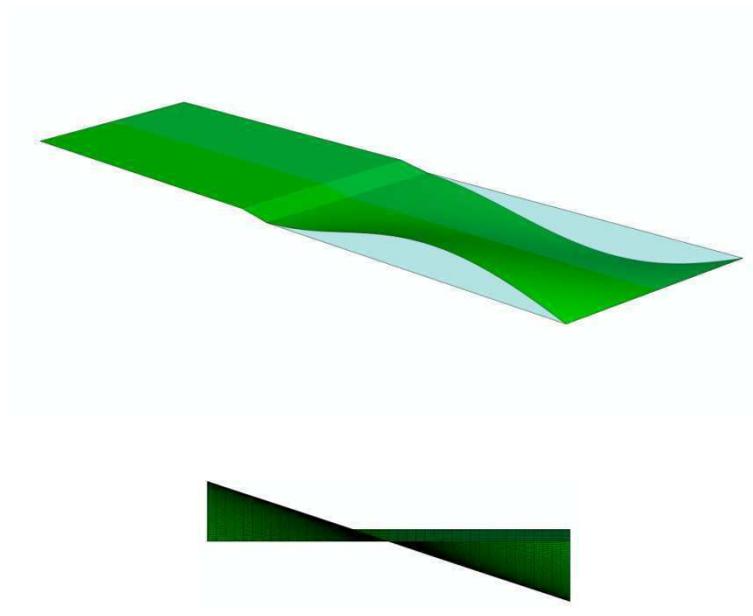


Abbildung 31: Platte $B=600$, UB, $t_1/t_2=3.0$, $\alpha=10$, $EVI=1.2201$, $k_\sigma=0.494$, $\sigma_{crit,ABQ}=416.52\text{ N/mm}^2$

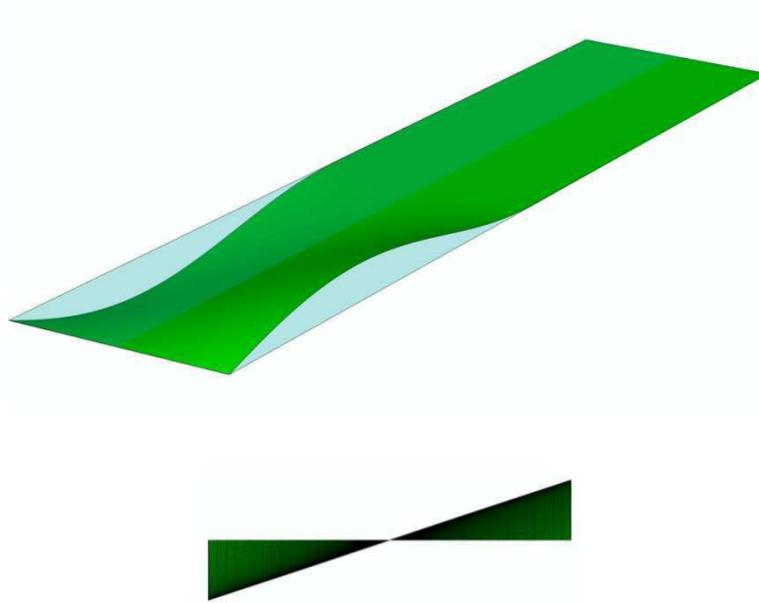


Abbildung 32: Platte $B=600$, Z, $t_1/t_2=3.0$, $\alpha=10$, $EV1=1.2158$, $k_\sigma=0.492$, $\sigma_{crit,ABQ}=415.05$ N/mm²

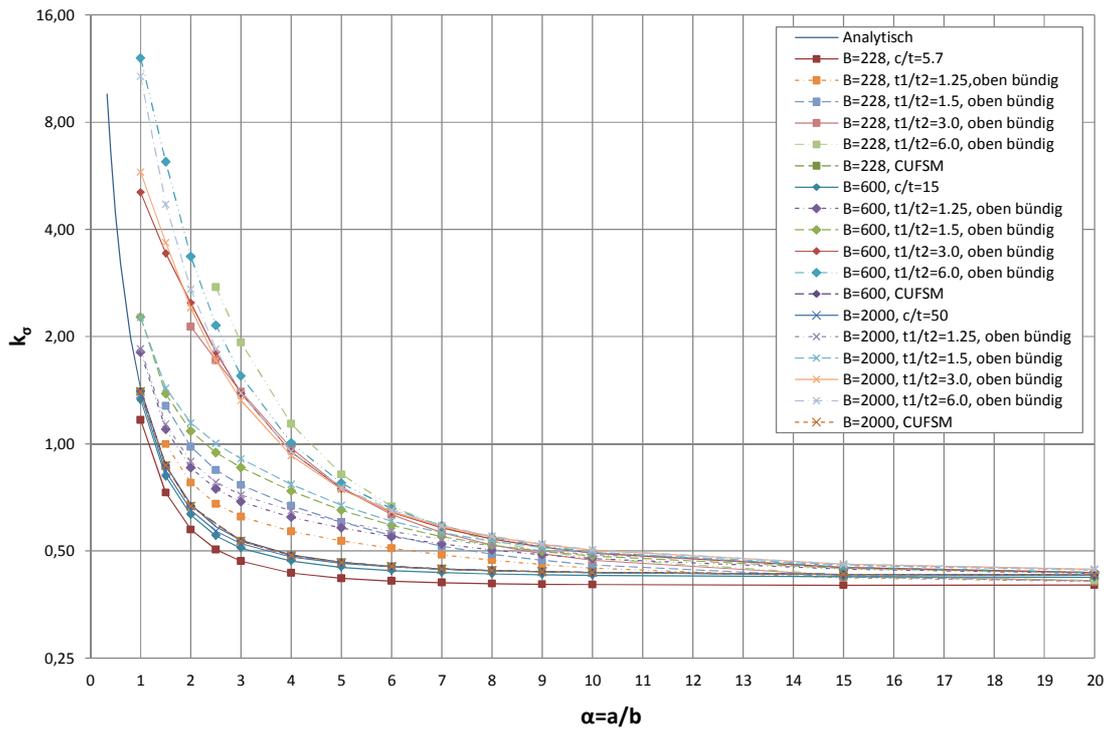
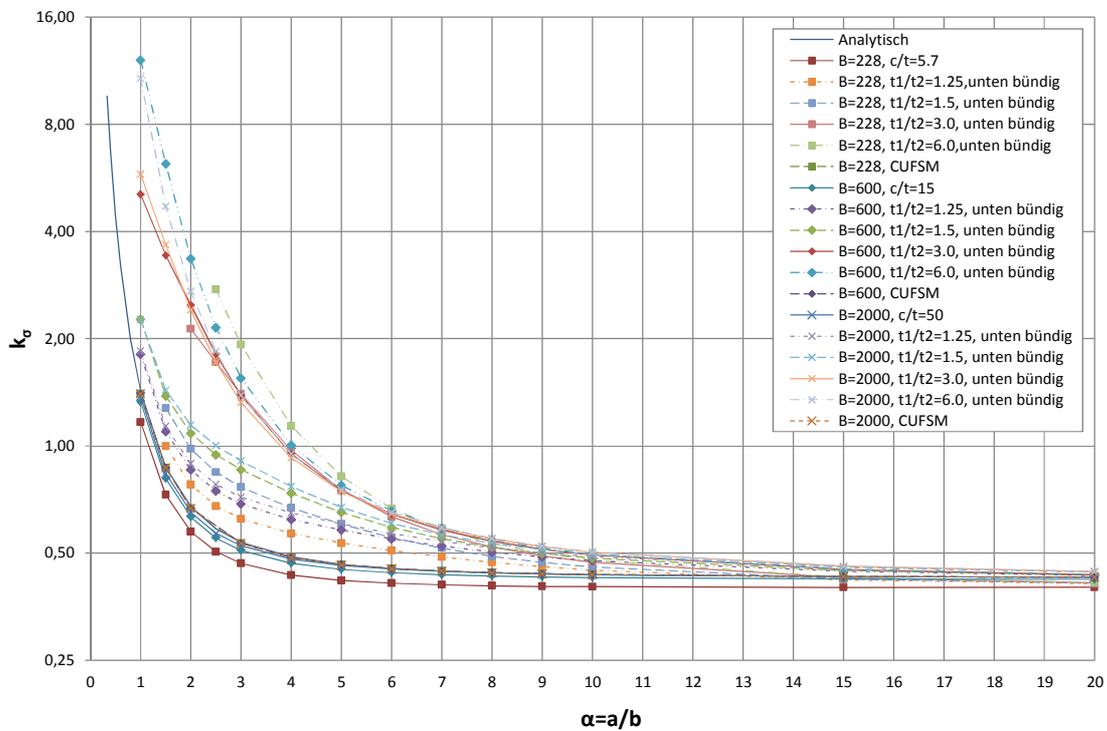
Die Abbildung 30 bis Abbildung 32 zeigen exemplarisch die erste Eigenform für die drei Dickensprünge OB, UB und Z. Aus den Abbildungen wird ersichtlich, dass sich bei Platten mit Dickensprüngen das Beulen der Platte auf die Plattenseite mit der dünneren Plattendicke einstellt. Auch ist eine leichte Einspannwirkung der dünnen Platte in die dicke Plattenhälfte ersichtlich. Bei den anderen t_1/t_2 - Verhältnissen ist diese Einspannwirkung je nach t_1 mehr oder weniger deutlich ausgeprägt.

Diese Berechnungen wurden für alle Varianten, wie oben beschrieben, durchgeführt. Die Rückrechnung auf den Beulwert k_σ erfolgte ebenfalls wie unter Pkt. 4.2 beschrieben. Diese Ergebnisse sollen nun für die einzelnen Dickensprünge getrennt dargestellt werden.

In Tabelle 4 wird exemplarisch für das Längenverhältnis $\alpha = 5$ den Breiten $B = 228, 600$ und 2000 mm der Vergleich der ABAQUS-Ergebnisse der unterschiedlichen Dickensprünge (OB, UB, Z) zur analytischen Lösung bzw. zum CUFSM Ergebnis dargestellt.

| α | B | t1/t2 | Dickensprung | Beulwert k_{σ} | | | Δ |
|----------|------|-------|--------------|-----------------------|-------|-----------------------|----------|
| | | | | analytische Lösung | CUFSM | Platte _{ABQ} | |
| 5 | 228 | 1,00 | | 0,465 | 0,464 | 0,419 | 90% |
| 5 | 228 | 1,25 | OB | | | 0,534 | 115% |
| 5 | 228 | 1,50 | OB | | | 0,603 | 130% |
| 5 | 228 | 3,00 | OB | | | 0,752 | 162% |
| 5 | 228 | 6,00 | OB | | | 0,820 | 176% |
| 5 | 228 | 1,25 | UB | | | 0,534 | 115% |
| 5 | 228 | 1,50 | UB | | | 0,603 | 130% |
| 5 | 228 | 3,00 | UB | | | 0,752 | 162% |
| 5 | 228 | 6,00 | UB | | | 0,820 | 176% |
| 5 | 228 | 1,25 | Z | | | 0,530 | 114% |
| 5 | 228 | 1,50 | Z | | | 0,595 | 128% |
| 5 | 228 | 3,00 | Z | | | 0,737 | 158% |
| 5 | 228 | 6,00 | Z | | | 0,805 | 173% |
| 5 | 600 | 1,00 | | 0,465 | 0,464 | 0,450 | 97% |
| 5 | 600 | 1,25 | OB | | | 0,651 | 140% |
| 5 | 600 | 1,50 | OB | | | 0,749 | 161% |
| 5 | 600 | 3,00 | OB | | | 0,580 | 125% |
| 5 | 600 | 6,00 | OB | | | 0,775 | 167% |
| 5 | 600 | 1,25 | UB | | | 0,651 | 140% |
| 5 | 600 | 1,50 | UB | | | 0,749 | 161% |
| 5 | 600 | 3,00 | UB | | | 0,580 | 125% |
| 5 | 600 | 6,00 | UB | | | 0,775 | 167% |
| 5 | 600 | 1,25 | Z | | | 0,639 | 137% |
| 5 | 600 | 1,50 | Z | | | 0,738 | 159% |
| 5 | 600 | 3,00 | Z | | | 0,573 | 123% |
| 5 | 600 | 6,00 | Z | | | 0,765 | 165% |
| 5 | 2000 | 1,00 | | 0,465 | 0,464 | 0,461 | 99% |
| 5 | 2000 | 1,25 | OB | | | 0,603 | 130% |
| 5 | 2000 | 1,50 | OB | | | 0,672 | 144% |
| 5 | 2000 | 3,00 | OB | | | 0,744 | 160% |
| 5 | 2000 | 6,00 | OB | | | 0,755 | 162% |
| 5 | 2000 | 1,25 | UB | | | 0,603 | 130% |
| 5 | 2000 | 1,50 | UB | | | 0,672 | 144% |
| 5 | 2000 | 3,00 | UB | | | 0,744 | 160% |
| 5 | 2000 | 6,00 | UB | | | 0,755 | 162% |
| 5 | 2000 | 1,25 | Z | | | 0,590 | 127% |
| 5 | 2000 | 1,50 | Z | | | 0,656 | 141% |
| 5 | 2000 | 3,00 | Z | | | 0,734 | 158% |
| 5 | 2000 | 6,00 | Z | | | 0,748 | 161% |

Tabelle 4: Darstellung Beulwerte k_{σ} für die Plattenbreiten $B=228, 600, 2000\text{mm}$ mit $\alpha=5$

Abbildung 33: Darstellung rückgerechnete Beulwerte k_σ für Dicken sprung OBAbbildung 34: Darstellung rückgerechnete Beulwerte k_σ für Dicken sprung UB

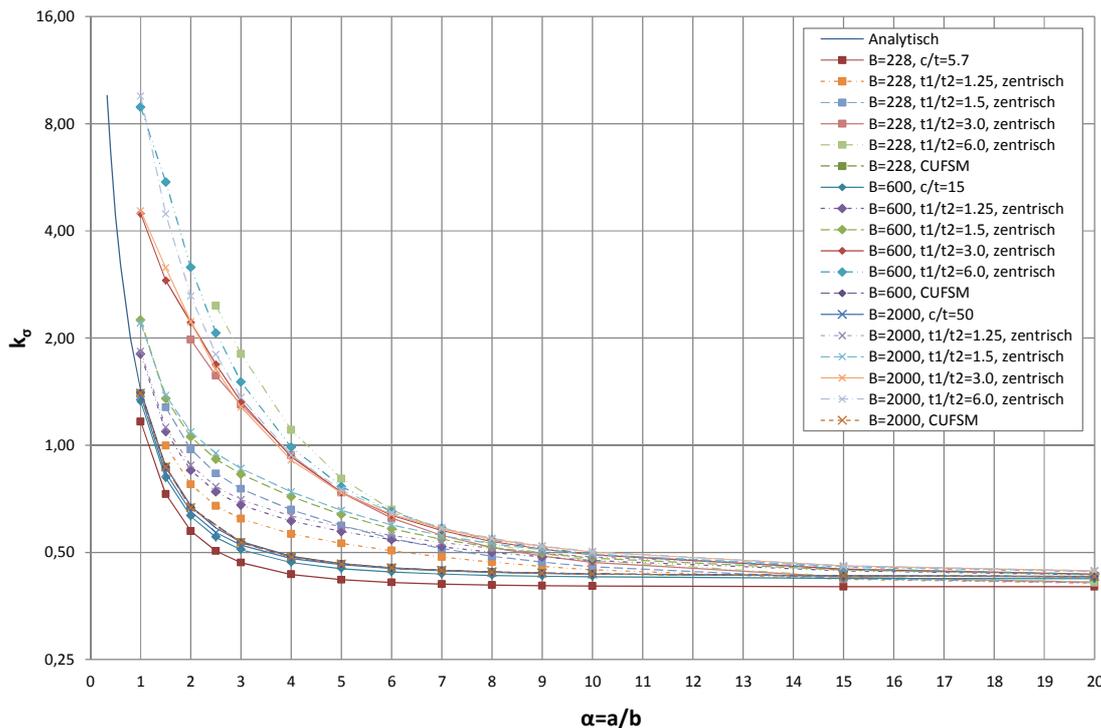


Abbildung 35: Darstellung rückgerechnete Beulwerte k_σ für Dicksprung Z

Wie in Abbildung 33, Abbildung 34 und Abbildung 35 ersichtlich wird, erhöht sich der Beulwert k_σ je größer das Verhältnis $t1/t2$ wird. Dies ist speziell im Bereich $\alpha < 10$ deutlich zu erkennen.

Die Erhöhung des Beulwertes lässt sich auf die Einspannwirkung des Dicksprungs zurückführen. Auch lässt sich zeigen, dass der Einfluss der Dicksprünge für große Längenverhältnisse α immer kleiner wird. Dies begründet sich dadurch, dass die Ausbildung der Beulform bei langen Trägerlängen schon vor dem Erreichen des Dicksprunges abgeschlossen ist und somit die stabilisierende Wirkung des Dicksprunges für das Gesamtfeld nicht aktiviert werden kann.

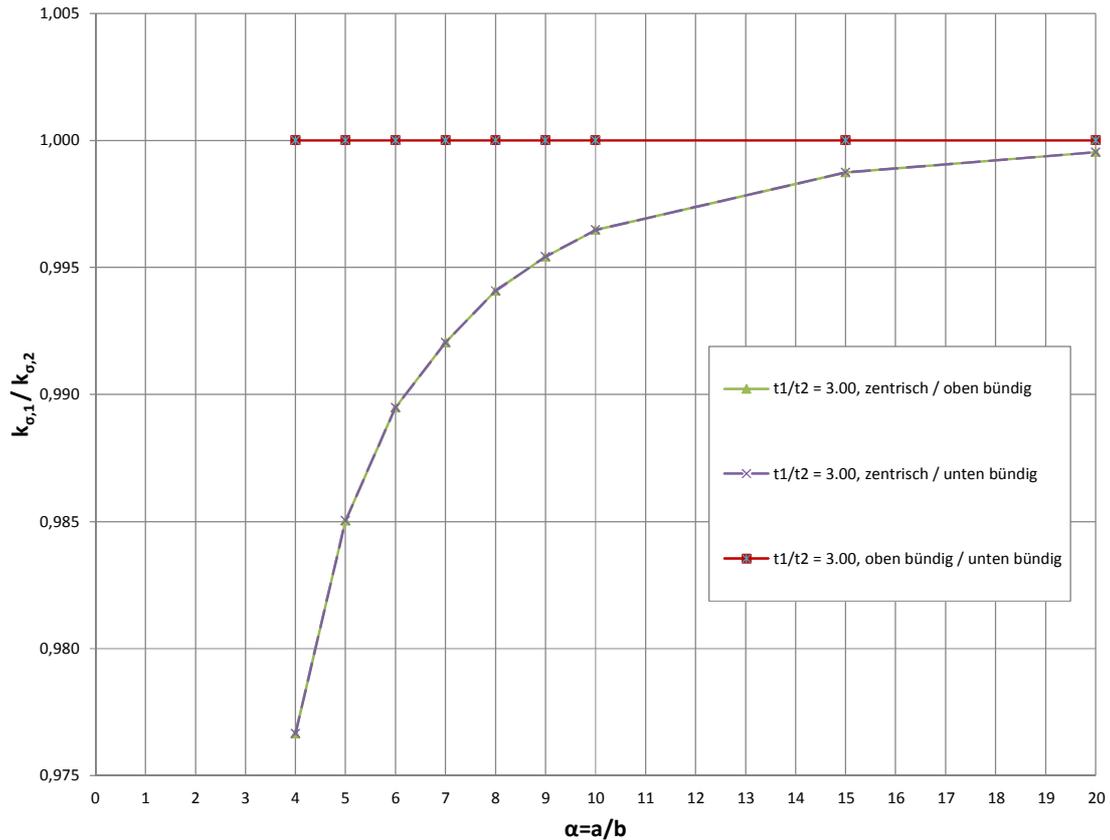


Abbildung 36: Darstellung Unterschied der Dickensprungvarianten OB/UB/Z für $t1/t2=3.0$

In Abbildung 36 wird der Unterschied zwischen den einzelnen Dickensprüngen für $t1/t2=3.00$ veranschaulicht. Es wird gezeigt, dass sich die Dickensprünge OB und UB gleich verhalten. Der zentrische Dickensprung weist im Maximalfall einen um 2.5% niedrigeren Beulwert, als die Dickensprünge OB und UB aus.

Dieses Ergebnis gilt dem Verhalten nach auch für die restlichen Dickenvariationen von 1.25, 1.50 und 6.00. Die Einzelergebnisse werden im Anhang C gezeigt.

5. Beuluntersuchung Träger

5.1. Allgemeines

Nachdem im vorangegangenen Kapitel 4 die Beuluntersuchung an der Platte durchgeführt wurde, soll nun dieselbige am Träger mit und ohne Dickensprung am Trägeruntergurt vorgenommen werden. Diese Ergebnisse sollen mit der analytischen Lösung der dreiseitig gelagerten Platte, der CUFSM Berechnung der Platte und der Plattenrechnung im ABAQUS verglichen werden.

Bei Trägern mit Gurtdickensprung treten üblicherweise neben den Sprüngen in der Gurtspannung auch Differenzen in den Gurtnormalkräften im Übergangsbereich auf (Abbildung 22). Dies war vergleichsweise bei den Untersuchungen an der Platte (Abschnitt 4) nicht der Fall.

Der Unterschied in den Normalkräften steht in direktem Zusammenhang mit dem Flächenverhältnis von Stegfläche zu Gurtfläche, sowie von der Schwerlage der beiden verbundenen Querschnitte.

Daher wurde vorab eine Untersuchung zur Maximierung des Verhältnisses der Untergurtnormalkräfte N_{UG1}/N_{UG2} durchgeführt. N_{UG2} beschreibt die Gurtkraft im dünneren Gurt (t_2), N_{UG1} diese im Gurt mit der größeren Blechdicke (t_1).

Daraus wurden zwei Querschnitte ermittelt, welche den möglichen Parameterbereich für I-Querschnitte gut abdecken, siehe Abschnitt 5.2. Mit den daraus resultierenden I-Träger Querschnitten wurde anschließend die Beuluntersuchung am Träger durchgeführt. Zuerst wurden die Beulwerte am Träger ohne Dickensprung ($t_1=t_2$) als Referenzwerte und Vergleichswerte für die Plattenlösung ermittelt. Anschließend erfolgte die Beulwerteermittlung für drei bekannte Varianten des Dickensprungs (OB, UB, Z). Die untersuchten Gurtdickenverhältnisse liegen im Bereich von $t_1/t_2 = 1.25$ bis $t_1/t_2 = 6.0$ als oberer Grenzwert. Kleinere bzw. größere Dickensprünge sind praktisch nicht relevant und werden in weiterer Folge auch nicht näher untersucht.

Alle Beulberechnungen an den Trägern werden mit dem Finite Element Programm ABAQUS [1] ausgeführt.

5.2. Untersuchung zur Maximierung N_{UG2}/N_{UG1}

Nachstehend soll über

$$N_{UG} = \frac{M}{W} \cdot A_{UG} \quad (6)$$

W ... Widerstandsmoment auf die Achse des Flansches bezogen

das Verhältnis

$$\frac{N_{UG1}(t_1 \geq t_2)}{N_{UG2}(t_2 = 20)} \quad (7)$$

und der Steganteil

$$\frac{A_{\text{Steg}}}{A_{\text{Ges}}} \quad (8)$$

berechnet werden.

| | | | | | | | | | |
|---------------------------|---|---|---------|---------|--------|--------|--------|---------|---------|
| 1. | Doppelsym. QS: $h_{\text{ges, QS2}}=1200$ mm | | 600/20 | - | - | - | - | - | |
| | | | 1160/15 | - | - | - | - | - | |
| | | | 600/20 | 600/30 | 600/40 | 600/60 | 600/80 | 600/120 | |
| | $\frac{N_{UG1}}{N_{UG2}}$ | OB | 1.00 | 1.1123 | 1.1747 | 1.2412 | 1.2721 | 1.2868 | |
| | | Z | 1.00 | 1.1164 | 1.1854 | 1.2628 | 1.3045 | 1.3294 | |
| | | UB | 1.00 | 1.1218 | 1.1963 | 1.2850 | 1.3383 | 1.3749 | |
| | Steganteil = 0.4203 | | | | | | | | |
| | 2. | Monosym. QS: $h_{\text{ges, QS2}}=1200$ mm | | 200/10 | - | - | - | - | - |
| | | | | 1170/12 | - | - | - | - | - |
| | | | | 600/20 | 600/30 | 600/40 | 600/60 | 600/80 | 600/120 |
| $\frac{N_{UG1}}{N_{UG2}}$ | | OB | 1.00 | 1.0845 | 1.1301 | 1.1746 | 1.1923 | 1.1975 | |
| | | Z | 1.00 | 1.0894 | 1.1403 | 1.1947 | 1.2220 | 1.2364 | |
| | | UB | 1.00 | 1.0945 | 1.1504 | 1.2155 | 1.2533 | 1.2780 | |
| Steganteil = 0.5007 | | | | | | | | | |
| 3. | | Monosym. QS: $h_{\text{ges, QS2}}=1200$ mm | | 800/60 | - | - | - | - | - |
| | | | | 1120/15 | - | - | - | - | - |
| | | | | 600/20 | 600/30 | 600/40 | 600/60 | 600/80 | 600/120 |
| | $\frac{N_{UG1}}{N_{UG2}}$ | OB | 1.00 | 1.1148 | 1.1808 | 1.2516 | 1.2830 | 1.2994 | |
| | | Z | 1.00 | 1.1206 | 1.1923 | 1.2737 | 1.3182 | 1.3457 | |
| | | UB | 1.00 | 1.1263 | 1.2048 | 1.2979 | 1.3550 | 1.3955 | |
| | Steganteil = 0.2188 | | | | | | | | |
| | 4. | Doppelsym. QS: $h_{\text{ges, QS2}}=1200$ mm | | 600/20 | - | - | - | - | - |
| | | | | 1160/40 | - | - | - | - | - |
| | | | | 600/20 | 600/30 | 600/40 | 600/60 | 600/80 | 600/120 |
| $\frac{N_{UG1}}{N_{UG2}}$ | | OB | 1.00 | 1.2110 | 1.3522 | 1.5255 | 1.6244 | 1.6846 | |
| | | Z | 1.00 | 1.2179 | 1.3665 | 1.5556 | 1.6703 | 1.7461 | |
| | | UB | 1.00 | 1.2246 | 1.3862 | 1.5868 | 1.7185 | 1.8116 | |
| Steganteil = 0.6591 | | | | | | | | | |
| 5. | | Doppelsym. QS: $h_{\text{ges, QS2}}=3910$ mm | | 600/20 | - | - | - | - | - |
| | | | | 3870/12 | - | - | - | - | - |
| | | | | 600/20 | 600/30 | 600/40 | 600/60 | 600/80 | 600/120 |
| | $\frac{N_{UG1}}{N_{UG2}}$ | OB | 1.00 | 1.2121 | 1.3554 | 1.1749 | 1.6437 | 1.7147 | |
| | | Z | 1.00 | 1.2142 | 1.3598 | 1.5449 | 1.6578 | 1.7334 | |
| | | UB | 1.00 | 1.2162 | 1.3641 | 1.5542 | 1.6720 | 1.7528 | |
| | Steganteil = 0.6593 | | | | | | | | |

Tabelle 5: Vergleiche N_{UG1}/N_{UG2}

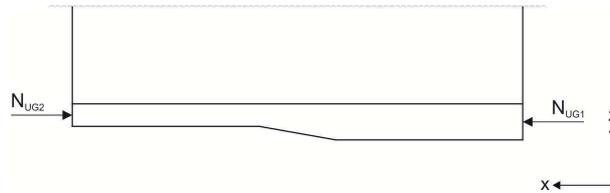


Abbildung 37: Definition N_{UG}

In Tabelle 5 wurden die Stegflächenanteile unterschiedlicher Trägerquerschnitte und Gurt dickensprünge untersucht. Es wurden doppelsymmetrische und monosymmetrische Träger unterschiedlicher Bauhöhen herangezogen. Berechnet wurde das jeweilige Gurtkraftverhältnis N_{UG2}/N_{UG1} (dünnes Gurtblech / dickes Gurtblech) um einen oberen bzw. unteren Wert für realistische Querschnittsabmessungen zu finden. Der Steganteil kann als eine der relevanten Größen angesehen werden.

Aus obigen Ergebnissen wurde gefolgert, dass die Untersuchung an doppelsymmetrischen Trägern mit I-Querschnitt mit Stegflächenanteilen von 0.4203 und 0.6593 bei einer Trägerhöhe von 1200 mm bzw. 3910 mm den Bereich üblicher Trägerabmessungen recht gut abdeckt. Die maximalen Gurtkraftverhältnisse N_{UG1}/N_{UG2} für die ausgewählten Querschnitte betragen:

QS1:

- | | | |
|------------------------------------|--------------|-----------|
| OG 600/20 | Steg 1160/15 | UG 600/30 |
| $\frac{N_{UG1}}{N_{UG2}} = 1.1123$ | | |

- | | | |
|------------------------------------|--------------|------------|
| OG 600/20 | Steg 1160/15 | UG 600/120 |
| $\frac{N_{UG1}}{N_{UG2}} = 1.3749$ | | |

QS2:

- | | | |
|------------------------------------|--------------|-----------|
| OG 600/20 | Steg 3870/12 | UG 600/30 |
| $\frac{N_{UG1}}{N_{UG2}} = 1.2121$ | | |

- | | | |
|------------------------------------|--------------|------------|
| OG 600/20 | Steg 3870/12 | UG 600/120 |
| $\frac{N_{UG1}}{N_{UG2}} = 1.7528$ | | |

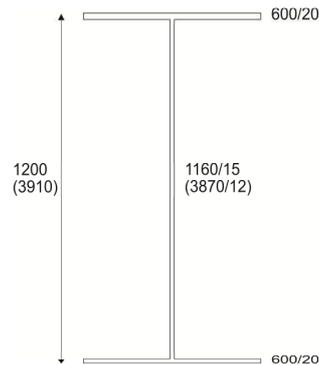


Abbildung 38: Darstellung des untersuchten Querschnittes

Die Darstellung in Abbildung 38 zeigt den symmetrischen Querschnitt mit den unterschiedlichen Bauhöhen von 1200 mm (QS1) und 3910 mm (QS2). Für diese beiden Querschnitte wurde eine Beulanalyse mit konstantem Untergurt ($t_1=t_2$) und den Untergurtdickensprüngen (OB, UB, Z) durchgeführt. Es wurden somit in den nachfolgenden Rechnungen baupraktisch übliche Querschnitte mit Normalkraftverhältnissen von 1.3749 (QS1) bzw. 1.7528 (QS2) untersucht.

5.3. Beulanalyse ohne Dickensprung

Für die Beulanalyse wurden die Träger mit einem konstanten Moment belastet. Die Modellierung der Träger wurde im Finite Element Programm ABAQUS mit S4 Schalen-Elementen (siehe Pkt. 2.4.3) durchgeführt. Die Lasteinleitung erfolgte gleich wie bei der Platte über Connector Elemente (siehe Abbildung 9). Die Verbindung des Steges mit dem Ober- und Untergurt wurde, wie bei den Rechnungen unter Pkt. 2.4.1 ersichtlich ist, gelenkig modelliert. Daher ist der Steg ebenfalls über die gesamte Höhe in die y-Richtung gehalten. Somit ist gewährleistet, dass in der Folge konservativer Weise nur das lokale Beulen am Untergurt untersucht und verglichen wird.

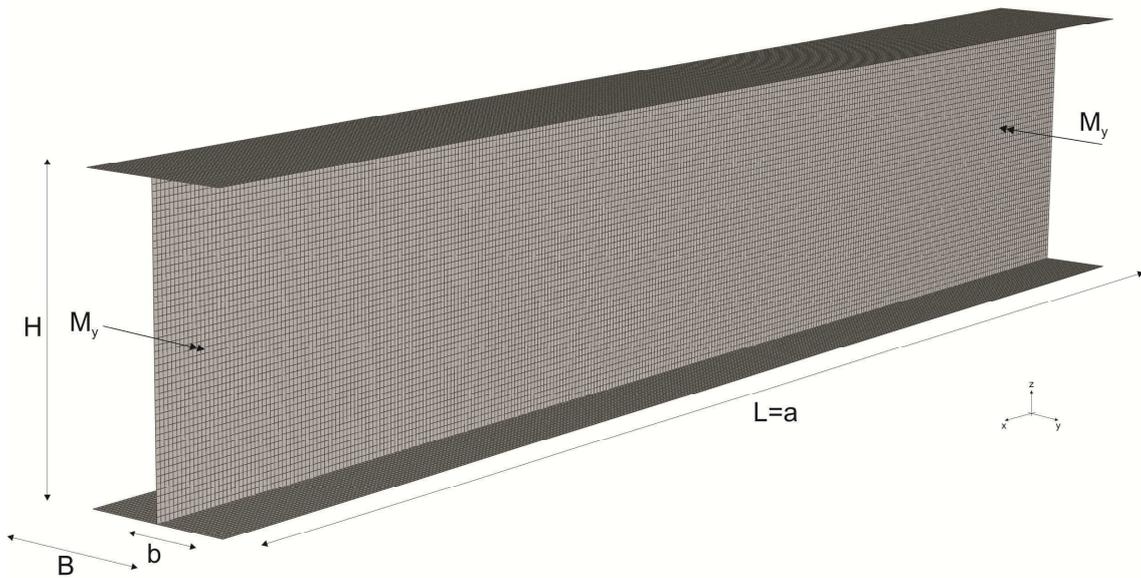


Abbildung 39: Darstellung der Belastung und Abmessungen

Die Ermittlung der Querschnittswerte ist dem Anhang A zu entnehmen.

Untersucht wurden die zwei Träger mit der Höhe von 1200 mm (QS1) und 3910 mm (QS2). Variiert wurde das Längenverhältnis $\alpha=a/b$, in der Größenordnung von 1 bis 20.

| α | 1 | 1,5 | 2 | 2,5 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 15 | 20 |
|----------|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|------|------|
| L(=a) | 300 | 450 | 600 | 750 | 900 | 1200 | 1500 | 1800 | 2100 | 2400 | 2700 | 3000 | 4500 | 6000 |

Tabelle 6: Darstellung Längenverhältnis α mit zugehöriger Trägerlänge [mm]

Die Breite B wurde bei beiden Trägervarianten konstant mit 600 mm gehalten. Die Blechdicke wurde mit $t_1 = t_2 = 20$ mm ausgeführt. Als Belastung wurde ein Moment M_y von 6000 kNm vorzeichenrichtig (Druck im Untergurt) aufgebracht (siehe Abbildung 39).

Nachstehend soll für die Träger mit den Höhen $H=1200$ mm und $H=3910$ mm die erste Eigenform für ein Längenverhältnis von $\alpha=10$ (Gesamtlänge $L=3000$ mm) dargestellt werden.

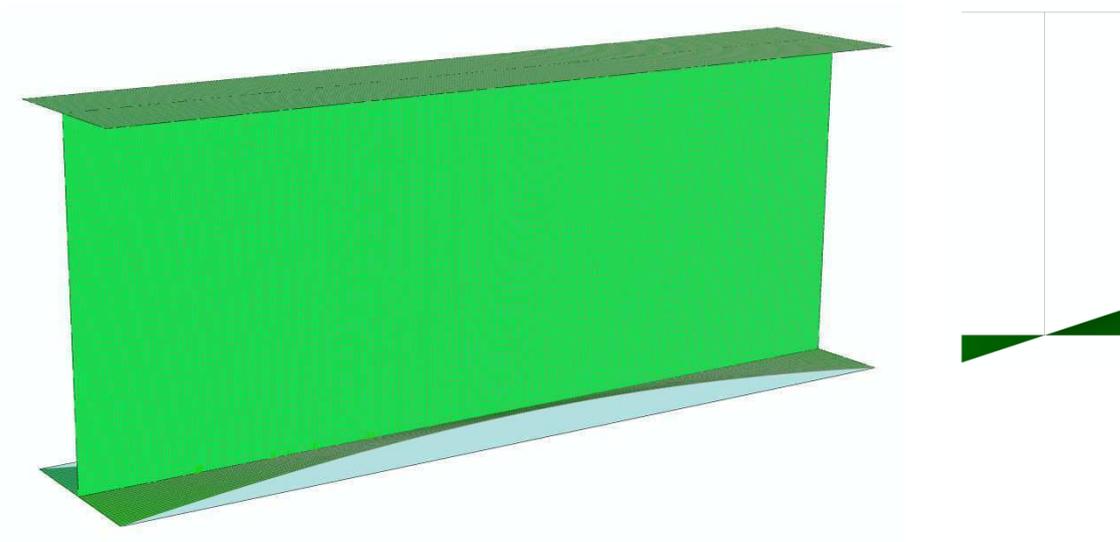


Abbildung 40: Träger $H=1200$, $t1/t2=1.0$, $\alpha=10$, $EV1=1.0492$, $k_{\sigma}=0.423$, $\sigma_{crit,ABQ}=356.82 \text{ N/mm}^2$

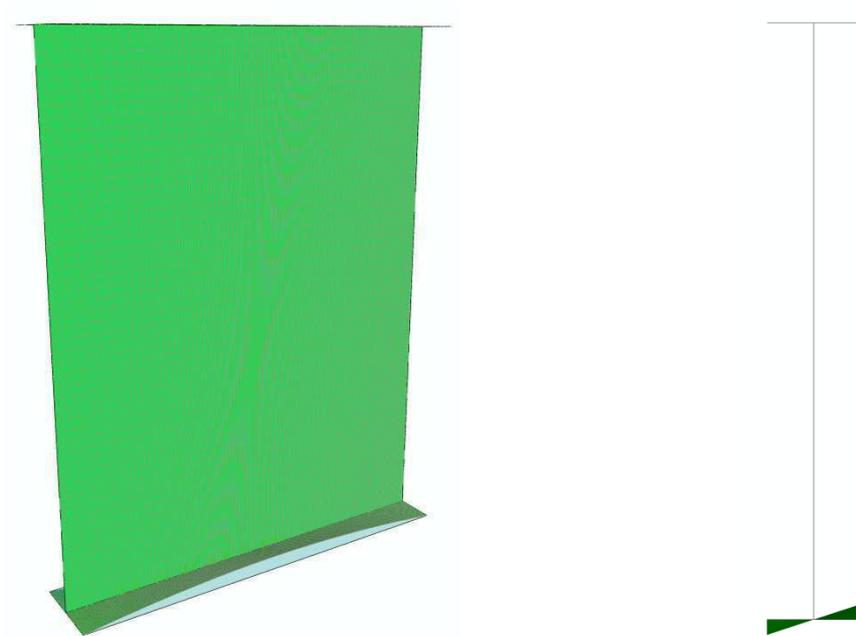


Abbildung 41: Träger $H=3910$, $t1/t2=1.0$, $\alpha=10$, $EV1=4.5720$, $k_{\sigma}=0.423$, $\sigma_{crit,ABQ}=356.82 \text{ N/mm}^2$

Wie aus der Abbildung 40 und Abbildung 41 ersichtlich wird, bildet sich die erste Eigenform auch beim Träger in einer Halbwelle aus, wie schon zuvor bei der Plattenberechnung erkennbar war.

| | analytische Lösung | Platte | Träger H=1200 mm | Träger H=3910 mm |
|-------------------|--------------------|--------|------------------|------------------|
| $k_{\sigma, EV1}$ | 0.435 | 0.427 | 0.423 | 0.423 |

Tabelle 7: Rückgerechnete Beulwerte k_{σ} für $\alpha=10$, $B=600$ mm

Tabelle 7 zeigt, dass die rückgerechneten Beulwerte der Platte und des Trägers leicht unter der analytischen Lösung, berechnet nach Pkt. 2.6, liegen. Die Differenz zwischen der Träger- und Platten-Berechnung liegt bei 1% und der Unterschied zur analytischen Lösung bei 3%.

Nachstehend soll der Vergleich für einen größeren Bereich in Bezug auf die Länge dargestellt werden.

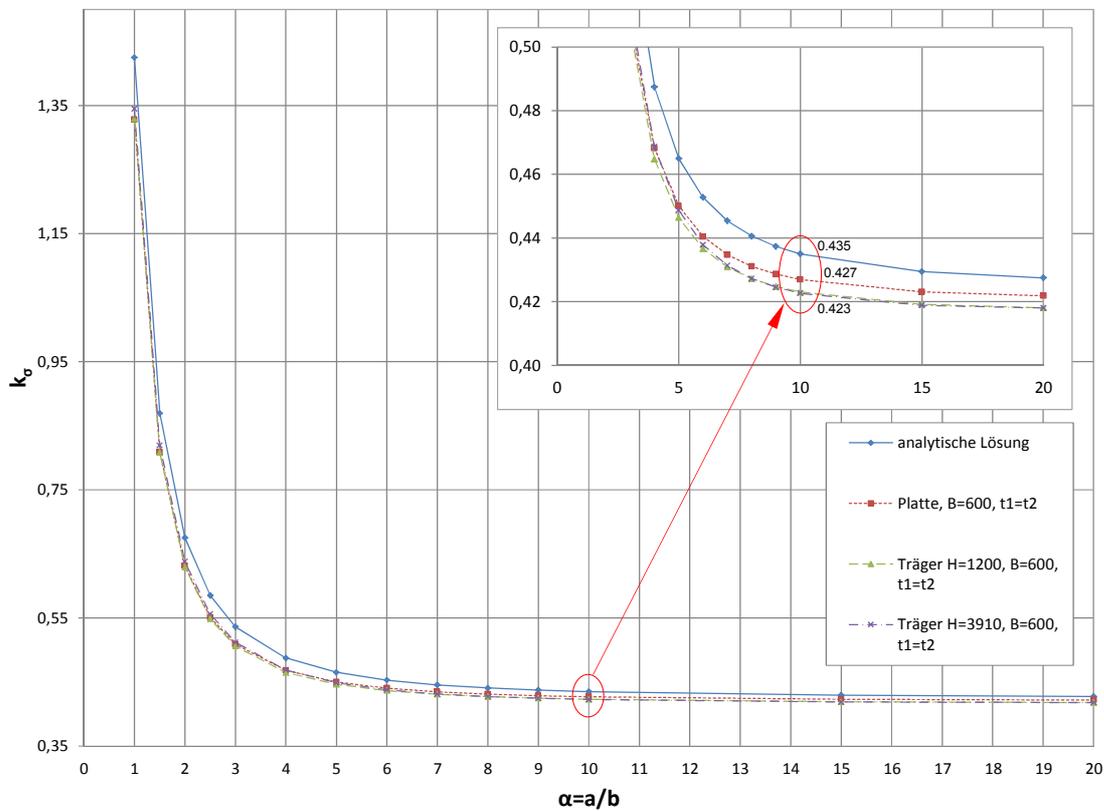


Abbildung 42: Darstellung der rückgerechneten Beulwerte k_{σ}

Erwartungsgemäß zeigt sich, dass die analytische Lösung und die ABAQUS Ergebnisse für Platte und Träger zu annähernd gleichen Ergebnissen führen. Die Unterschiede zwischen der analytischen Lösung und der ABAQUS Berechnung liegen, für den betrachteten Bereich von $\alpha=1$ bis 20, bei 3 bis 5 Prozent.

Unter Anhang B, Pkt. c soll dargestellt werden, dass sich auch die zweite und dritte Eigenform des Trägers gleich verhält wie die entsprechenden Eigenformen der Platte (vgl. Anhang B, Pkt. a).

5.4. Beulanalyse mit Dickensprung

Die Dickensprünge oben bündig (OB), unten bündig (UB) und zentrisch (Z) im Untergurt wurden analog zu Pkt. 4.3, Abbildung 26 bis Abbildung 28 modelliert. Die Größe der Dickensprünge bewegten sich in einem Dickenverhältnis t_1/t_2 von 1.25, 1.5, 3.0 und 6.0 als oberer Grenzwert. Die Berechnungen wurden an den zuvor schon behandelten zwei Trägern mit der Bauhöhe von 1200 mm und 3910 mm vorgenommen.

Die beiden Träger wurden jeweils für unterschiedliche Trägerlängen, welche über das Längenverhältnis α bestimmt wurden, berechnet (siehe Tabelle 8).

| α | 1 | 1,5 | 2 | 2,5 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 15 | 20 |
|----------|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|------|------|
| L(=a) | 300 | 450 | 600 | 750 | 900 | 1200 | 1500 | 1800 | 2100 | 2400 | 2700 | 3000 | 4500 | 6000 |

Tabelle 8: Darstellung des Längenverhältnisses α mit den dazugehörigen Trägerlängen

Nachstehend soll für den Träger mit $H=1200$ mm die erste Eigenform der drei Varianten des Dickensprunges (OB, UB, Z) gezeigt werden.

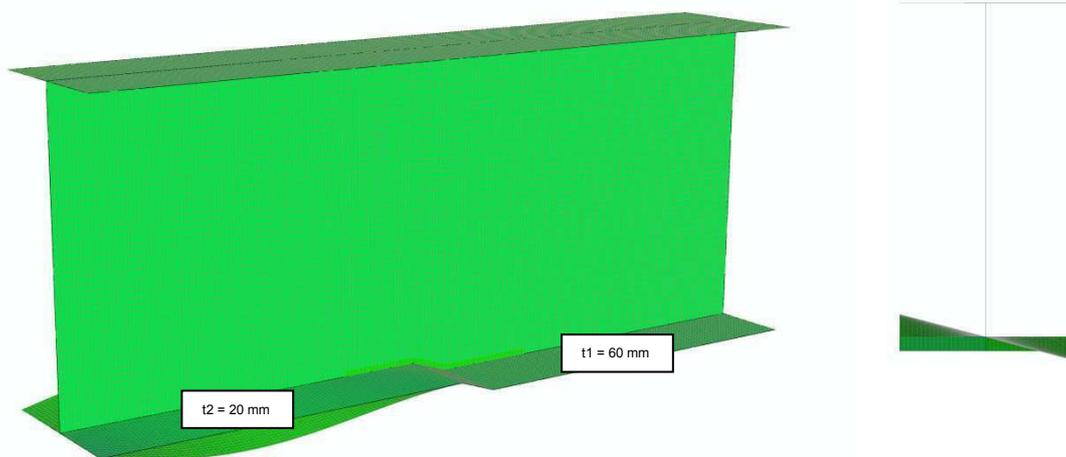


Abbildung 43: Träger $H=1200$, $t_1/t_2=6.0$, $\alpha=10$, OB, $EVI=1.2106$, $k_\sigma=0.488$, $\sigma_{crit,ABQ}=411.71$ N/mm²

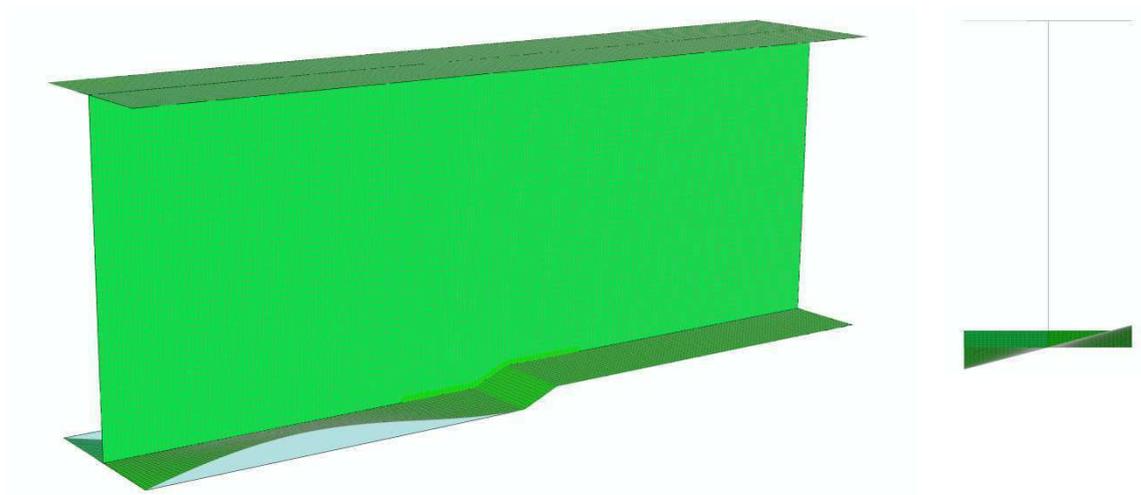


Abbildung 44: Träger $H=1200$, $t1/t2=6.0$, $\alpha=10$, UB, $EV1=1.2106$, $k_{\sigma}=0.488$, $\sigma_{crit,ABQ}=411.71 \text{ N/mm}^2$

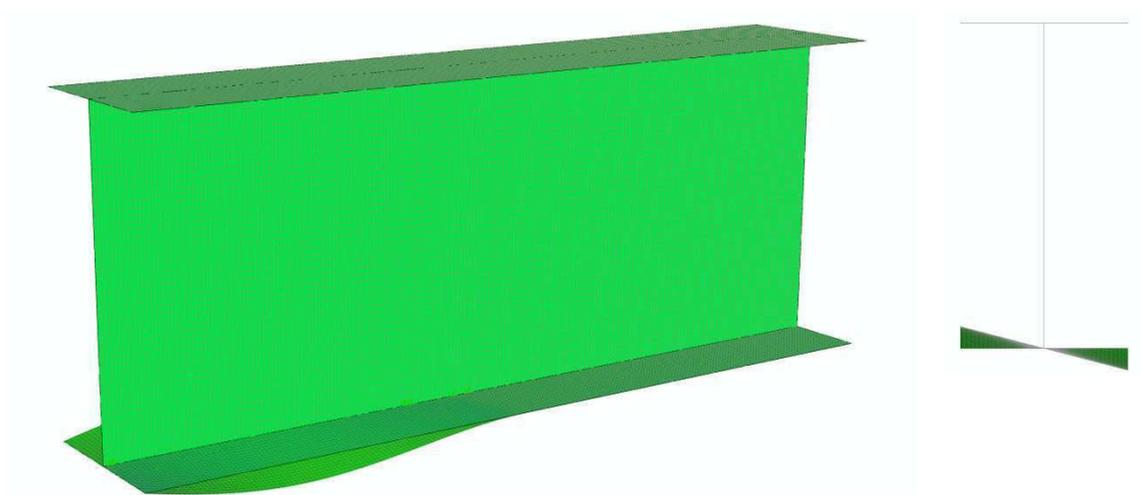


Abbildung 45: Träger $H=1200$, $t1/t2=6.0$, $\alpha=10$, Z, $EV1=1.1986$, $k_{\sigma}=0.483$, $\sigma_{crit,ABQ}=407.63 \text{ N/mm}^2$

Wie aus Abbildung 43 bis Abbildung 45 ersichtlich ist, ergeben sich dieselben Eigenformmuster, welche schon unter Pkt. 4.3 für die Platte mit Blechdickensprüngen gezeigt wurden. Dies bedeutet einerseits die Richtigkeit der ABAQUS Berechnungen und andererseits ermöglicht es einen Vergleich Träger mit Platte herzustellen.

Analog ergeben sich dieselben Eigenformen der verschiedenen Dickensprünge für den Träger mit der Bauhöhe $H=3910 \text{ mm}$.

Im Anhang B, Pkt. d werden weitere Eigenformen zur Veranschaulichung des Trägers gezeigt. Diese bilden sich analog den Eigenformen der Platte mit Dickensprung aus.

Für die nachstehenden Ergebnisse wurden jeweils die erste Eigenform und der erste Eigenwert berechnet um dadurch die Rückrechnung auf den Beulwert k_{σ} laut Formel (5)

durchzuführen. Anhand dieser rückgerechneten Beulwerte soll der Vergleich mit der analytischen Lösung und der Trägerlösung ohne Dickensprung hergestellt werden.

Für die Längenverhältnisse $\alpha=4$ und $\alpha=10$ wurden zusätzliche Berechnungen mit einer Steife am dünnen Blech vor dem Dickensprung angefertigt, um eine etwaige Auswirkung auf den Beulwert zu zeigen. Die Steife wurde in der FE-Modellierung durch Gleichsetzen der Vertikalverschiebungen (*EQUATION) modelliert.



Abbildung 46: Anordnung der Steife für $\alpha=4$ und $\alpha=10$

| | α | t1/t2 | ohne Steife | | mit Steife | | α | t1/t2 | ohne Steife | | mit Steife | |
|------|----------|-------|--------------|----------|--------------|----------|----------|-------|--------------|----------|--------------|----------|
| | | | k_{σ} | Δ | k_{σ} | Δ | | | k_{σ} | Δ | k_{σ} | Δ |
| a.L. | 4 | 1,00 | 0,488 | | | | 10 | 1,00 | 0,435 | | | |
| | 4 | 1,00 | 0,465 | 0,95 | | | 10 | 1,00 | 0,423 | 0,97 | | |
| OB | 4 | 1,25 | 0,602 | 1,29 | 0,802 | 1,33 | 10 | 1,25 | 0,472 | 1,12 | 0,480 | 1,02 |
| UB | 4 | 1,25 | 0,602 | 1,29 | 0,802 | 1,33 | 10 | 1,25 | 0,472 | 1,12 | 0,480 | 1,02 |
| Z | 4 | 1,25 | 0,598 | 1,29 | 0,800 | 1,34 | 10 | 1,25 | 0,471 | 1,11 | 0,479 | 1,02 |
| OB | 4 | 1,50 | 0,702 | 1,51 | 0,853 | 1,21 | 10 | 1,50 | 0,479 | 1,13 | 0,482 | 1,01 |
| UB | 4 | 1,50 | 0,702 | 1,51 | 0,853 | 1,21 | 10 | 1,50 | 0,479 | 1,13 | 0,482 | 1,01 |
| Z | 4 | 1,50 | 0,694 | 1,49 | 0,851 | 1,23 | 10 | 1,50 | 0,478 | 1,13 | 0,482 | 1,01 |
| OB | 4 | 3,00 | 0,897 | 1,93 | 0,912 | 1,02 | 10 | 3,00 | 0,486 | 1,15 | 0,485 | 1,00 |
| UB | 4 | 3,00 | 0,897 | 1,93 | 0,912 | 1,02 | 10 | 3,00 | 0,486 | 1,15 | 0,485 | 1,00 |
| Z | 4 | 3,00 | 0,872 | 1,88 | 0,907 | 1,04 | 10 | 3,00 | 0,483 | 1,14 | 0,484 | 1,00 |
| OB | 4 | 6,00 | 0,948 | 2,04 | 0,936 | 0,99 | 10 | 6,00 | 0,488 | 1,15 | 0,486 | 0,99 |
| UB | 4 | 6,00 | 0,948 | 2,04 | 0,936 | 0,99 | 10 | 6,00 | 0,488 | 1,15 | 0,486 | 0,99 |
| Z | 4 | 6,00 | 0,913 | 1,96 | 0,921 | 1,01 | 10 | 6,00 | 0,483 | 1,14 | 0,484 | 1,00 |

Tabelle 9: Darstellung der einzelnen Beulwerte k_{σ} , $H=1200$ [-]

Der in Tabelle 9 gezeigte Vergleich zwischen der analytischen Lösung (a.L., $k_{\sigma} = 0.488$), der Trägerberechnung ohne Dickensprung ($k_{\sigma} = 0.465$) und der Trägerberechnung mit Dickensprung, mit und ohne Steife ($k_{\sigma,1.5,OB} = 0.702$; $k_{\sigma,1.5,OB,ST} = 0.853$), zeigt, dass die Träger, die einen Untergurtdickensprung haben, einen höheren Beulwert erreichen.

Der Beulwert wird im Vergleich zur Berechnung ohne Dickensprung im Untergurt umso höher, je kleiner das Längenverhältnis α ausfällt. Dies zeigt sich für $\alpha = 10$ von $k_{\sigma,1.5,OB} = 0.479$ zu $k_{\sigma,1.0} = 0.423$ mit einer Erhöhung von 13%.

Wobei hingegen die Erhöhung des Beulwertes bei $\alpha = 4$ für den selben betrachteten Fall mit 51% ausfällt ($k_{\sigma,1.5,OB} = 0.702$; $k_{\sigma,1.0} = 0.465$; $\Delta = 51\%$). Auch zeigt sich, wie schon unter Pkt. 5.3 festgestellt, dass sich der Beulwert der ABAQUS Rechnung ohne Dickensprung ($t1=t2$) etwas unter der analytischen Lösung befindet (~5%).

Es zeigt sich weiters, dass der Beulwert für große Verhältnisse der Blechdicken $t1$ zu $t2$ nur gering höher ist, als für kleine $t1/t2$ Verhältnisse ($k_{\sigma,10,1.5,OB} = 0.479$; $k_{\sigma,10,6.0,OB} = 0.488$).

Dies lässt sich mit dem geringen Einfluss bei langen Trägerlängen erklären. Untermuert wird dieses Ergebnis das durch die Anordnung von Steifen bei größeren Trägerlängen keine weitere Laststeigerung erreicht wird.

Der Beulwert erhöht sich durch die Anordnung von Steifen in Richtung der oberen Werte der t_1/t_2 -Verhältnisse. Deutlich ersichtlich ist dies beim Beispiel des Längenverhältnisses $\alpha=4$, wo sich der Beulwert $k_{\sigma,1.25,OB} = 0.602$ um 33% auf $k_{\sigma,1.25,OB} = 0.802$ durch die Anordnung der Steife erhöht.

Bei dem Längenverhältnis von $\alpha=10$ wird der Einfluss der Steife nicht so stark tragend ($k_{\sigma,3.0,Z} = 0.483$; $k_{\sigma,3.0,Z,ST} = 0.484$). Die Erhöhung bewegt sich im Bereich von ein bis zwei Prozent.

Dies lässt sich, wie auch schon unter Pkt. 4.3 ersichtlich wird, durch die Abnahme des Einflusses der Einspannwirkung des Dicken Sprunges bei größeren Längenverhältnissen erklären.

Nachstehend sollen die betrachteten α -Werte dargestellt und Vergleiche mit den Dicken sprüngen ersichtlich gemacht werden.

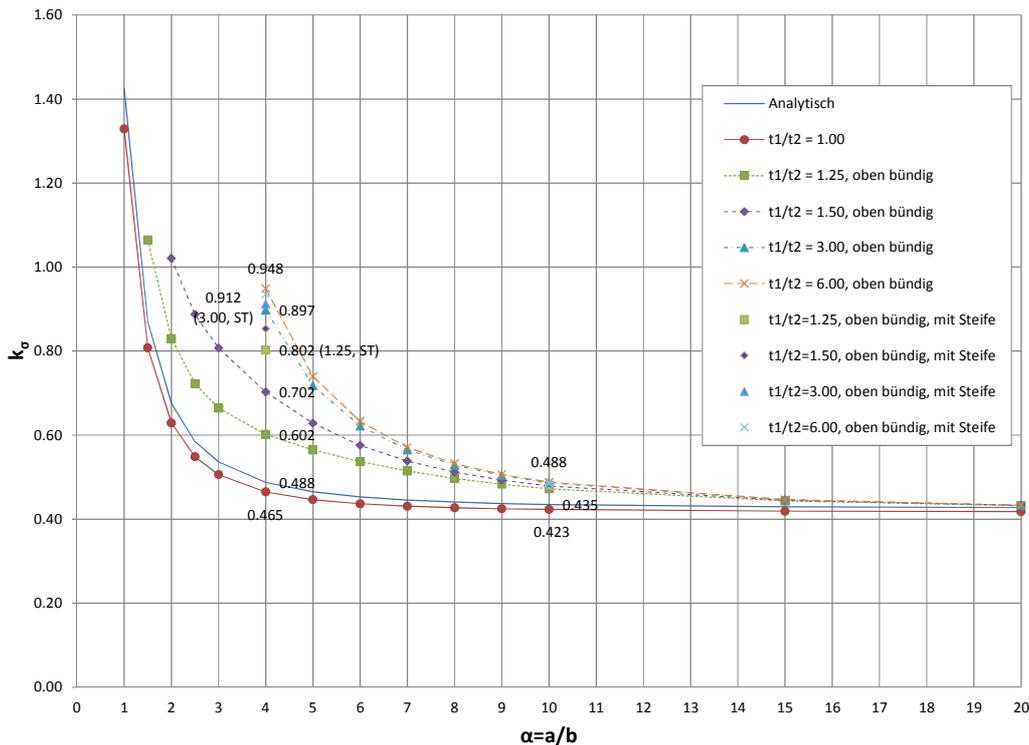


Abbildung 47: Darstellung der k_{σ} -Werte für den Dicken sprung OB, $H=1200$ mm

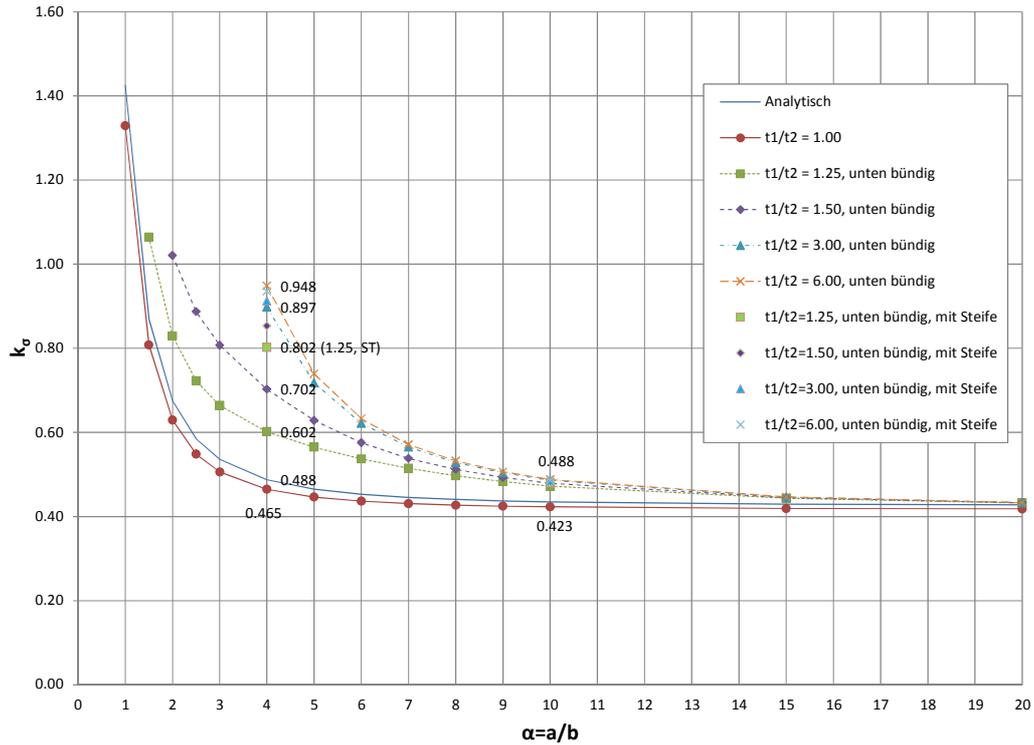


Abbildung 48: Darstellung der k_σ -Werte für den Dicken sprung UB, $H=1200$ mm

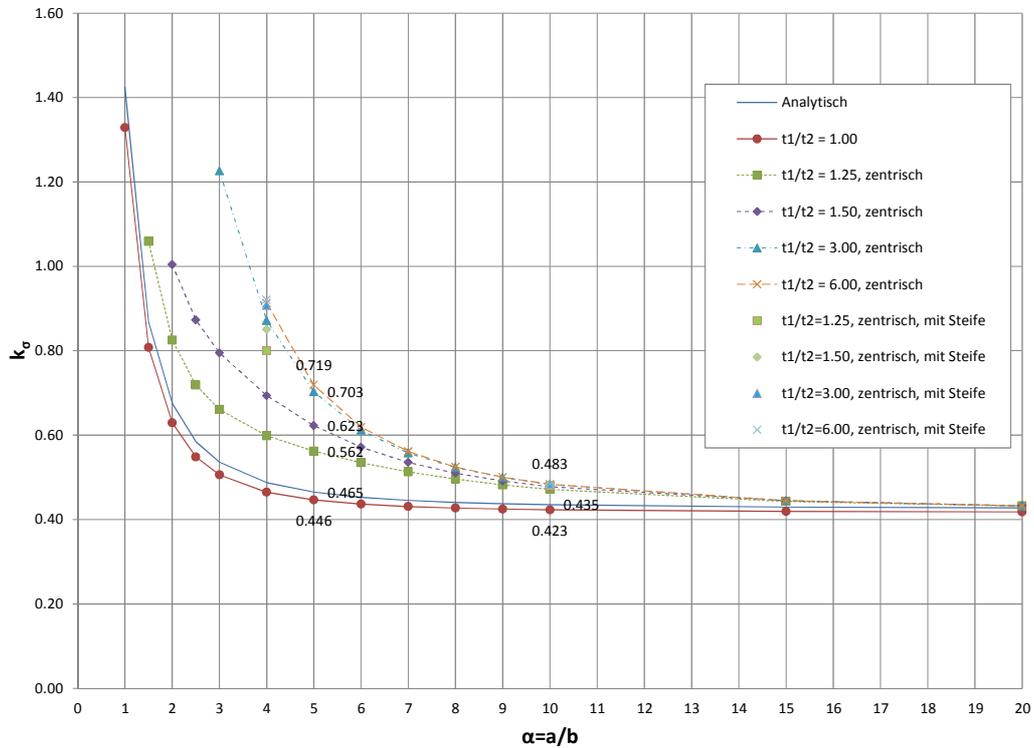


Abbildung 49: Darstellung der k_σ -Werte für den Dicken sprung Z, $H=1200$ mm

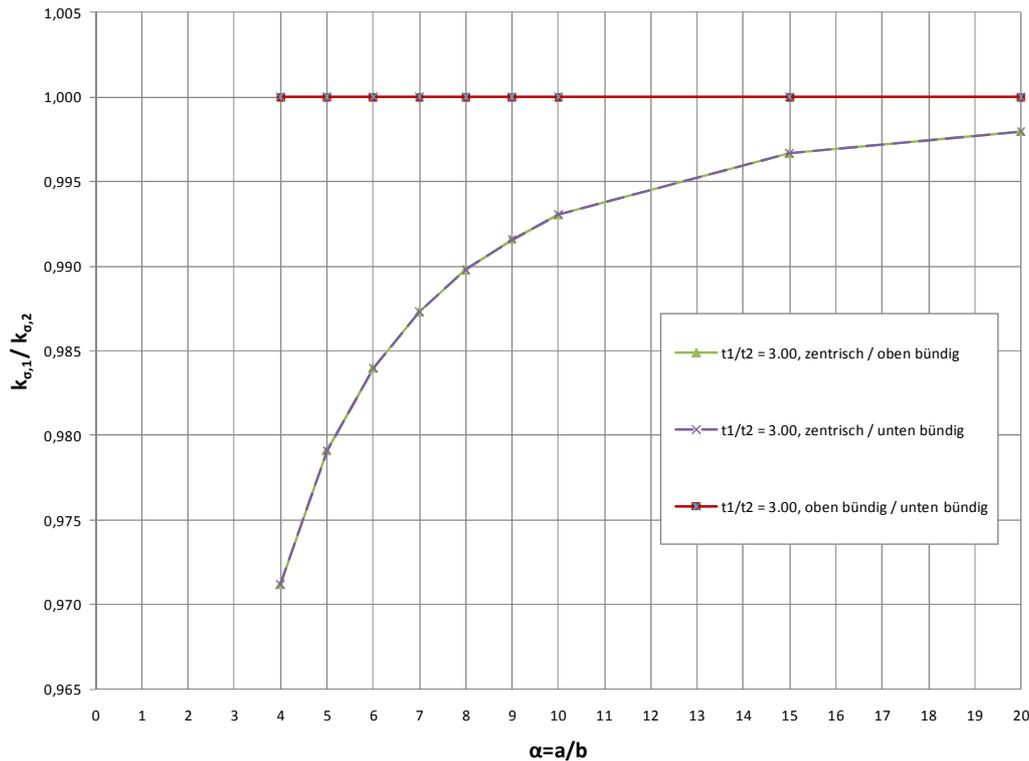


Abbildung 50: Darstellung des Unterschiedes der Dicken sprungvarianten OB/UB/Z für $t_1/t_2=3.00$, $H=1200$ mm

Aus Abbildung 50 wird ersichtlich, dass bei der Trägeruntersuchung der Dicken sprung oben bündig (OB) die gleichen rückgerechneten Beulwerte ergibt, wie der Dicken sprung mit der Ausführung unten bündig (UB), $k_{\sigma,10,3.0,OB} = 0.486$; $k_{\sigma,10,3.0,UB} = 0.486$. Die rückgerechneten Beulwerte des zentrischen Dicken sprunges (Z) sind unwesentlich (max 3%) niedriger, als die Beulwerte des oben bzw. unten bündigen Dicken sprunges ($k_{\sigma,10,3.0,Z} = 0.486$).

Die Vergleiche für die weiteren Dicken sprungverhältnisse t_1/t_2 (1.25, 1.50, 6.00) sind dem Anhang C, Pkt. b zu entnehmen.

Wie mit den Diagrammen im Anhang C, Pkt. c gezeigt wird, gelten die Erkenntnisse für den Träger mit $H=1200$ mm sinngemäß auch für den Träger $H=3910$ mm.

Auf den genauen Vergleich der Ergebnisse soll im nächsten Kapitel 5.5 eingegangen werden.

5.5. Vergleich Träger H=1200 mm mit Träger H=3910 mm

In diesem Kapitel soll der Unterschied zwischen den beiden Trägern H=1200 mm und H=3910 mm herausgearbeitet werden. Die Träger wurden mit der gleichen Netzteilung und derselben Belastung modelliert. Dies erleichtert einen Vergleich der rückgerechneten Beulwerte $k_{\sigma,ABQ}$.

| α | H=1200mm | H=3910mm | Δ |
|----------|------------------|------------------|----------|
| | $k_{\sigma,ABQ}$ | $k_{\sigma,ABQ}$ | |
| 1,5 | 0,808 | 0,819 | 0,986 |
| 2 | 0,629 | 0,638 | 0,986 |
| 2,5 | 0,549 | 0,556 | 0,987 |
| 3 | 0,506 | 0,512 | 0,988 |
| 4 | 0,465 | 0,469 | 0,992 |
| 5 | 0,446 | 0,449 | 0,995 |
| 6 | 0,437 | 0,438 | 0,997 |
| 7 | 0,431 | 0,431 | 0,999 |
| 8 | 0,427 | 0,427 | 1,000 |
| 9 | 0,425 | 0,425 | 1,001 |
| 10 | 0,423 | 0,423 | 1,001 |
| 15 | 0,419 | 0,419 | 1,001 |
| 20 | 0,418 | 0,418 | 1,000 |

Tabelle 10: Vergleich der Träger H=1200 und H=3910 ohne Untergurtdickensprung ($t1=t2$), [-]

| α | $t1/t2=3.00$ oben bündig | | | $t1/t2=3.00$ unten bündig | | | $t1/t2=3.00$ zentrisch | | |
|----------|--------------------------|------------------|----------|---------------------------|------------------|----------|------------------------|------------------|----------|
| | H=1200mm | H=3910mm | Δ | H=1200mm | H=3910mm | Δ | H=1200mm | H=3910mm | Δ |
| | $k_{\sigma,ABQ}$ | $k_{\sigma,ABQ}$ | | $k_{\sigma,ABQ}$ | $k_{\sigma,ABQ}$ | | $k_{\sigma,ABQ}$ | $k_{\sigma,ABQ}$ | |
| 4 | 0,897 | 0,824 | 1,089 | 0,897 | 0,824 | 1,089 | 0,872 | 0,796 | 1,095 |
| 5 | 0,718 | 0,658 | 1,090 | 0,718 | 0,658 | 1,090 | 0,703 | 0,641 | 1,096 |
| 6 | 0,622 | 0,571 | 1,089 | 0,622 | 0,571 | 1,089 | 0,612 | 0,559 | 1,094 |
| 7 | 0,565 | 0,520 | 1,087 | 0,565 | 0,520 | 1,087 | 0,558 | 0,511 | 1,091 |
| 8 | 0,528 | 0,488 | 1,083 | 0,528 | 0,488 | 1,083 | 0,523 | 0,481 | 1,087 |
| 9 | 0,504 | 0,467 | 1,079 | 0,504 | 0,467 | 1,079 | 0,500 | 0,461 | 1,083 |
| 10 | 0,486 | 0,453 | 1,074 | 0,486 | 0,453 | 1,074 | 0,483 | 0,448 | 1,078 |
| 15 | 0,446 | 0,424 | 1,053 | 0,446 | 0,424 | 1,053 | 0,445 | 0,422 | 1,055 |
| 20 | 0,433 | 0,417 | 1,039 | 0,433 | 0,417 | 1,039 | 0,432 | 0,415 | 1,041 |

Tabelle 11: Vergleich der Träger H=1200 und H=3910 mit Untergurtdickensprung ($t1/t2=3.00$), [-]

Wie aus Tabelle 10 hervorgeht, gibt es in den unteren Längenverhältnissen $\alpha \leq 5$ eine Abweichung der beiden untersuchten Träger ohne Gurtdickensprung. Diese ist mit einer Größe von 1% jedoch sehr gering ($k_{\sigma,3,1,0,1200} = 0.506$; $k_{\sigma,3,1,0,3910} = 0.512$; $\Delta = 0.988$).

Wird jedoch ein Untergurtdickensprung ausgeführt, erhöht sich der Beulwert des Trägers mit H=1200 mm ($k_{\sigma,5,3,0,OB,1200} = 0.718$) um bis zu 10% gegenüber dem Träger mit H=3910 mm ($k_{\sigma,5,3,0,OB,3910} = 0.658$). Dies wird aus Tabelle 11 und den nachstehenden Diagrammen ersichtlich.

Dieser Umstand lässt sich aufgrund des höheren Steganteiles beim Träger H=3910 mm und durch ein höheres Normalkraftverhältnis $N1/N2$ im Übergangsbereich der zwei Blechdicken erklären.

Die Erhöhung des Beulwertes ist besonders für Blechdickenverhältnisse $t_1/t_2 = 6.00$ (oberer Grenzwert) im Bereich des Längenverhältnisses $\alpha < 10$ prägnant ausgeprägt (bis zu 14% Erhöhung Beulwert Träger₁₂₀₀ / Beulwert Träger₃₉₁₀, Abb. Abbildung 53).

Mit größeren Längenverhältnissen wird der Unterschied der Beulwerte immer geringer (Träger₁₂₀₀/Träger₃₉₁₀ = 3%).

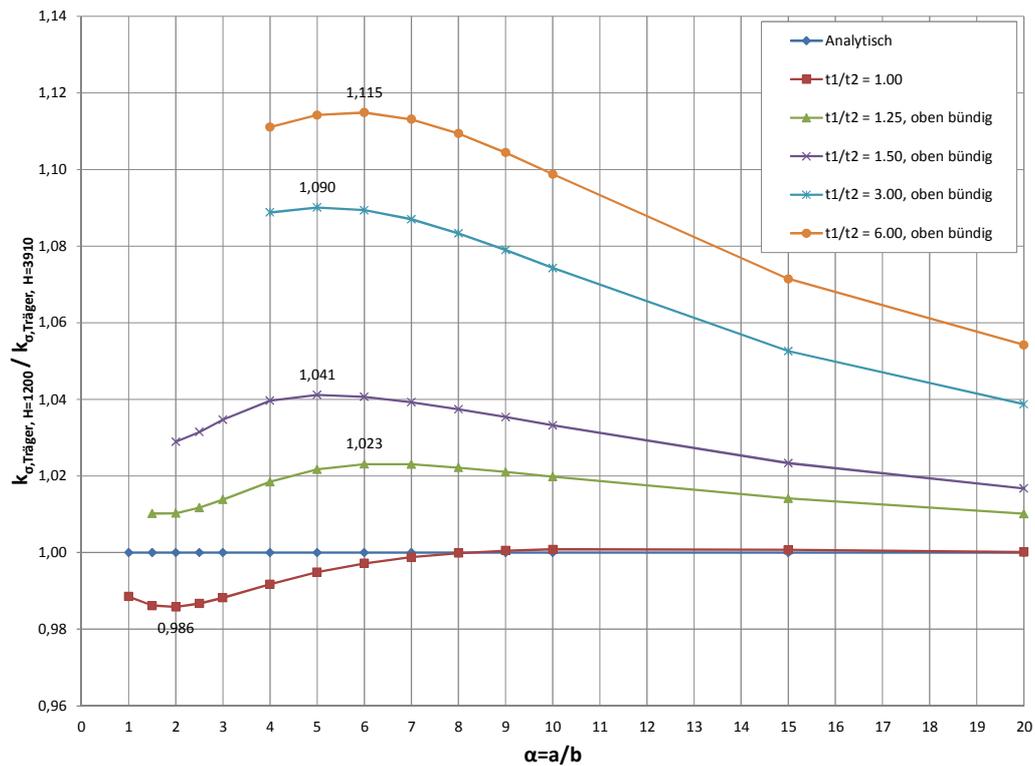


Abbildung 51: Vergleich der rückgerechneten Beulwerte der Träger $H=1200$ und $H=3910$ mm, OB

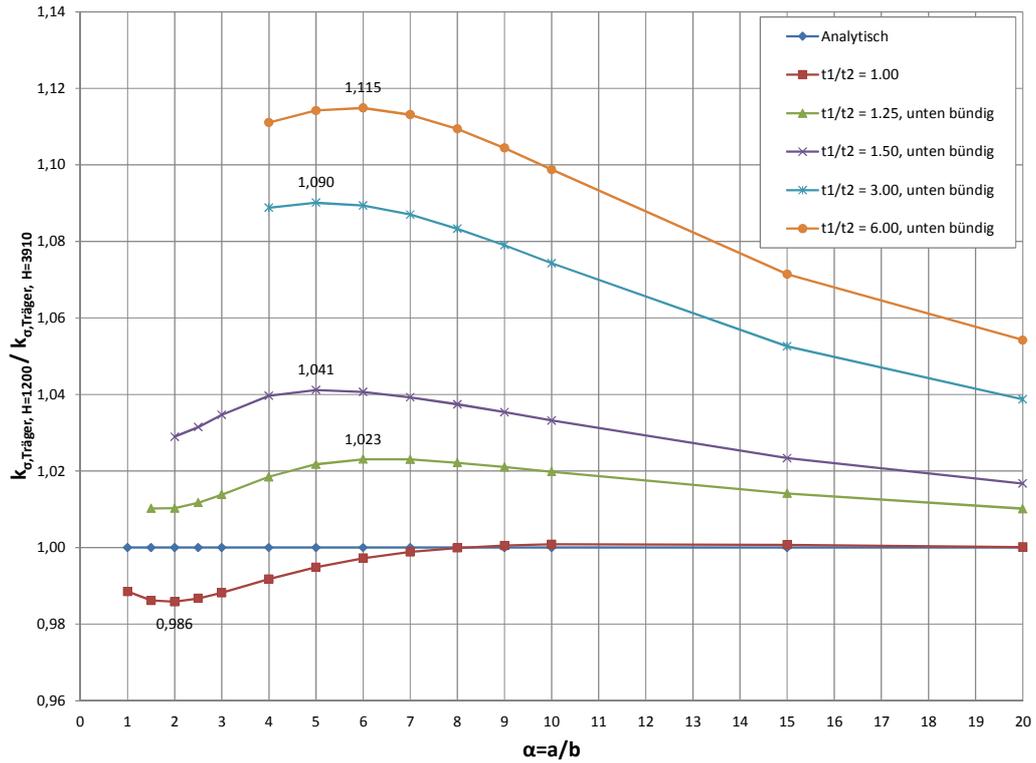


Abbildung 52: Vergleich der rückgerechneten Beulwerte der Träger $H=1200$ und $H=3910$ mm, UB

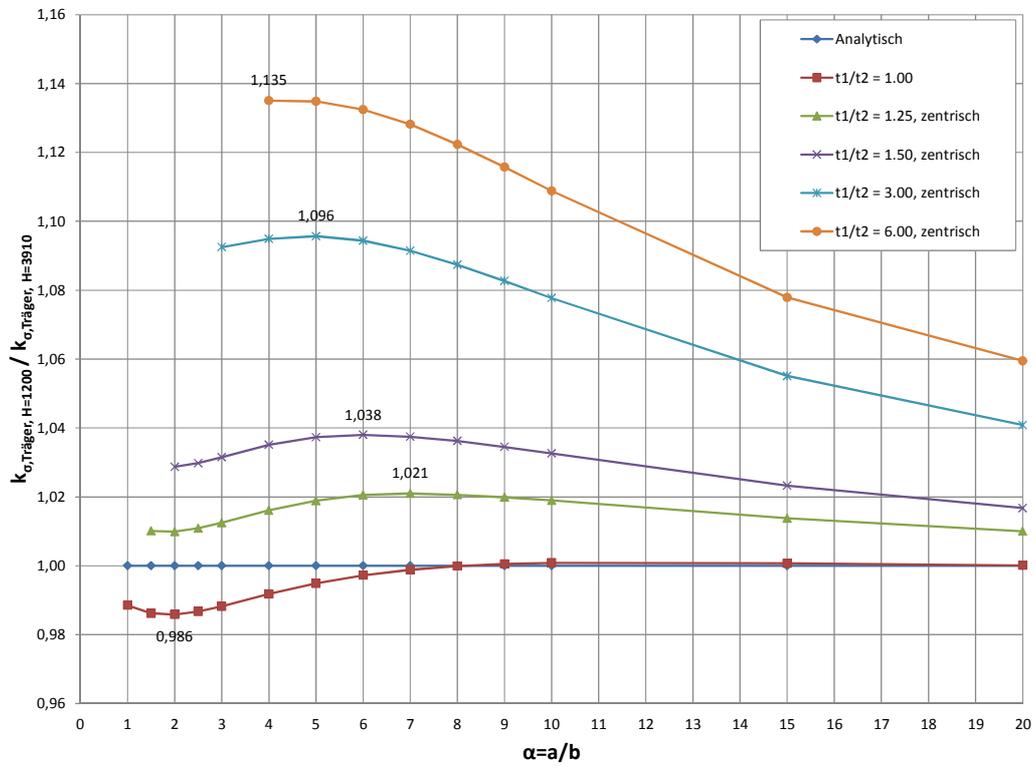


Abbildung 53: Vergleich der rückgerechneten Beulwerte der Träger $H=1200$ und $H=3910$ mm, Z

5.6. Vergleich der Träger mit der Platte

5.6.1. Trägerberechnung für H=1200 mm mit der Plattenberechnung

Nun soll der Vergleich zwischen der kritischen Plattenberechnung mit der Trägerberechnung der Bauhöhe 1200 mm dargestellt werden. Die Vergleiche wurden für eine Untergurtbreite B von 600 mm mit oder ohne Dickensprünge ausgeführt.

| α | H=1200mm | Platte | Δ |
|----------|------------------|------------------|----------|
| | $k_{\sigma,ABQ}$ | $k_{\sigma,ABQ}$ | |
| 1,5 | 0,808 | 0,809 | 0,999 |
| 2 | 0,629 | 0,631 | 0,997 |
| 2,5 | 0,549 | 0,551 | 0,995 |
| 3 | 0,506 | 0,509 | 0,994 |
| 4 | 0,465 | 0,468 | 0,993 |
| 5 | 0,446 | 0,450 | 0,992 |
| 6 | 0,437 | 0,440 | 0,991 |
| 7 | 0,431 | 0,435 | 0,991 |
| 8 | 0,427 | 0,431 | 0,991 |
| 9 | 0,425 | 0,429 | 0,991 |
| 10 | 0,423 | 0,427 | 0,991 |
| 15 | 0,419 | 0,423 | 0,991 |
| 20 | 0,418 | 0,422 | 0,991 |

Tabelle 12: Vergleich Träger H=1200 mm mit Platte ohne Dickensprung ($t1=t2$), [-]

| α | $t1/t2=3.00$ oben bündig | | | $t1/t2=3.00$ unten bündig | | | $t1/t2=3.00$ zentrisch | | |
|----------|--------------------------|------------------|----------|---------------------------|------------------|----------|------------------------|------------------|----------|
| | H=1200mm | Platte | Δ | H=1200mm | Platte | Δ | H=1200mm | Platte | Δ |
| | $k_{\sigma,ABQ}$ | $k_{\sigma,ABQ}$ | | $k_{\sigma,ABQ}$ | $k_{\sigma,ABQ}$ | | $k_{\sigma,ABQ}$ | $k_{\sigma,ABQ}$ | |
| 4 | 0,897 | 0,948 | 0,946 | 0,897 | 0,948 | 0,946 | 0,872 | 0,926 | 0,941 |
| 5 | 0,718 | 0,749 | 0,959 | 0,718 | 0,749 | 0,959 | 0,703 | 0,738 | 0,953 |
| 6 | 0,622 | 0,643 | 0,967 | 0,622 | 0,643 | 0,967 | 0,612 | 0,636 | 0,962 |
| 7 | 0,565 | 0,580 | 0,973 | 0,565 | 0,580 | 0,973 | 0,558 | 0,576 | 0,969 |
| 8 | 0,528 | 0,540 | 0,978 | 0,528 | 0,540 | 0,978 | 0,523 | 0,537 | 0,974 |
| 9 | 0,504 | 0,513 | 0,982 | 0,504 | 0,513 | 0,982 | 0,500 | 0,511 | 0,978 |
| 10 | 0,486 | 0,494 | 0,985 | 0,486 | 0,494 | 0,985 | 0,483 | 0,492 | 0,982 |
| 15 | 0,446 | 0,450 | 0,993 | 0,446 | 0,450 | 0,993 | 0,445 | 0,449 | 0,991 |
| 20 | 0,433 | 0,435 | 0,996 | 0,433 | 0,435 | 0,996 | 0,432 | 0,435 | 0,995 |

Tabelle 13: Vergleich Träger H=1200 mm mit Platte mit Dickensprung ($t1/t2=3.00$), [-]

In den nachstehenden Diagrammen wird ersichtlich, dass der Träger bei der Untergurtausführung ohne Dickensprung ($k_{\sigma,10,1.0} = 0.423$) nur um 1% von der Plattenberechnung ($k_{\sigma,10,1.0} = 0.427$) abweicht. Für die Ausführung mit den Dickensprüngen OB, UB, Z bewegt sich die Abweichung im Bereich von max. 8% für $t1/t2 = 6.0$ bei zentrischer Anordnung des Dickensprunges. Für $t1/t2 = 3.0$ beträgt dieser Unterschied max. 4% ($k_{\sigma,5,3.0,OB,1200} = 0.718$; $k_{\sigma,5,3.0,OB,PL} = 0.749$).

Wie schon der Vergleich der Träger untereinander ergeben hat, nimmt die Abweichung zu, je kleiner das Längenverhältnis wird. Dies gilt besonders für den Untergurt mit Dickensprung; ohne Dickensprung bleibt die Abweichung annähernd konstant bei 1%.

Bei größeren Längenverhältnissen α nähert sich die Trägerlösung der Plattenrechnung (Unterschied < 1%). Der Grund hierfür liegt in den kürzeren Abmessungen a des Beulfeldes, wodurch die Einspannwirkung durch den dickeren Gurt einen größeren Effekt auf das lokale Beulverhalten ausübt.

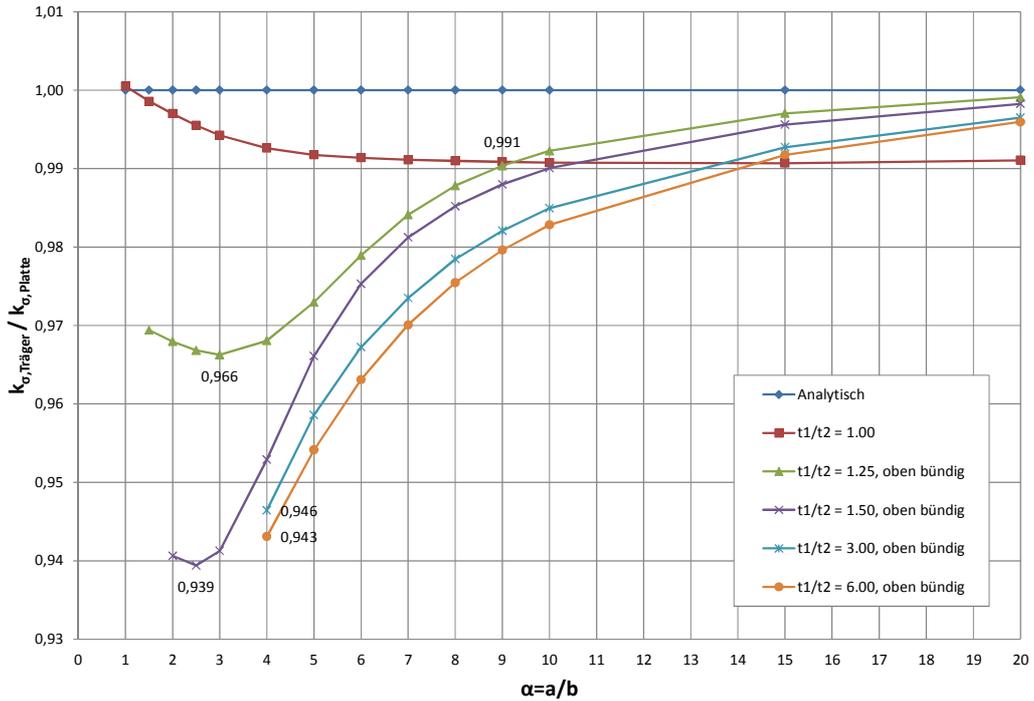


Abbildung 54: Vergleich Träger H=1200 mit Platte, Dickensprung OB

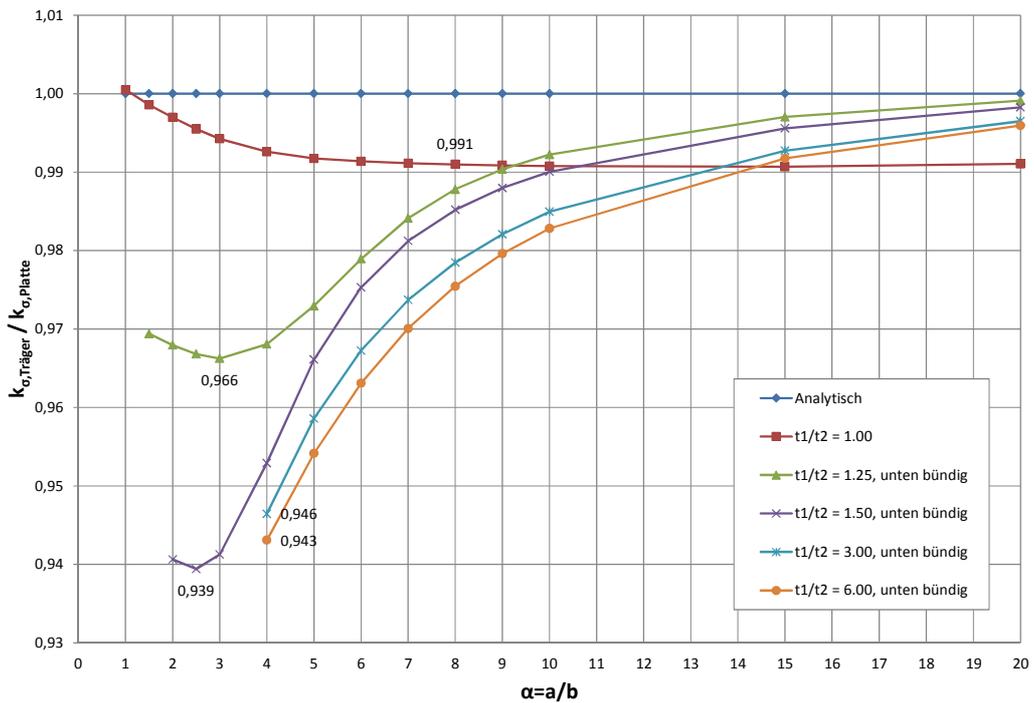


Abbildung 55: Vergleich Träger H=1200 mit Platte, Dickensprung UB

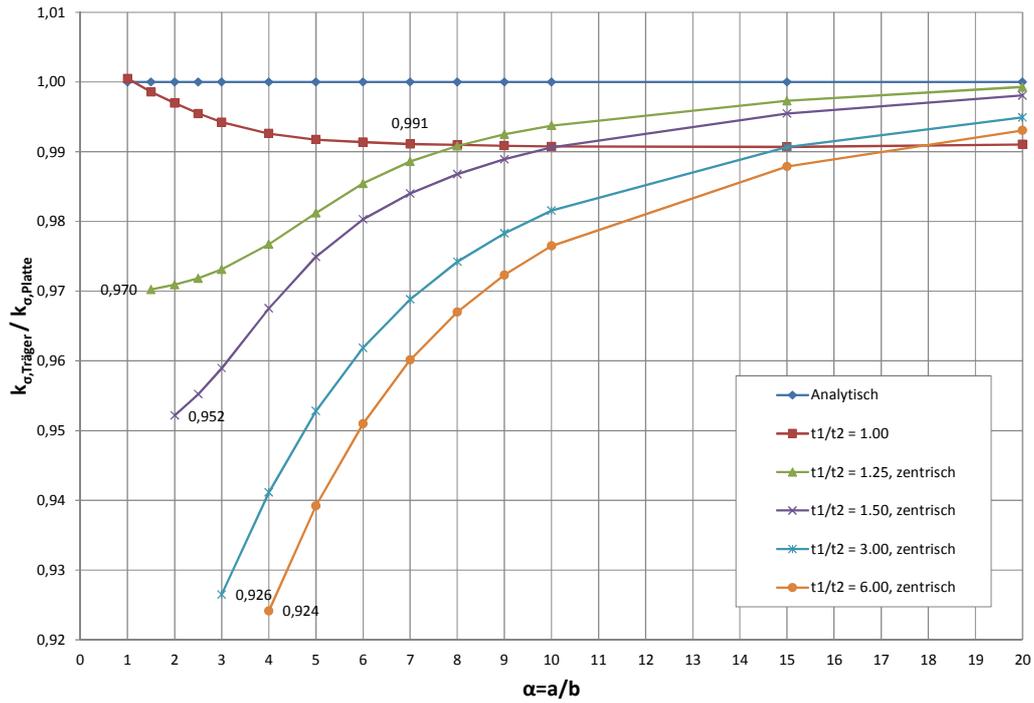


Abbildung 56: Vergleich Träger $H=1200$ mit Platte, Dickensprung Z

5.6.2. Trägerberechnung für H=3910 mm mit der Plattenberechnung

Nun soll der Träger mit H=3910 mm mit der Platte verglichen werden. Hier wird wesentlich, dass sich der Träger ohne Dickensprung, wie unter Pkt. 5.6.1 aufgezeigt wurde, nur minimal (1%) von der Plattenberechnung unterscheidet.

Die Beulergebnisse der Träger mit Dickensprung liegen im Vergleich zu den Ergebnissen an der Platte um bis zu 18% ($t_1/t_2 = 6.0$) niedriger. Ebenfalls gilt, dass sich der Träger bei größeren Längenverhältnissen α deutlich der Plattenlösung annähert (Unterschied von 4%). Nachstehend soll dies tabellarisch und in Diagrammen veranschaulicht werden.

Die Gründe hierfür liegen im großen Normalkraftsprung an der Übergangsstelle der beiden Blechdicken.

| α | H=3910mm | Platte | Δ |
|----------|------------------|------------------|----------|
| | $k_{\sigma,ABQ}$ | $k_{\sigma,ABQ}$ | |
| 1,5 | 0,819 | 0,809 | 1,013 |
| 2 | 0,638 | 0,631 | 1,011 |
| 2,5 | 0,556 | 0,551 | 1,009 |
| 3 | 0,512 | 0,509 | 1,006 |
| 4 | 0,469 | 0,468 | 1,001 |
| 5 | 0,449 | 0,450 | 0,997 |
| 6 | 0,438 | 0,440 | 0,994 |
| 7 | 0,431 | 0,435 | 0,992 |
| 8 | 0,427 | 0,431 | 0,991 |
| 9 | 0,425 | 0,429 | 0,990 |
| 10 | 0,423 | 0,427 | 0,990 |
| 15 | 0,419 | 0,423 | 0,990 |
| 20 | 0,418 | 0,422 | 0,991 |

Tabelle 14: Vergleich Träger H=3910 mm mit Platte ohne Dickensprung ($t_1=t_2$), [-]

| $t_1/t_2=3.00$ oben bündig | | | | $t_1/t_2=3.00$ unten bündig | | | $t_1/t_2=3.00$ zentrisch | | |
|----------------------------|------------------|------------------|----------|-----------------------------|------------------|----------|--------------------------|------------------|----------|
| α | H=3910mm | Platte | Δ | H=3910mm | | Δ | H=3910mm | | Δ |
| | $k_{\sigma,ABQ}$ | $k_{\sigma,ABQ}$ | | $k_{\sigma,ABQ}$ | $k_{\sigma,ABQ}$ | | $k_{\sigma,ABQ}$ | $k_{\sigma,ABQ}$ | |
| 4 | 0,824 | 0,948 | 0,869 | 0,824 | 0,948 | 0,869 | 0,796 | 0,926 | 0,860 |
| 5 | 0,658 | 0,749 | 0,879 | 0,658 | 0,749 | 0,879 | 0,641 | 0,738 | 0,870 |
| 6 | 0,571 | 0,643 | 0,888 | 0,571 | 0,643 | 0,888 | 0,559 | 0,636 | 0,879 |
| 7 | 0,520 | 0,580 | 0,896 | 0,520 | 0,580 | 0,896 | 0,511 | 0,576 | 0,888 |
| 8 | 0,488 | 0,540 | 0,903 | 0,488 | 0,540 | 0,903 | 0,481 | 0,537 | 0,896 |
| 9 | 0,467 | 0,513 | 0,910 | 0,467 | 0,513 | 0,910 | 0,461 | 0,511 | 0,904 |
| 10 | 0,453 | 0,494 | 0,917 | 0,453 | 0,494 | 0,917 | 0,448 | 0,492 | 0,911 |
| 15 | 0,424 | 0,450 | 0,943 | 0,424 | 0,450 | 0,943 | 0,422 | 0,449 | 0,939 |
| 20 | 0,417 | 0,435 | 0,959 | 0,417 | 0,435 | 0,959 | 0,415 | 0,435 | 0,956 |

Tabelle 15: Vergleich Träger H=3910 mm mit Platte mit Dickensprung ($t_1/t_2=3.00$), [-]

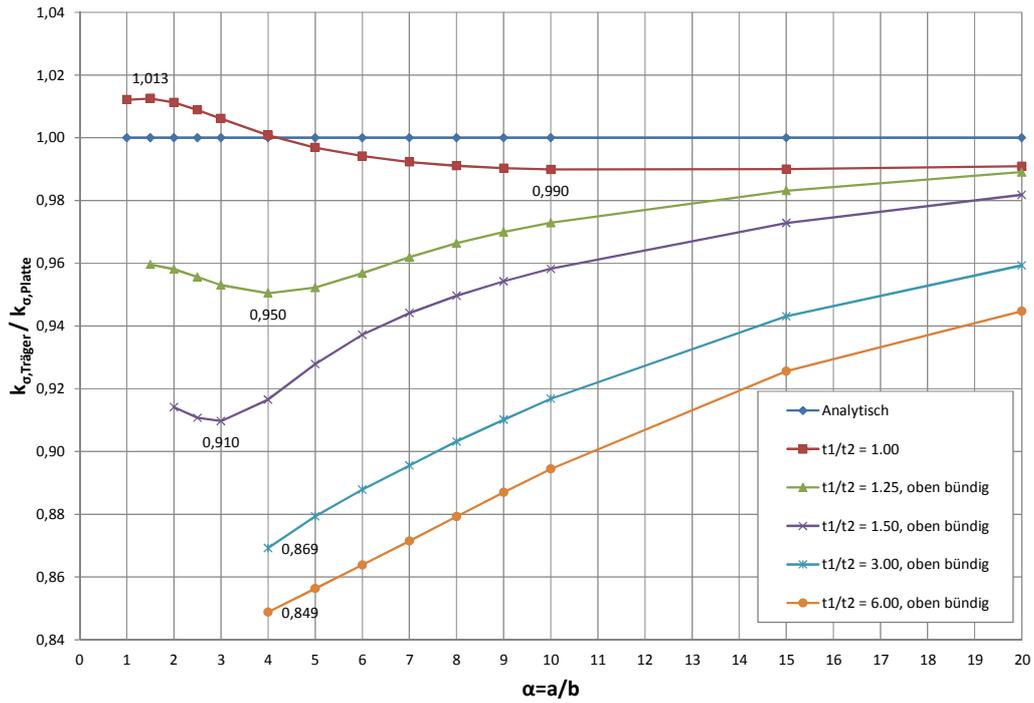


Abbildung 57: Vergleich Träger H=3910 mit Platte, Dickensprung OB

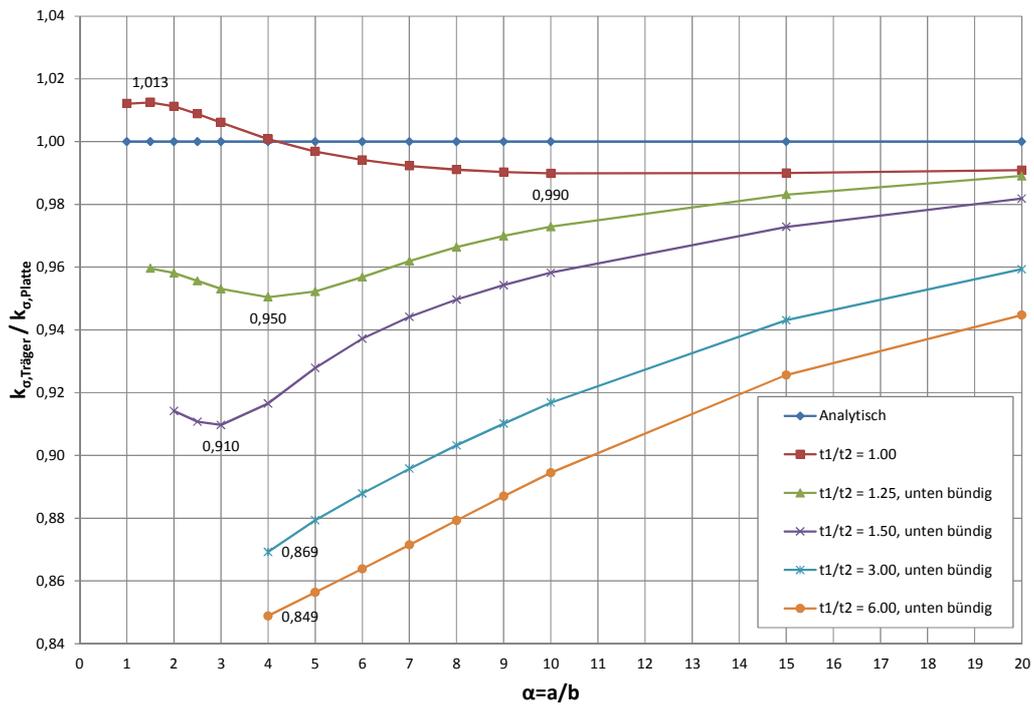


Abbildung 58: Vergleich Träger H=3910 mit Platte, Dickensprung UB

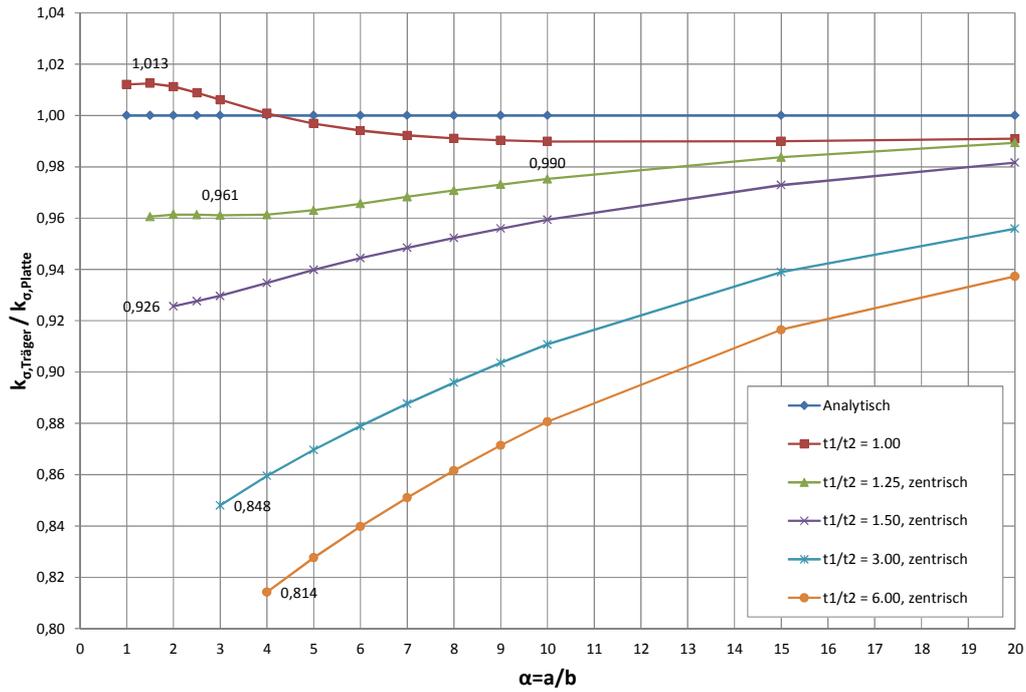


Abbildung 59: Vergleich Träger H=3910 mit Platte, Dickensprung Z

6. Nichtlineare Berechnungen

6.1. Allgemeines

Im folgenden Teil dieser Masterarbeit wird nun eine geometrisch und materiell nichtlineare Analyse im Imperfektionen (GMNIA) der beiden schon zuvor behandelten Träger ($h=1200$ mm und $h=3910$ mm) in Form einer Parameterstudie durchgeführt.

Zu diesem Zweck werden Imperfektionen mittels Ersatzimperfektionen aufgebracht, sofern nicht die geometrischen und strukturellen Imperfektionen des Stahlträgers getrennt modelliert werden können.

Als Referenzwerte sollen die Träger ohne Untergurtdickensprung berechnet werden. Anschließend wurde die nichtlineare Berechnung an den, schon in den Kapiteln zuvor behandelten Untergurtdickensprüngen OB, UB, Z, durchgeführt. Zusätzlich wurde auch die dazugehörige dreiseitig gelagerte Platte als Vergleichsrechnung für die verwendeten Variationen der Trägerberechnung untersucht.

Das Hauptaugenmerk wurde bei der nichtlinearen Berechnung auf das Längenverhältnis $\alpha = \text{Beulfeldlänge } a / \text{Beulfeldbreite } b = 20$ ($a = 6000$ mm, $b = 300$ mm) gelegt. Lediglich für den Untergurtdickensprung, unten bündig (UB), wurde auch das Längenverhältnis $\alpha = 10$ ($L = 3000$ mm) untersucht.

Das Verhältnis der zwei Blechdicken t_1/t_2 wurde für die baupraktisch üblichen Anwendungsfälle einerseits mit 1.5 ($t_1 = 30$ mm, $t_2 = 20$ mm) und andererseits mit 3.0 ($t_1 = 60$ mm, $t_2 = 20$ mm) definiert.

Für jeden untersuchten Fall erfolgten die Berechnungen einmal mit und einmal ohne einer Anordnung einer Quersteife am dünnen Blech vor dem Dickensprung.

Nun sollen vorab die Randbedingungen der GMNIA – Berechnungen etwas näher erläutert werden.

6.1.1. Geometrisch und materiell nichtlineare Berechnung

Eine mechanische Konstruktion verhält sich unter statischer Belastung linear, wenn eine Veränderung der Belastung um den Faktor a eine entsprechende Veränderung der Verschiebung um denselben Faktor a nach sich zieht. Andernfalls verhält sich die Konstruktion nichtlinear (über- oder unterlinear, siehe Abbildung 60).

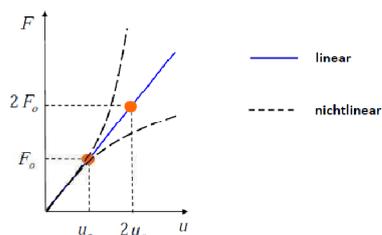


Abbildung 60: Lineares und nichtlineares Verhalten

Bei der linearen Berechnung der FE-Modelle werden lineare Differentialgleichungen (kontinuierlich für alle x) aufgestellt, wobei bei nichtlinearen Berechnungen diese Modelle „linearisiert“ werden. Dies bedeutet, dass die Berechnung in mehrere lineare Lösungsschritte unterteilt wird.

Bei geometrischer Nichtlinearität werden die nichtlinearen Anteile der Verschiebungen in die Dehnungen miteinbezogen (Längsverschiebung darf nicht vernachlässigt werden).

Unter materieller Nichtlinearität versteht man einen großen Dehnungszuwachs bei geringer Spannungssteigerung. Daraus ergeben sich bleibende Verformungen nach erfolgter Entlastung.

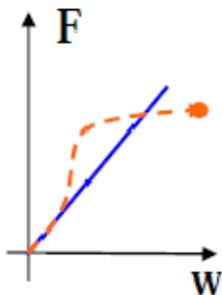


Abbildung 61: Geometrisch und materiell nichtlineares Last-Verformungsverhalten

6.1.2. Imperfektionen

Nach Eurocode 3-1-5 [4] sollen in der Regel bei FE-Berechnungen sowohl geometrische als auch strukturelle Imperfektionen (Eigenspannungen) angesetzt werden. Die erste Eigenform aus der Beulberechnung kann als geometrische Imperfektion angesetzt werden. Die Amplitude kann auf 80% der geometrischen Fertigungstoleranzen abgemindert werden.

Tabelle C.2: Geometrische Ersatzimperfektionen

| Imperfektionsansatz | Bauteil | Form | Amplitude |
|---------------------|--|----------|--------------------------------|
| global | Bauteil der Länge ℓ | Bogen | siehe EN 1993-1-1, Tabelle 5.1 |
| global | Längssteife der Länge a | Bogen | $\min(a/400, b/400)$ |
| lokal | Teilfeld oder Einzelfeld mit kurzer Länge a oder b | Beulform | $\min(a/200, b/200)$ |
| lokal | Verdrehung von Steifen und Flanschen | Bogen | $1 / 50$ |

Abbildung 62: Auszug aus [4], Tabelle Geometrische Ersatzimperfektionen

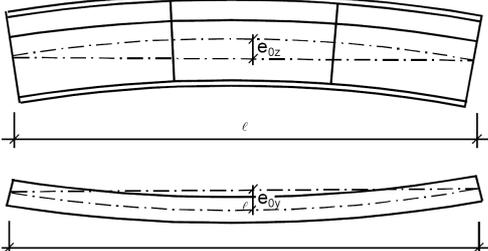
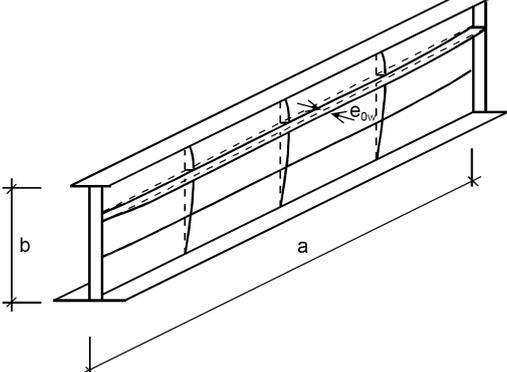
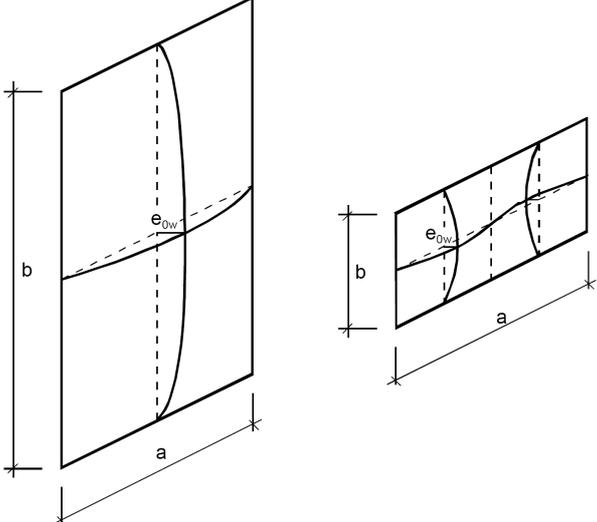
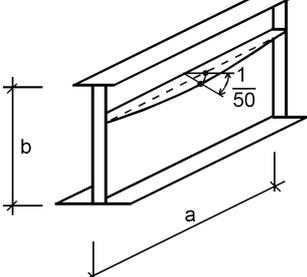
| Imperfektionsansatz | Bauteil |
|---|--|
| global, Bauteil der Länge l |  |
| global, Längssteife der Länge a |  |
| lokal, Teilfeld oder Einzelfeld |  |
| lokal, Verdrehung von Steifen oder Flanschen |  |

Bild C.1: Modellierung geometrischer Ersatzimperfektionen

Abbildung 63: Auszug aus [4], graphische Darstellung der Modellierung geometrischer Ersatzimperfektionen

Im Rahmen dieser Arbeit wurde die Imperfektion mit einer Amplitude von $e_0 = 4.8$ mm inkl. Eigenspannungen und $e_0 = 6.00$ mm ohne Eigenspannungen angesetzt.

Die Amplituden ergaben sich aus:

$e_0 = 4.8$ mm: lokale Imperfektion am Teilfeld oder Einzelfeld

$$80\% \text{ von } B_{bf} (= 600 \text{ mm}) / 100 = B_{bf}/125$$

$e_0 = 6.0$ mm: Ersatzimperfektion, Verdrehung von Steifen oder Flanschen

$$B_{bf}/100$$

Eigenspannungen:

Bei geschweißten I-Profilen entstehen infolge der örtlichen Wärmeentwicklung Zugeigenspannungen $\sigma_{res,Z}$ im Bereich der Nähte und zum Ausgleich dazu Druckeigenspannungen $\sigma_{res,D}$ an den Flanschenden und in der Stegmitte.

In den Berechnungen mit Eigenspannungen wurde folgende Eigenspannungsverteilung angesetzt (Abbildung 64):

$$\sigma_{res,D} = -0.2f_y$$

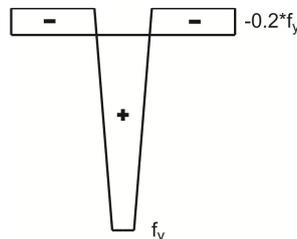


Abbildung 64: Eigenspannung

Um in den Berechnungen die Auswirkung des Dickensprunges genau untersuchen zu können, wurden, zusätzlich zu den Imperfektionen aus der ersten Eigenform der Beuluntersuchungen, noch zwei weitere Imperfektionen manuell erstellt. Diese sollten die maximale Deformation des Untergurtes möglichst nahe an den Dickensprung legen.

Damit die manuell erstellten Imperfektionsmuster im Berechnungsprogramm ABAQUS verwendet werden konnten, mussten diese auf die geforderte Amplitude skaliert werden. Zu diesem Zweck wurde die erforderliche Amplitude (e_0) durch die maximale Beule der manuellen Imperfektionsberechnung dividiert.

Die manuelle Imperfektion wurde durch Aufbringen von Einzellasten in unterschiedlichen Abständen vom Dickensprung erzeugt (siehe Abbildung 65).

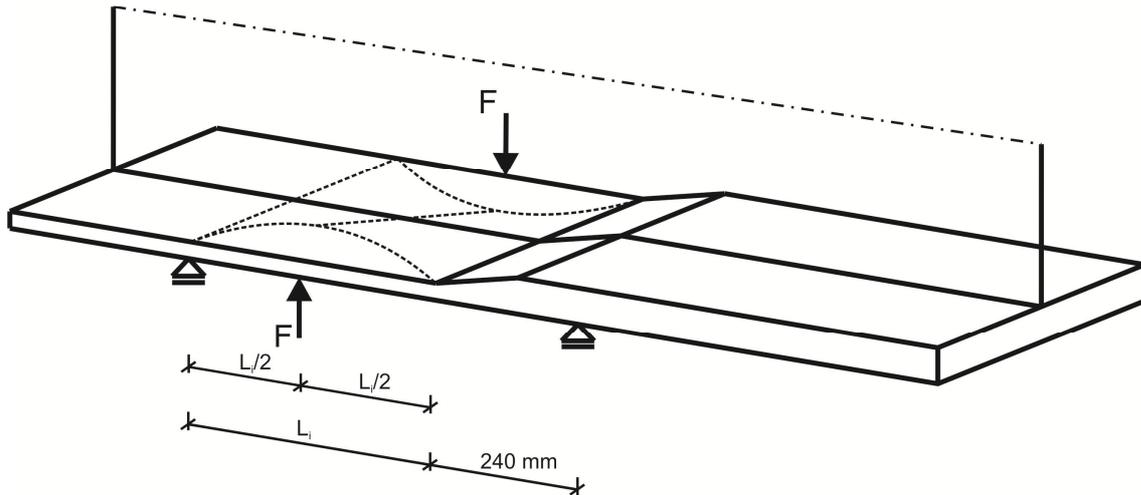


Abbildung 65: Manuelle Imperfektion

Für die Berechnungen wurden zwei Varianten der manuellen Imperfektion herangezogen.

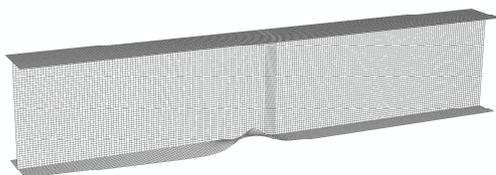
Die erste Variante der Imperfektion sollte die maximale Auslenkung der Beule möglichst nahe am Dickensprung hervorrufen. Diese wurde mit i_k bezeichnet.

Die zweite Imperfektion sollte einen Zwischenwert zwischen der manuellen Imperfektion i_k und der ersten Eigenform der Beulanalyse darstellen. Diese wurde i_m benannt.

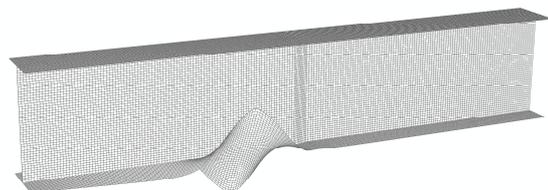
Der Abstand L_i wurde für die kurze Imperfektion mit $L_i = 600$ mm und für die mittlere Imperfektion $L_i = 1200$ mm festgesetzt.

Für die nichtlinearen Berechnungen wurde beim Vergleichsträger ($t_1=t_2$) die erste Eigenform der Beulanalyse angesetzt.

Bei den Berechnungen der unterschiedlichen Dickensprungsvarianten (OB, UB, Z) hingegen wurde die manuelle Imperfektion i_k angesetzt. Lediglich einige Vergleichsrechnungen wurden mit der manuellen Imperfektion i_m durchgeführt. Eine Eigenformkonforme Imperfektion wurde bei Dickensprüngen nicht angesetzt, da diese das Beulversagen nicht an der Stelle des Dickensprunges erzeugen würde. Es wurde somit die ungünstigsten Imperfektionen für die Fälle mit Dickensprung untersucht.



manuelle Imperfektion i_k



manuelle Imperfektion i_m

Tabelle 16: Manuelle Imperfektionen i_k und i_m

6.1.3. Materialeigenschaften und Berechnungseinstellungen

Für die gesamten Berechnungen wurde wie schon in der Beulanalyse (Pkt. 2.2), ein Stahl der Güte S355 mit einer Streckgrenze von $f_y = 355 \text{ N/mm}^2$ verwendet. Die nachfolgende Spannungsdehnungslinie wurde den Berechnungen zugrunde gelegt:

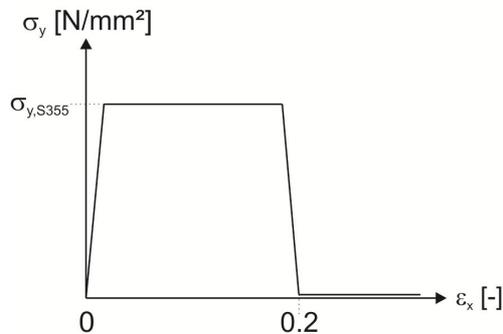


Abbildung 66: Verwendete Spannungsdehnungslinie Stahl S355

Da es bei der geometrisch nichtlinearen Rechnung zu einer, durch Querdehnung verursachten, Änderung des Querschnittes kommt, muss für die Eingabe der Spannungen und Dehnungen im ABAQUS eine Umrechnung der Spannungsdehnungslinie auf $\sigma_{true} - \epsilon^{ln}$ durchgeführt werden.

Diese Umrechnung basiert auf folgender Formel erfolgen (siehe ABAQUS User Manual).

$$\begin{aligned} \sigma_{true} &= \sigma_{nom} * (1 + \epsilon_{nom}) \\ \epsilon_{pl}^{ln} &= \ln*(1 + \epsilon_{nom}) - \frac{\sigma_{true}}{E} \end{aligned} \quad (9)$$

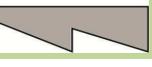
Im Rahmen dieser Berechnungen konnte auf die Umrechnung verzichtet werden. Stattdessen wurde bei den plastischen Materialdefinitionen im ABAQUS die Querdehnungszahl für die Shell Elemente in Dickenrichtung gleich Null gesetzt. Dies ermöglichte für die geometrisch nichtlinearen Rechnungen die Anwendung der oben dargestellten Spannungsdehnungslinie (siehe Abbildung 66).

6.2. Ergebnisse der nichtlinearen Berechnungen

Nun sollen die Ergebnisse der GMNIA - Berechnungen anhand der Verhältnisse $N_{GMNIA,bf} / N_{pl,bf}$ im gedrückten Gurt, sowie die Schubspannung τ_{Web} an der Unterkante des Steges in Diagrammen dargestellt werden. In Tabelle 17 sind die untersuchten Varianten der Parameterstudie aufgelistet.

Die Normalkräfte im Untergurt ($N_{GMNIA,bf}$) wurden aus den Membranspannungen SSAVG1 der einzelnen Elementen im Untergurt der nichtlinearen Berechnung durch Integration rückgerechnet. Ein Berechnungsbeispiel ist Anhang A zu entnehmen.

Tabelle 17: Untersuchte Träger- und Dickensprungvarianten

| # | Trägerhöhe [mm] | Dickensprung | α [-] | $t1/t2$ [-] | Imperfektion | Spannungsverlauf σ_x |
|----|-----------------|--------------|--------------|-------------|---|---|
| 1 | 1200 | - | 20 | 1.0 | 1.Eigenform $e_0, e_0+\sigma_R$ |  |
| | 1200 | - | 10 | 1.0 | 1.Eigenform $e_0, e_0+\sigma_R$ |  |
| 2 | 1200 | UB | 20 | 1.5 | $i_k, e_0, e_0+\sigma_R$, mit/ohne Steife |  |
| | 1200 | UB | 10 | 1.5 | $i_k, e_0, e_0+\sigma_R$, mit/ohne Steife |  |
| 3 | 1200 | OB | 20 | 1.5 | $i_k, e_0, e_0+\sigma_R$, mit/ohne Steife |  |
| 4 | 1200 | Z | 20 | 1.5 | $i_k, e_0, e_0+\sigma_R$, mit/ohne Steife |  |
| 5 | 1200 | UB | 20 | 3.0 | $i_k, e_0, e_0+\sigma_R$, mit/ohne Steife |  |
| | 1200 | UB | 10 | 3.0 | $i_k, e_0, e_0+\sigma_R$, mit/ohne Steife |  |
| 6 | 1200 | OB | 20 | 3.0 | $i_k, e_0, e_0+\sigma_R$, mit/ohne Steife |  |
| 7 | 1200 | Z | 20 | 3.0 | $i_k, e_0, e_0+\sigma_R$, mit/ohne Steife |  |
| 8 | 1200 | UB | 20 | 3.0 | $i_m, e_0, e_0+\sigma_R$, mit/ohne Steife |  |
| 9 | 3910 | UB | 20 | 1.5 | $i_k, e_0, e_0+\sigma_R$, mit/ohne Steife |  |
| 10 | 3910 | UB | 20 | 3.0 | $i_k, e_0, e_0+\sigma_R$, mit/ohne Steife |  |
| 11 | 1200 | UB | 20 | 1.5 | $i_k, e_0, e_0+\sigma_R$, mit/ohne Steife | $\Psi=0.2f_y$  |
| 12 | 1200 | UB | 20 | 3.0 | $i_k, e_0, e_0+\sigma_R$, mit/ohne Steife | $\Psi=0.2f_y$  |

| | |
|------------------|----------------------------------|
| e_0 | ... B/100 |
| $e_0 + \sigma_R$ | ... B/125 + $\sigma_{R,welding}$ |

mit/ohne Steife ... Position der Steife siehe Abb. Abbildung 46

Auswertung: wesentliche Zwischenzustände wurden zur besseren Verständlichkeit des nichtlinearen Verhaltens bis zum Lastmaximum in den Diagrammen dargestellt (zb.: INC10 – 0.715, INC120 – 1.093). Ebenfalls dargestellt wird der Abminderungsfaktor ρ (= 0.817 für $B/T = 600/20$) nach EC3. Dieser errechnet sich aus $\rho = \frac{\bar{\lambda}_p^{-0.188}}{\lambda_p^2} \leq 1.0$.

Als Referenzergebnisse der GMNIA-Berechnung wurden die Laststeigerungsfaktoren bei Bauteilverformungen im Bereich von 30-40 mm ausgewertet (INC20 – 0.839, INC25 – 1.064). Die plastischen Grenzwerte sind in den Last-Verschiebungs-Kurven als Endergebnisse der GMNIA-Berechnung angegeben (INC120 – 1.093). Diese besitzen allerdings keine baupraktische Relevanz nachdem Schweißnähte, etc. hierfür in der Regel nicht ausgelegt werden können.

Im Folgenden erfolgt eine umfassende Darstellung dieser Ergebnisse in ähnlicher Weise wie zuvor für Fall 1 genauer beschrieben wurde. Auf die Deutung dieser Daten und ihre Auswirkung auf die gegenwärtige stahlbauliche Bemessungspraxis kann allerdings im Zuge dieser Arbeit aus limitierten Zeit- und Platzgründen in weiterer Folge nicht eingegangen werden.

6.3. Träger H = 1200 mm mit konstanter Normalspannung im Gurt

6.3.1. Träger mit konstanter Untergurtdicke (t1=t2) - „Fall 1“

➤ $H = 1200 \text{ mm}$, $t1/t2 = 1.0$, $\alpha = 20$

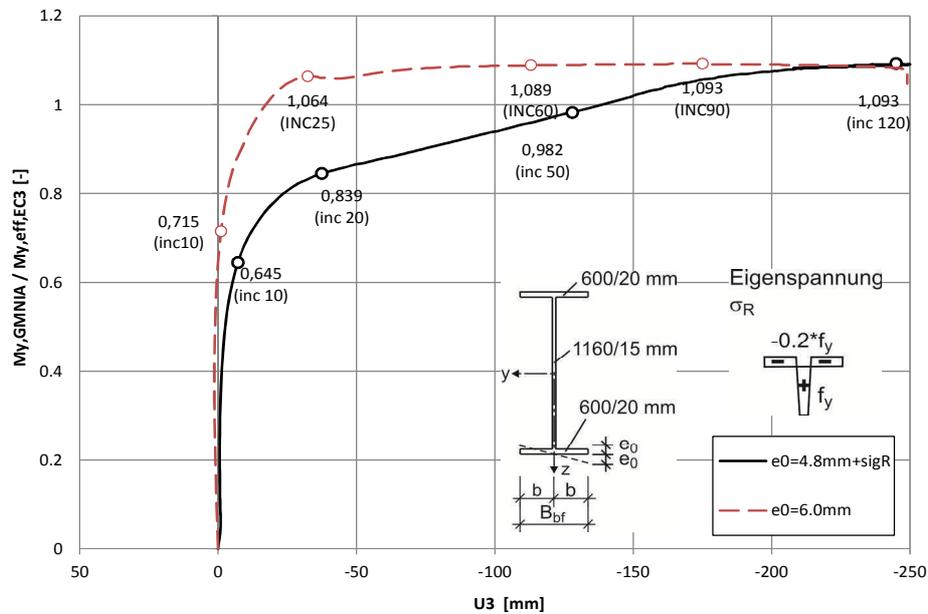


Abbildung 67: Lastverschiebungskurven, $h=1200$, $t1=t2$, $\alpha=20$

| Case | My | My,GMNIA / My,eff,EC3 | Nbf | Nbf,GMNIA / Npl,eff,EC3 |
|---|---------|-----------------------|----------|-------------------------|
| | [kNm] | [-] | [kN] | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha 20$, $t1/t2=1.0$, $e_0^{125} + \sigma_R$ | 4518.00 | 0.839 | -3005.23 | 0.705 |
| H1200, $\alpha 20$, $t1/t2=1.0$, e_0^{100} | 5733.00 | 1.064 | -3880.44 | 0.911 |

Tabelle 18: Vergleiche Träger $H = 1200 \text{ mm}$, $t1/t2 = 1.0$, $\alpha = 20$

➤ Eigenspannung INC 0

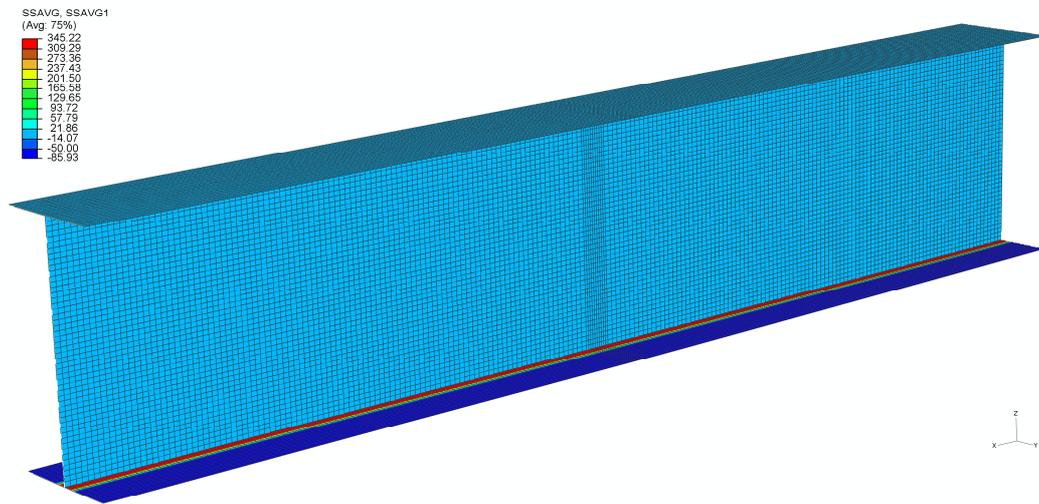


Abbildung 68: $h=1200\text{mm}$, $t1=t2$, $\alpha=20$, $B/125$, σ_R , INC 0

➤ $H = 1200\text{ mm}$, $t1/t2 = 1.0$, $\alpha = 20$, $e_0+\sigma_R$

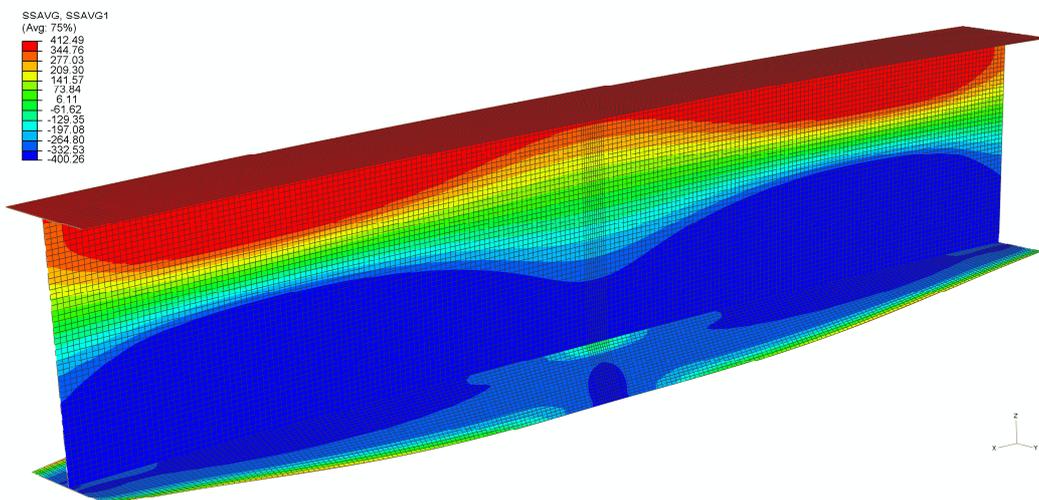


Abbildung 69: $h=1200\text{mm}$, $t1=t2$, $\alpha=20$, $B/125$, σ_R , INC 120

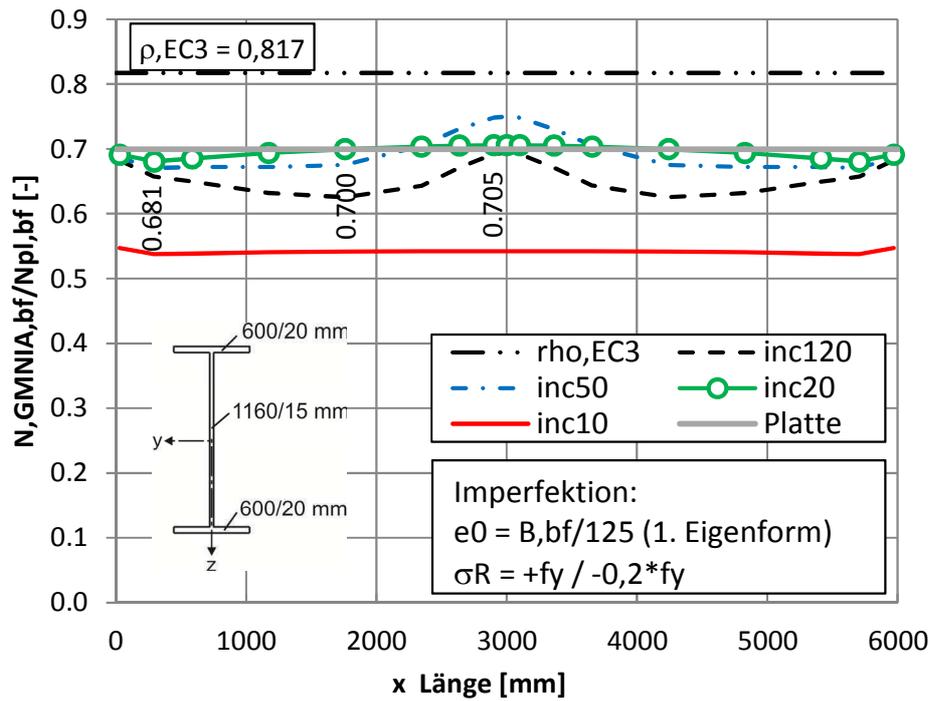


Abbildung 70: $h=1200mm, t_1=t_2, \alpha=20$, Untergurkräfte mit geom. Imperfektion und Eigenspannungen

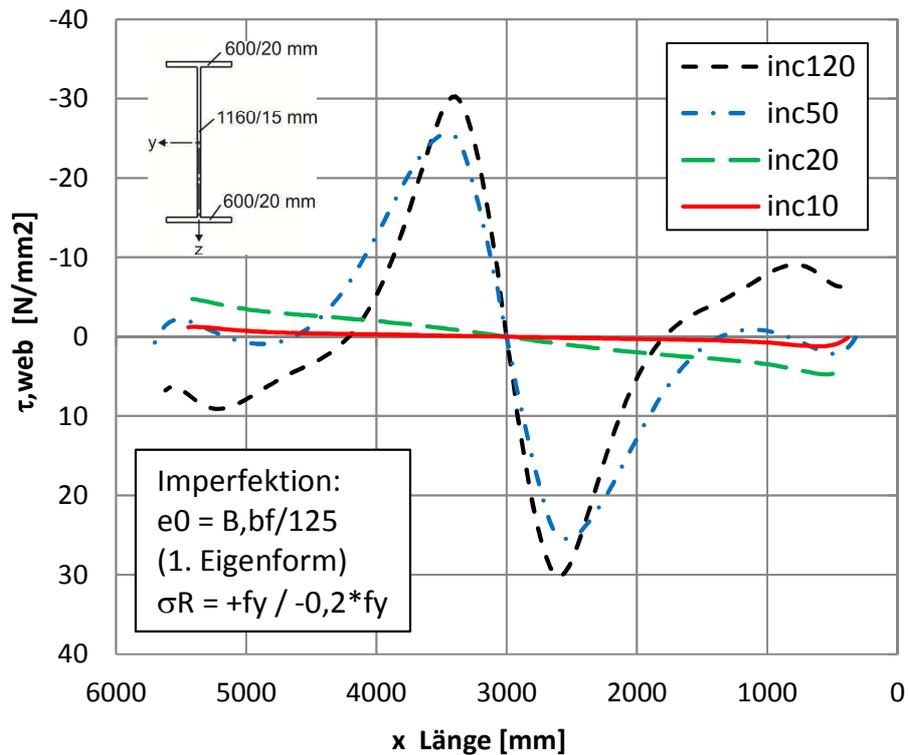


Abbildung 71: $h=1200mm, t_1=t_2, \alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 1200 \text{ mm}$, $t1/t2 = 1.0$, $\alpha = 20$, e_0

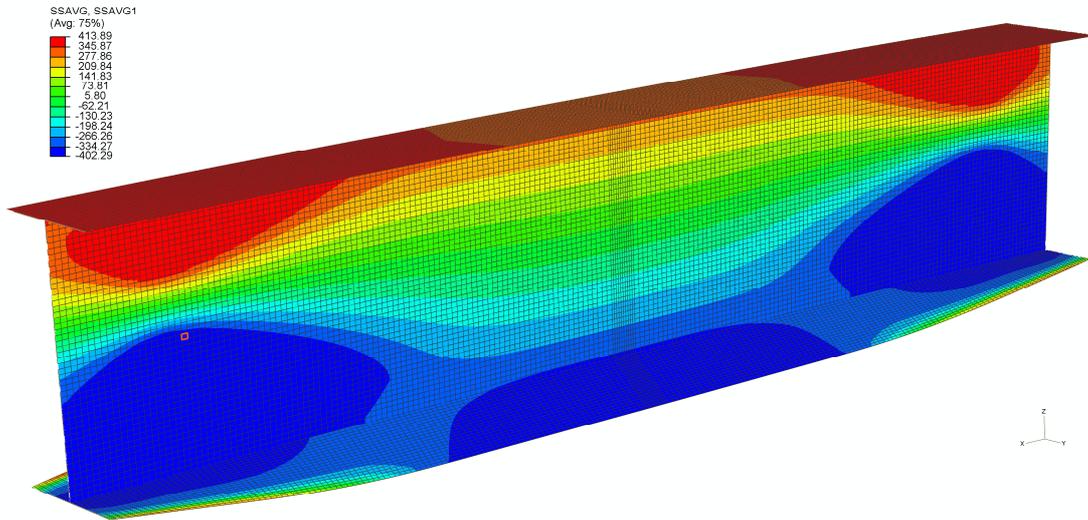


Abbildung 72: $h=1200\text{mm}$, $t1=t2$, $\alpha=20$, $B/100$, $INC\ 90$

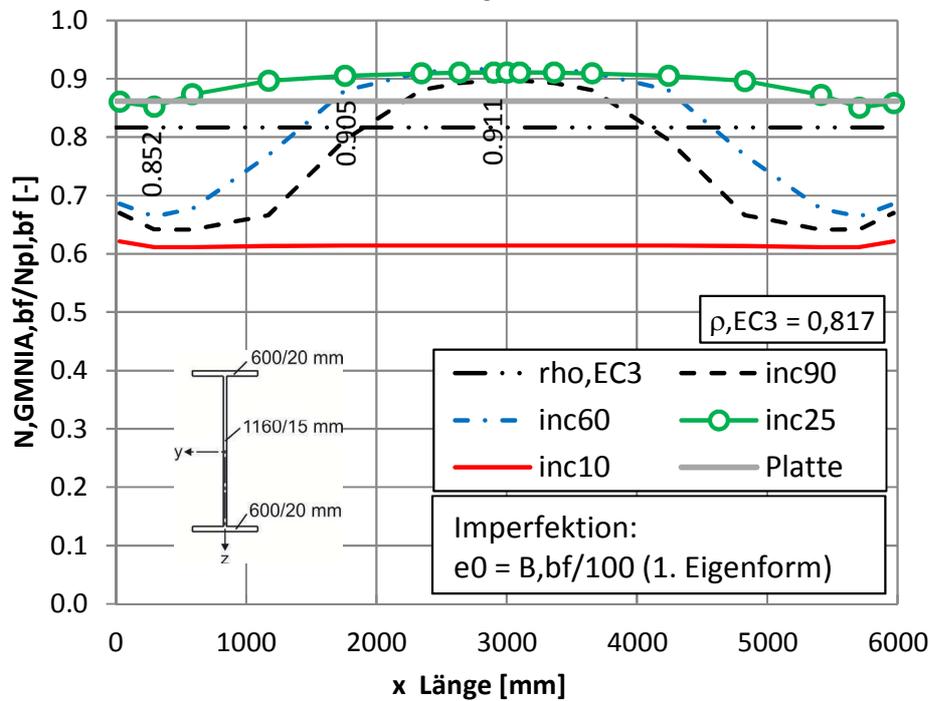


Abbildung 73: $h=1200\text{mm}$, $t1=t2$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion

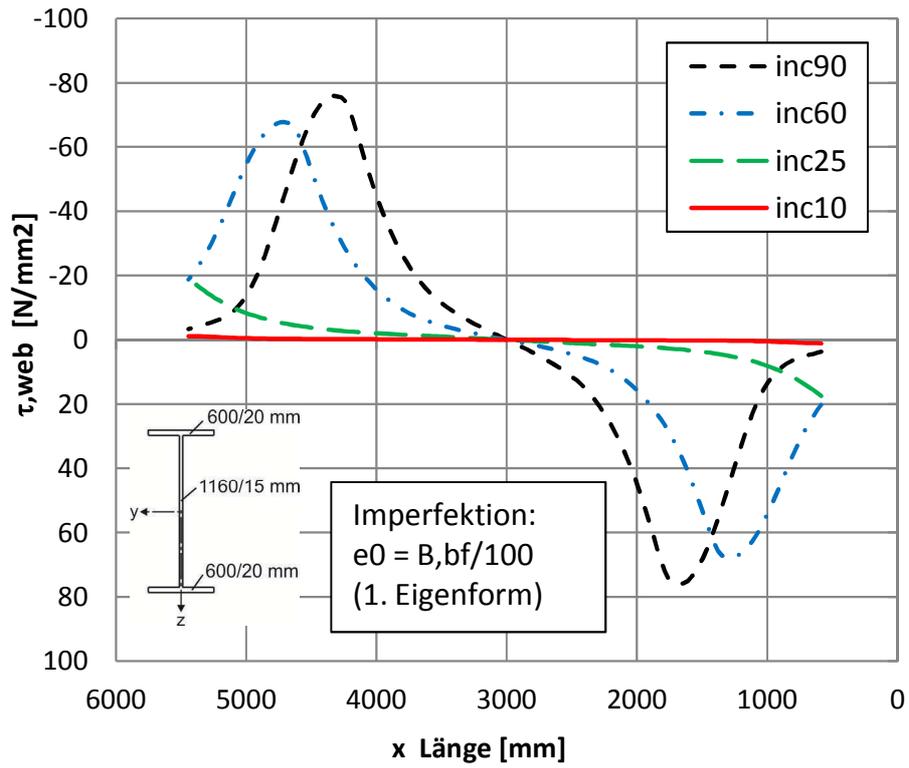


Abbildung 74: $h=1200\text{mm}$, $t_1=t_2$, $\alpha=20$, Schubspannungen mit geom. Imperfektion

➤ $H = 1200 \text{ mm}$, $t1/t2 = 1.0$, $\alpha = 10$

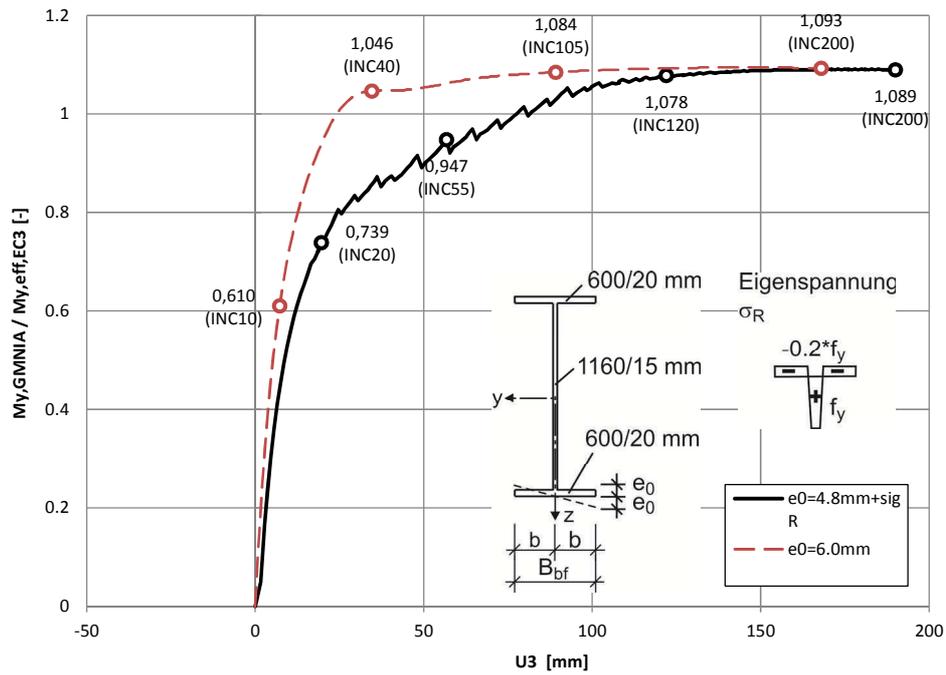


Abbildung 75: Lastverschiebungskurven, $h=1200$, $t1=t2$, $\alpha=10$

| Case | M_y | $M_y,GMNIA / M_y,eff,EC3$ | N_{bf} | $N_{bf,GMNIA} / N_{pl,eff,EC3}$ |
|---|---------|---------------------------|----------|---------------------------------|
| | [kNm] | [-] | [kN] | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha=10$, $t1/t2=1.0$, $e_0^{125} + \sigma_R$ | 5103.00 | 0.947 | -3076.15 | 0.722 |
| H1200, $\alpha=10$, $t1/t2=1.0$, e_0^{100} | 5634.00 | 1.046 | -3776.28 | 0.886 |

Tabelle 19: Vergleich Träger $H = 1200 \text{ mm}$, $t1/t2 = 1.0$, $\alpha = 10$

➤ $H = 1200 \text{ mm}$, $t1/t2 = 1.0$, $\alpha = 10$, $e_0 + \sigma_R$

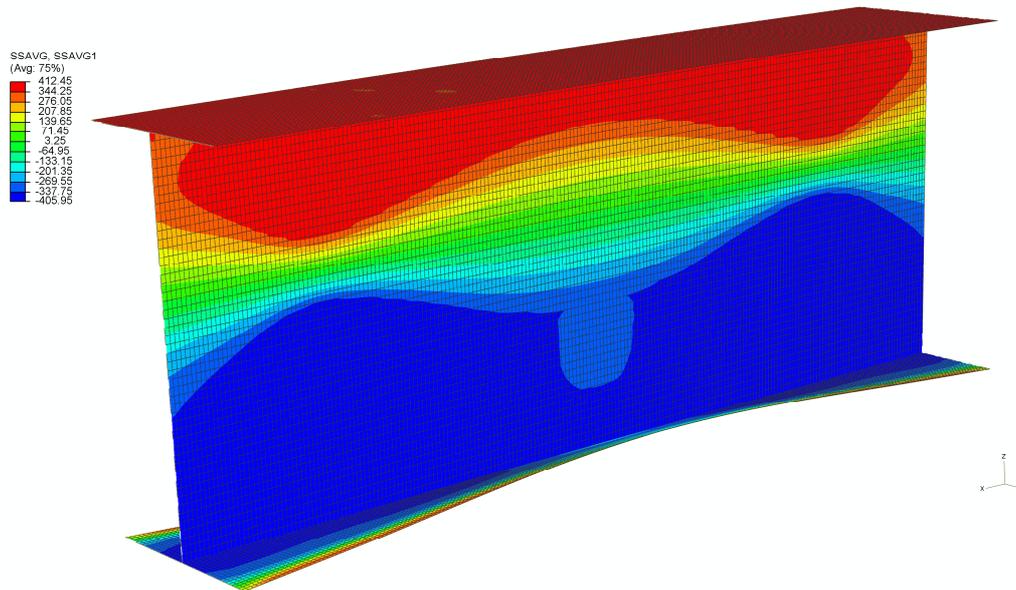


Abbildung 76: $h=1200\text{mm}$, $t1=t2$, $\alpha=10$, $B/125$, σ_R , INC 200

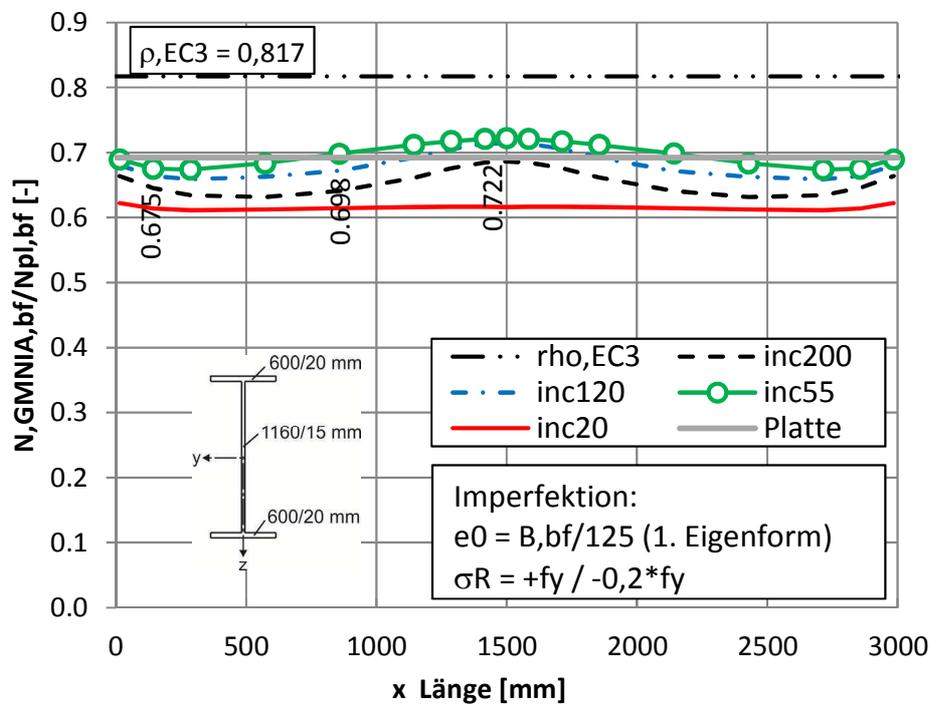


Abbildung 77: $h=1200\text{mm}$, $t1=t2$, $\alpha=10$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen

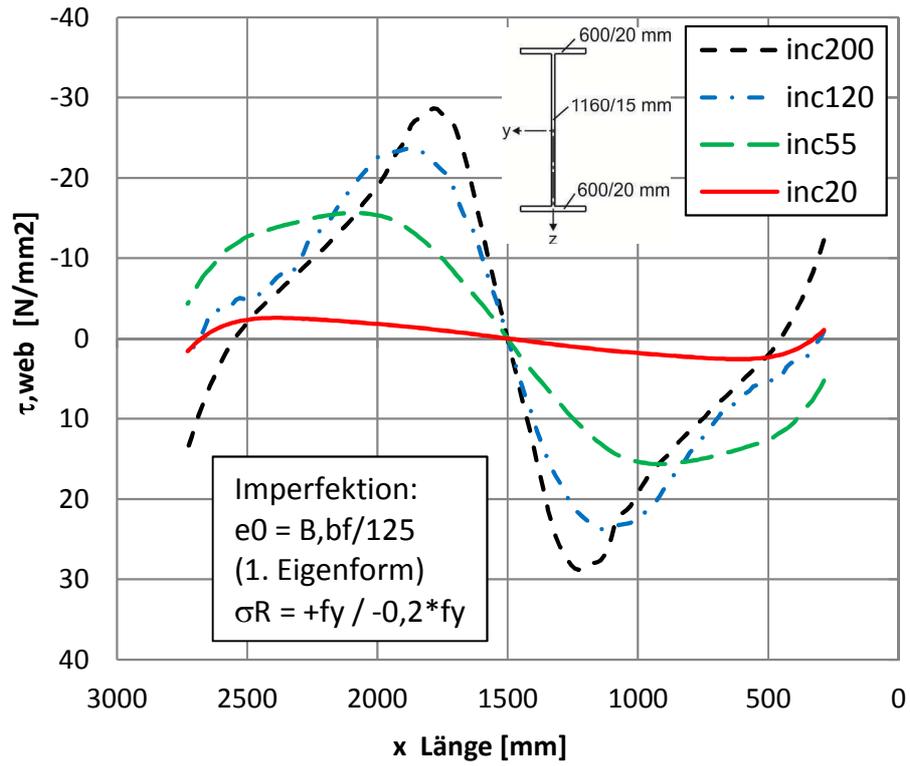


Abbildung 78: $h=1200\text{mm}$, $t_1=t_2$, $\alpha=10$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 1200 \text{ mm}$, $t_1/t_2 = 1.0$, $\alpha = 10$, e_0

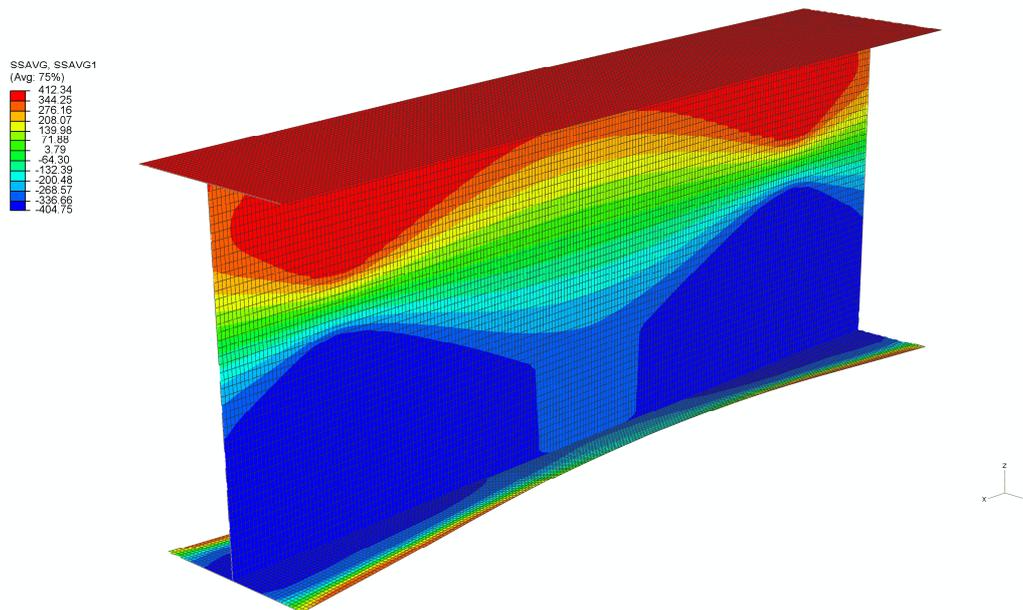


Abbildung 79: $h=1200\text{mm}$, $t_1=t_2$, $\alpha=10$, $B/100$, INC 200

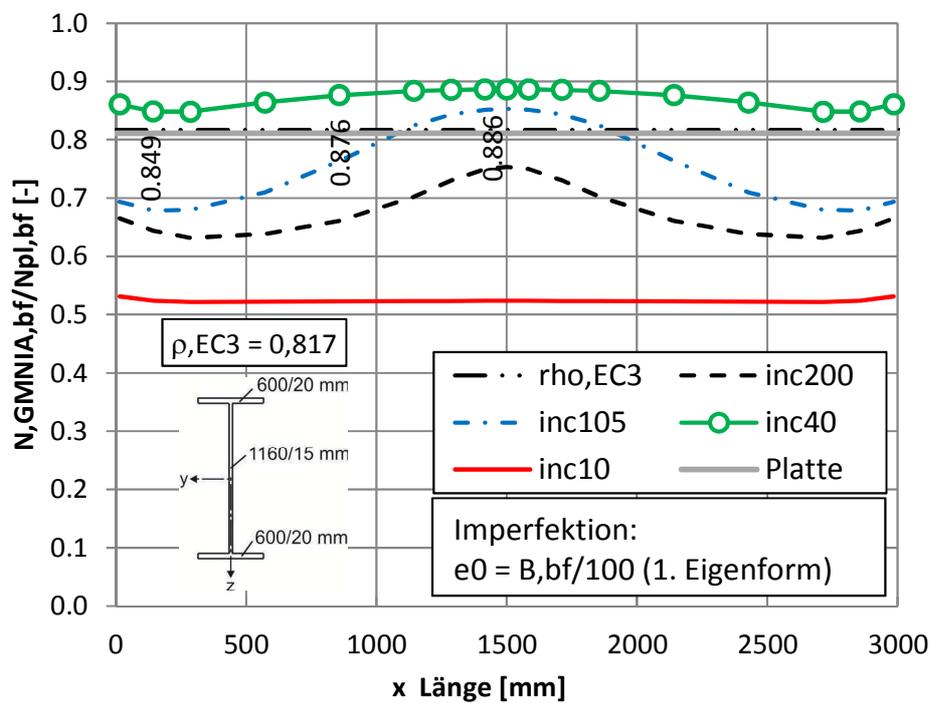


Abbildung 80: $h=1200\text{mm}$, $t_1=t_2$, $\alpha=10$, Untergurkräfte mit geom. Imperfektion

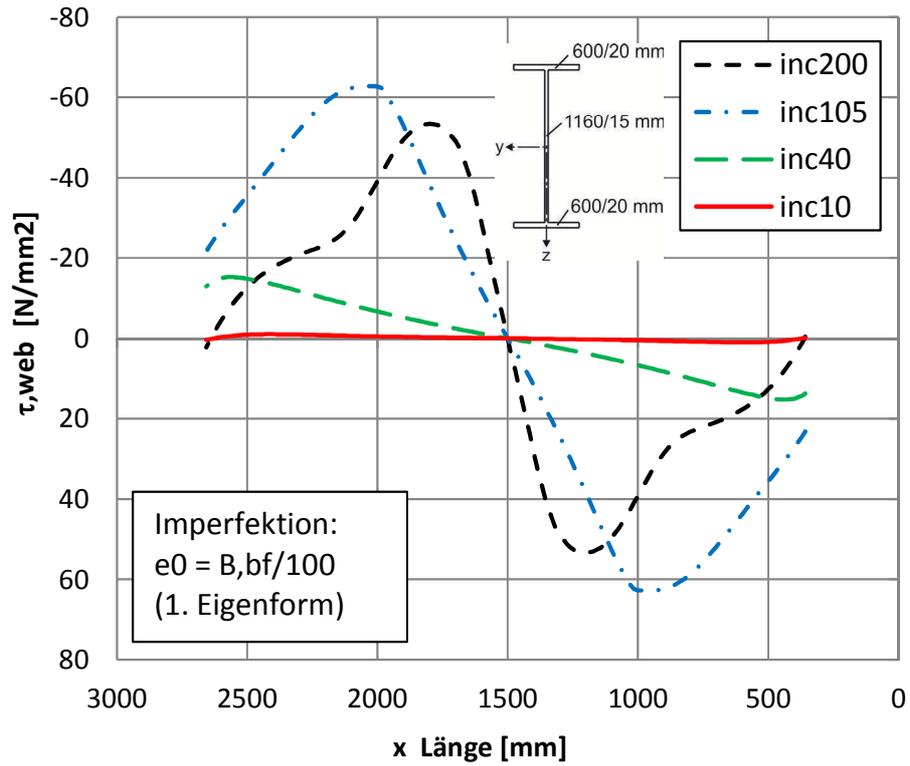


Abbildung 81: $h=1200\text{mm}$, $t_1=t_2$, $\alpha=10$, Schubspannungen mit geom. Imperfektion

6.3.2. Träger mit Untergurtdickensprung unten bündig $t1/t2 = 1.5$ - „Fall 2“

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$

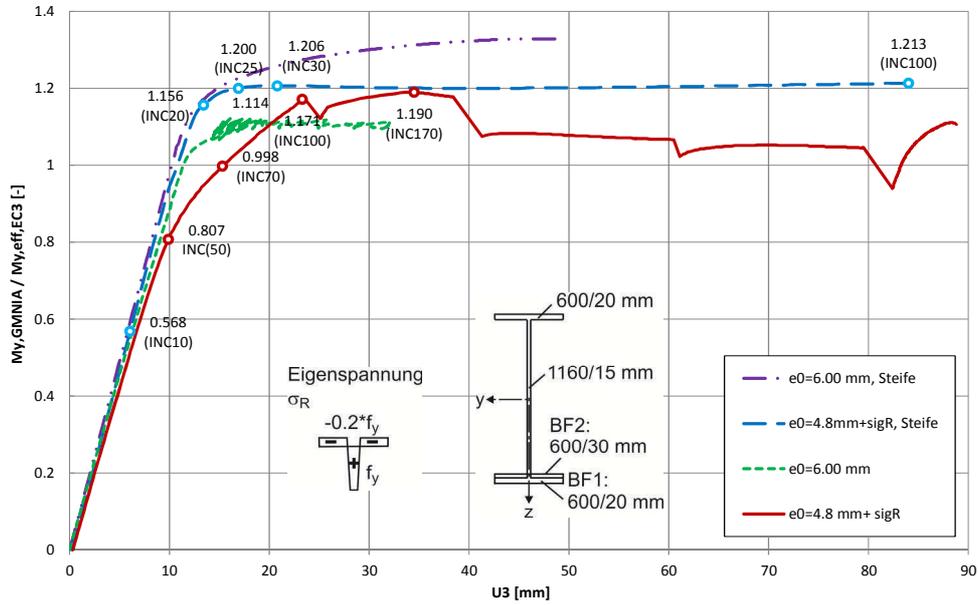


Abbildung 82: Lastverschiebungskurven, $h=1200$, UB, $t1/t2=1.5$, $\alpha=20$

| Case | My | My,GMNIA / | Nbf | Nbf,GMNIA / |
|--|---------|------------|----------|-------------|
| | [kNm] | My,eff,EC3 | | |
| | | [-] | [kN] | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha 20$, $t1/t2=1.5$, $e_0^{125} + \sigma R$ | 6309.00 | 1.171 | -3265.55 | 0.767 |
| H1200, $\alpha 20$, $t1/t2=1.5$, e_0^{100} | 5958.00 | 1.106 | -3692.58 | 0.867 |
| H1200, $\alpha 20$, $t1/t2=1.5$, $e_0^{125} + \sigma R$, ST | 6498.01 | 1.206 | -3328.53 | 0.781 |
| H1200, $\alpha 20$, $t1/t2=1.5$, e_0^{100} , ST | 6444.01 | 1.196 | -3055.84 | 0.717 |

Tabelle 20: Vergleiche Träger $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$, $e_0 + \sigma_R$

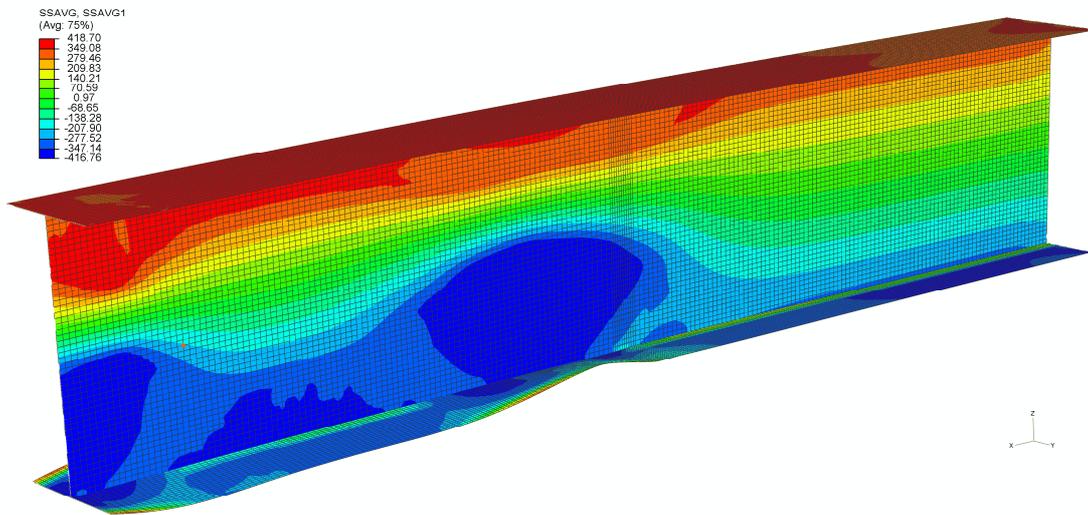


Abbildung 83: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , INC 170

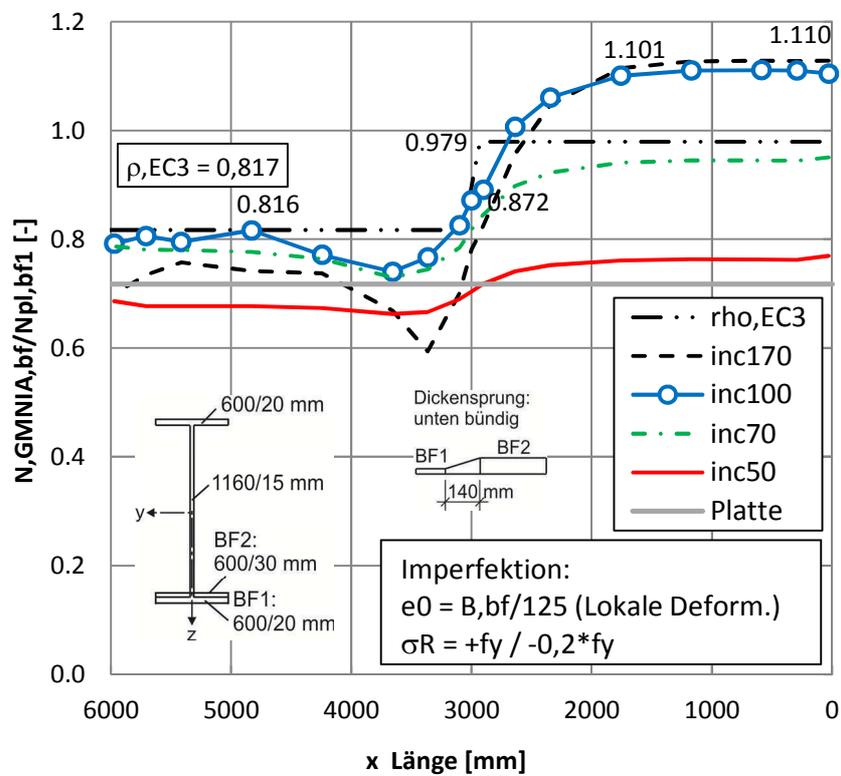


Abbildung 84: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen

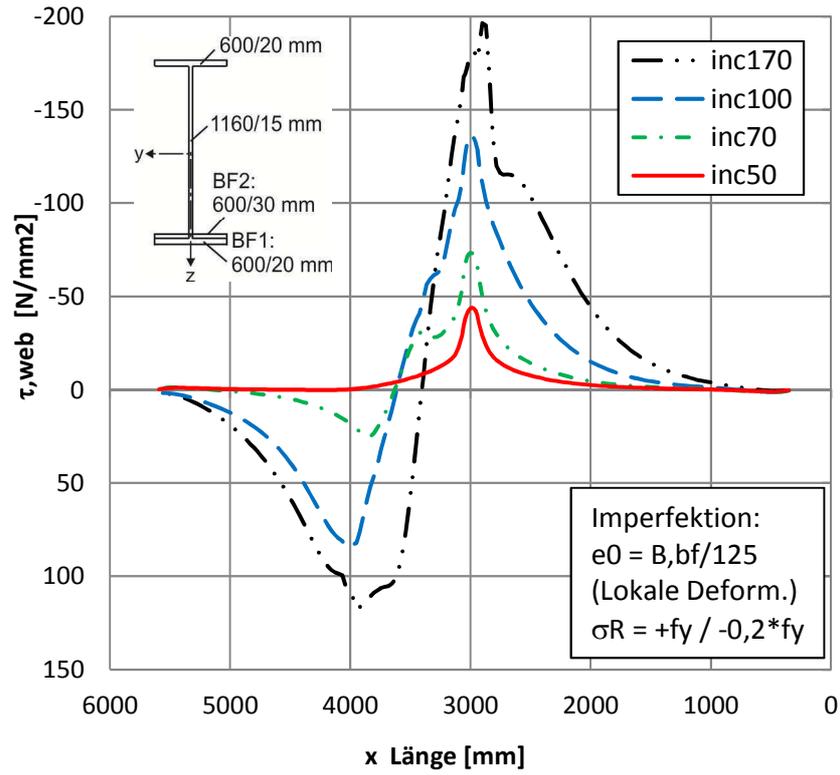


Abbildung 85: $h=1200$ mm, UB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$, e_0

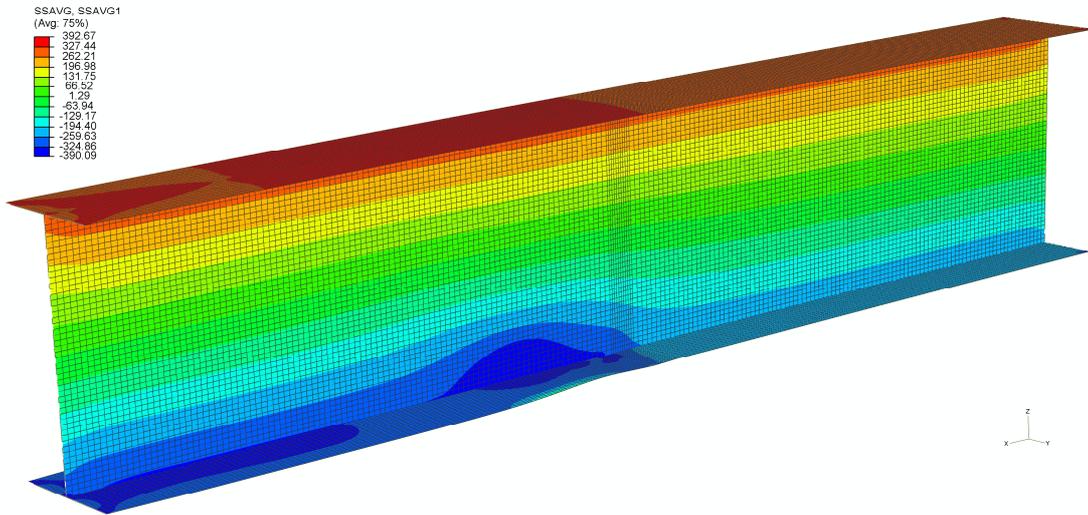


Abbildung 86: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/100$, INC 75

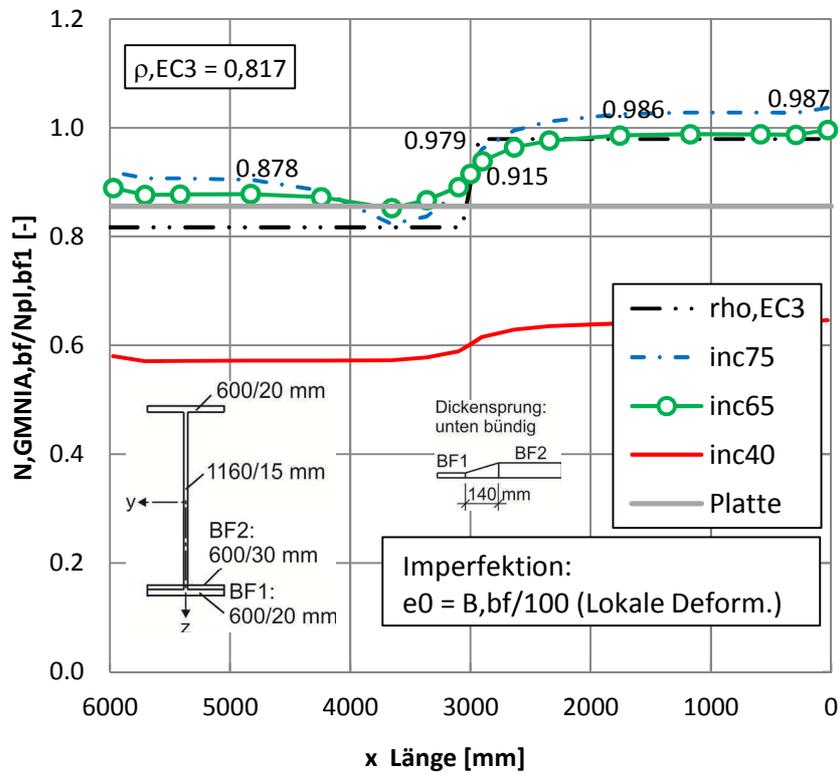


Abbildung 87: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, Untergurkräfte mit geom. Imperfektion

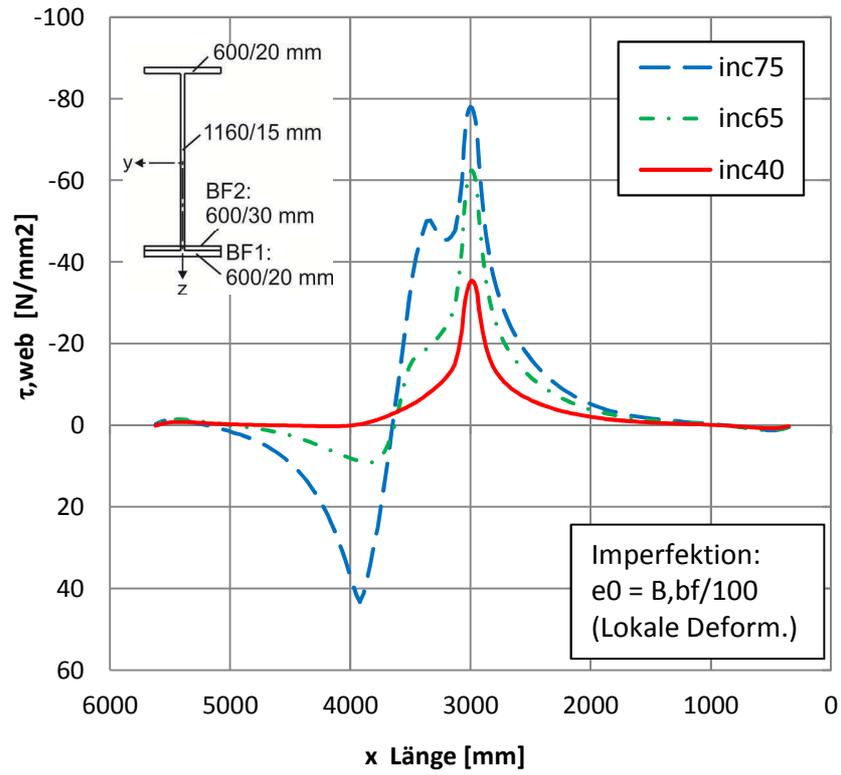


Abbildung 88: $h=1200\text{mm}$, UB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$, $e_0 + \sigma_R$, Steife

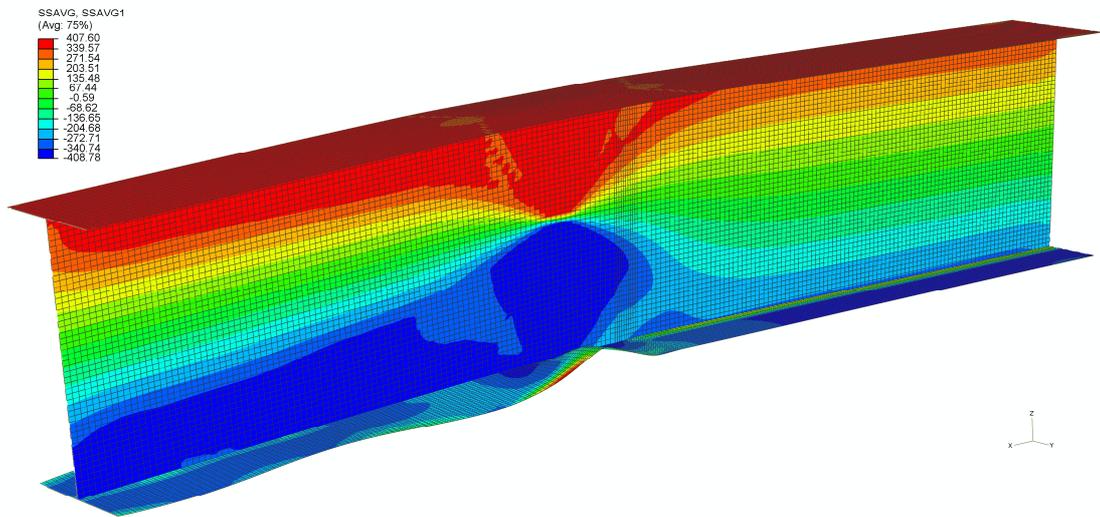


Abbildung 89: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , ST, INC 170

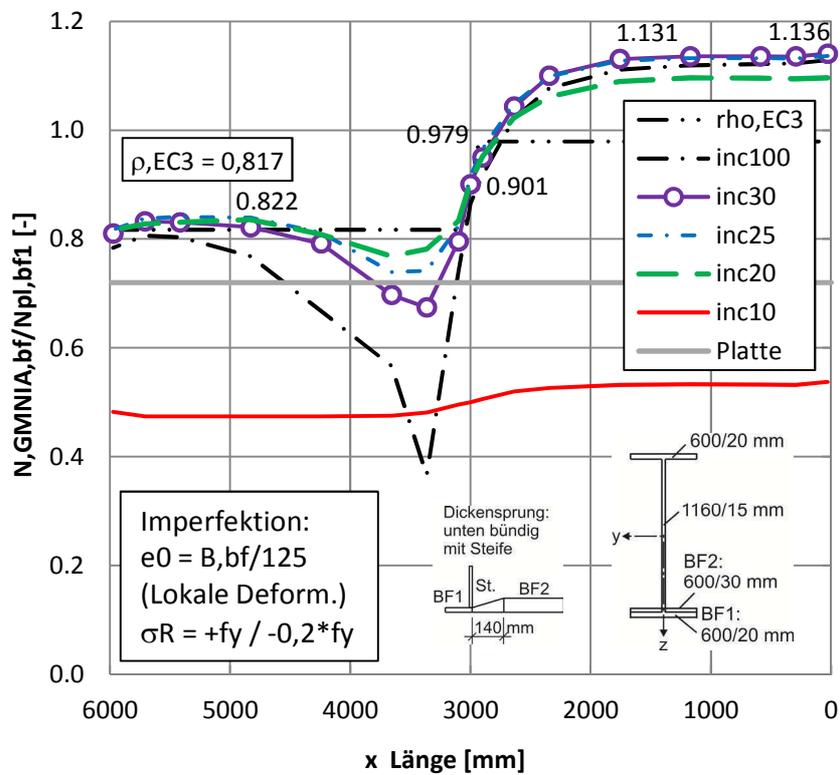


Abbildung 90: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife

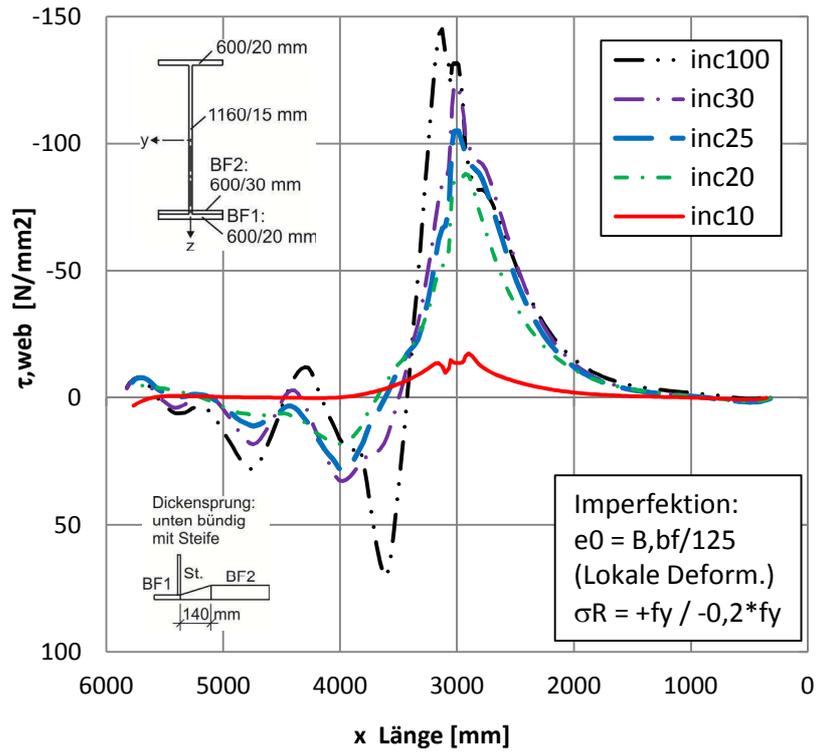


Abbildung 91: $h=1200\text{mm}$, UB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen, mit Steife

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$, e_0 , Steife

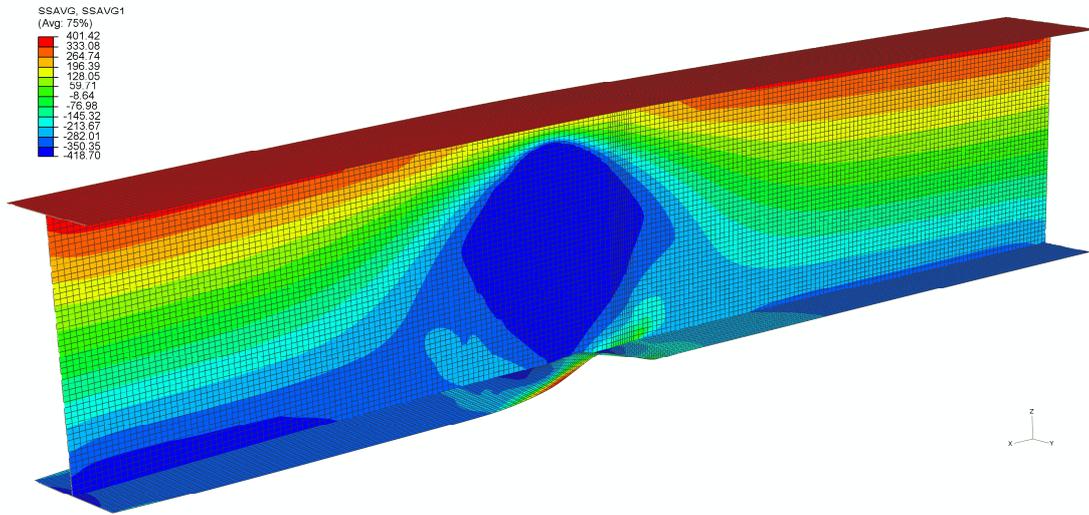


Abbildung 92: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/100$, ST, INC 275

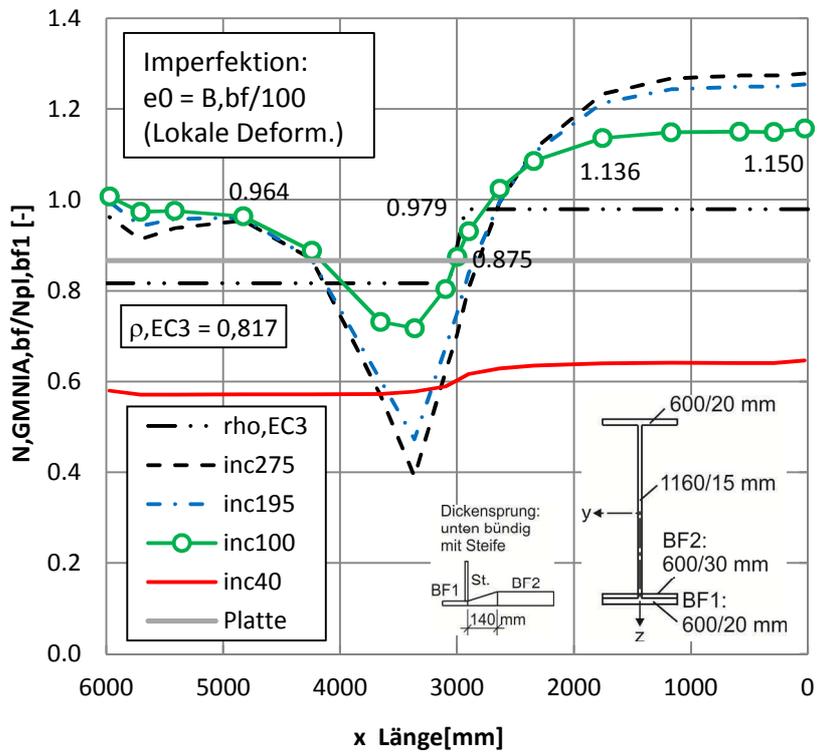


Abbildung 93: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, Untergurkräfte mit geom. Imperfektion, mit Steife

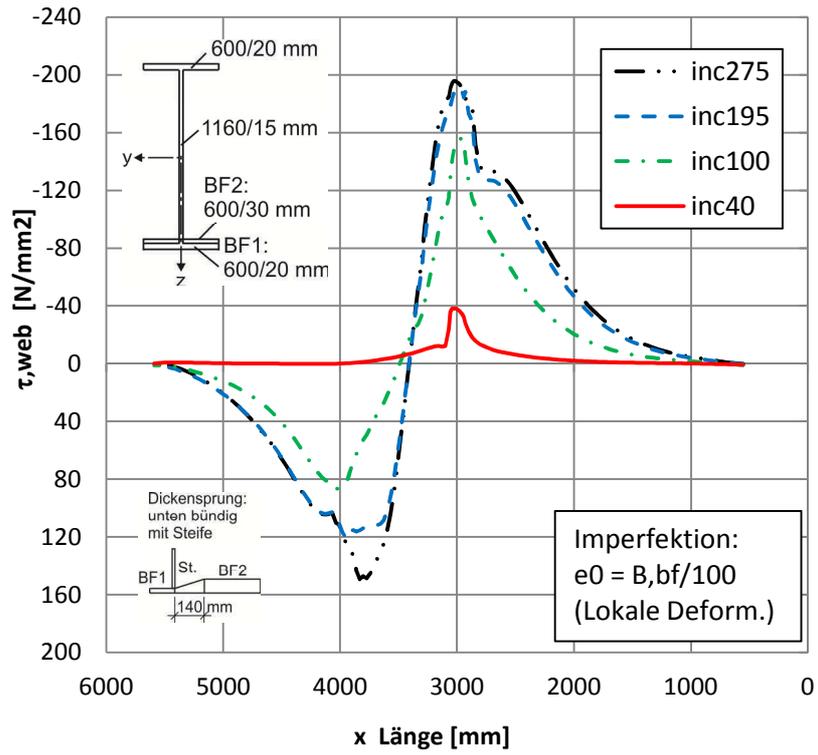


Abbildung 94: $h=1200mm, UB, t1/t2=1.5, \alpha=20$, Schubspannungen mit geom. Imperfektion, mit Steife

➤ $H = 1200 \text{ mm}$, UB, $t_1/t_2 = 1.5$, $\alpha = 10$

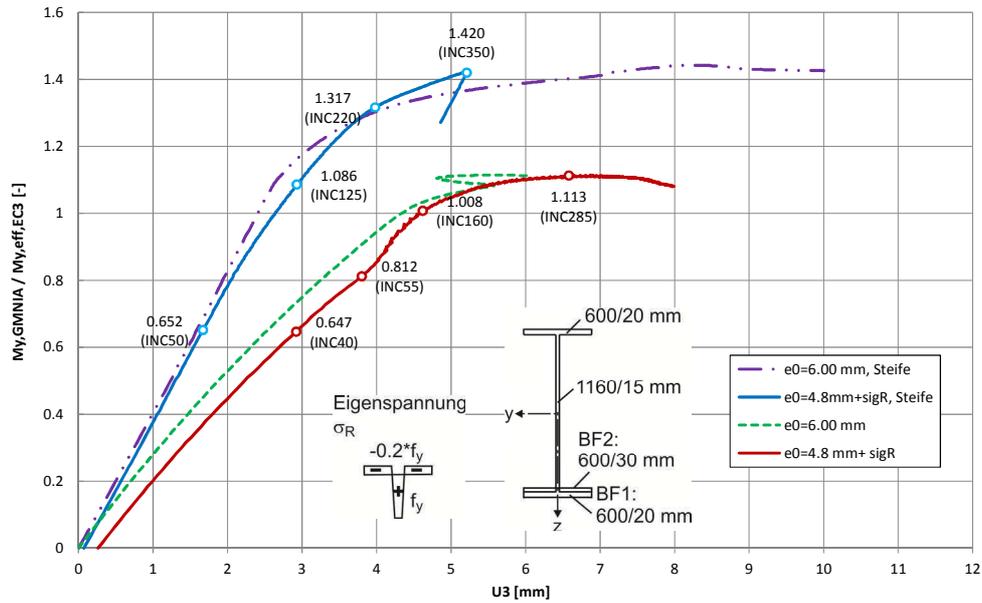


Abbildung 95: Lastverschiebungskurven, $h=1200$, UB, $t_1/t_2=1.5$, $\alpha=10$

| Case | My | My,GMNIA / | Nbf | Nbf,GMNIA / |
|--|---------|------------|----------|-------------|
| | [kNm] | My,eff,EC3 | [kN] | Npl,eff,EC3 |
| | | [-] | | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha=10$, $t_1/t_2=1.5$, $e_0^{125} + \sigma_R$ | 5994.00 | 1.113 | -3403.51 | 0.799 |
| H1200, $\alpha=10$, $t_1/t_2=1.5$, e_0^{100} | 5859.00 | 1.088 | -3800.96 | 0.892 |
| H1200, $\alpha=10$, $t_1/t_2=1.5$, $e_0^{125} + \sigma_R$, ST | 7650.01 | 1.420 | -3520.32 | 0.826 |
| H1200, $\alpha=10$, $t_1/t_2=1.5$, e_0^{100} , ST | 7038.01 | 1.307 | -3801.76 | 0.892 |

Tabelle 21: Vergleiche Träger $H = 1200 \text{ mm}$, UB, $t_1/t_2 = 1.5$, $\alpha = 10$

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 10$, $e_0 + \sigma_R$

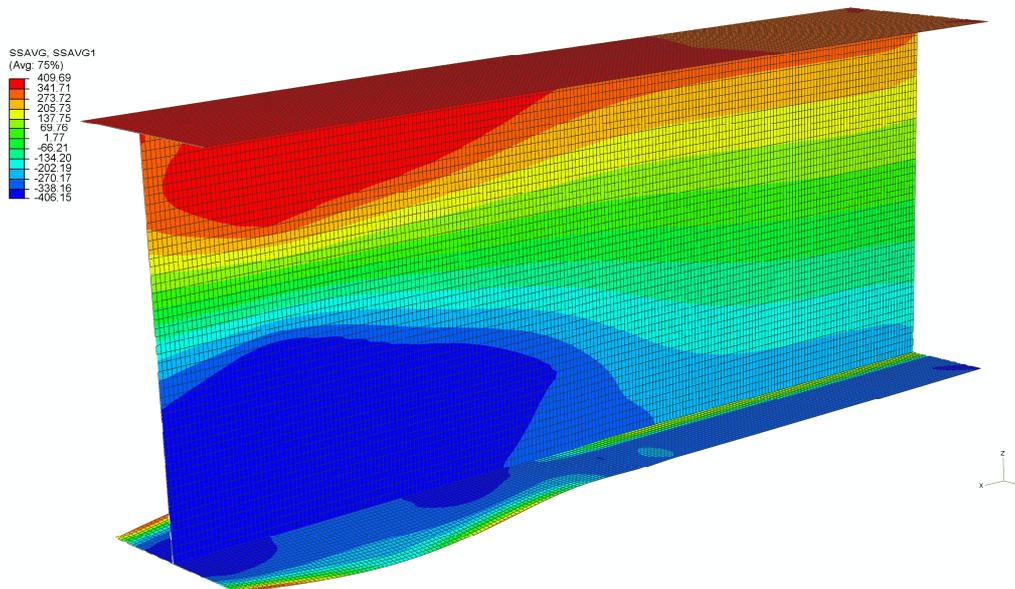


Abbildung 96: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=10$, $B/125$, σ_R , INC 285

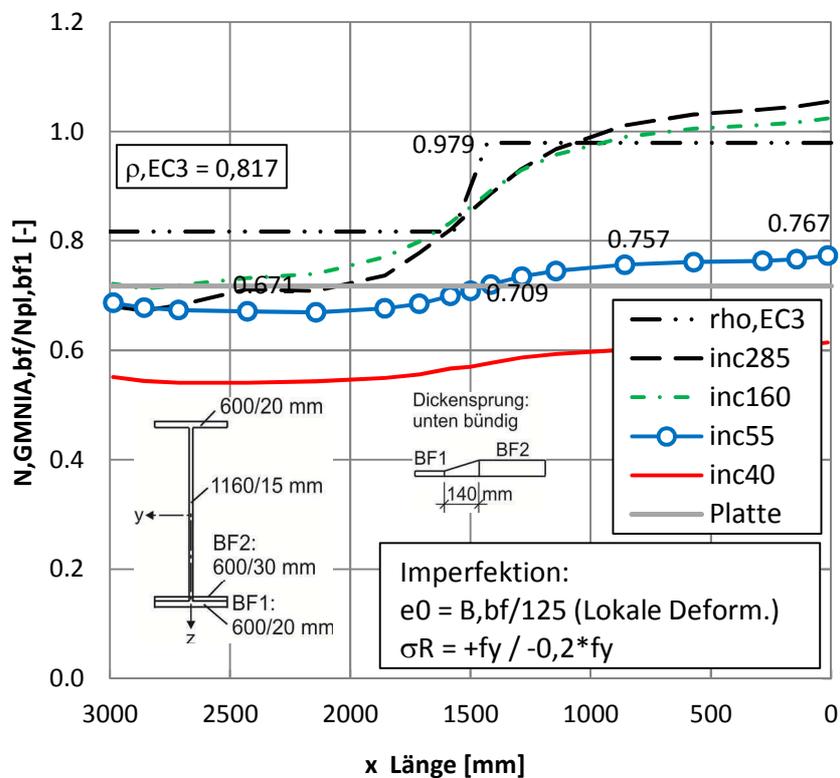


Abbildung 97: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=10$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen

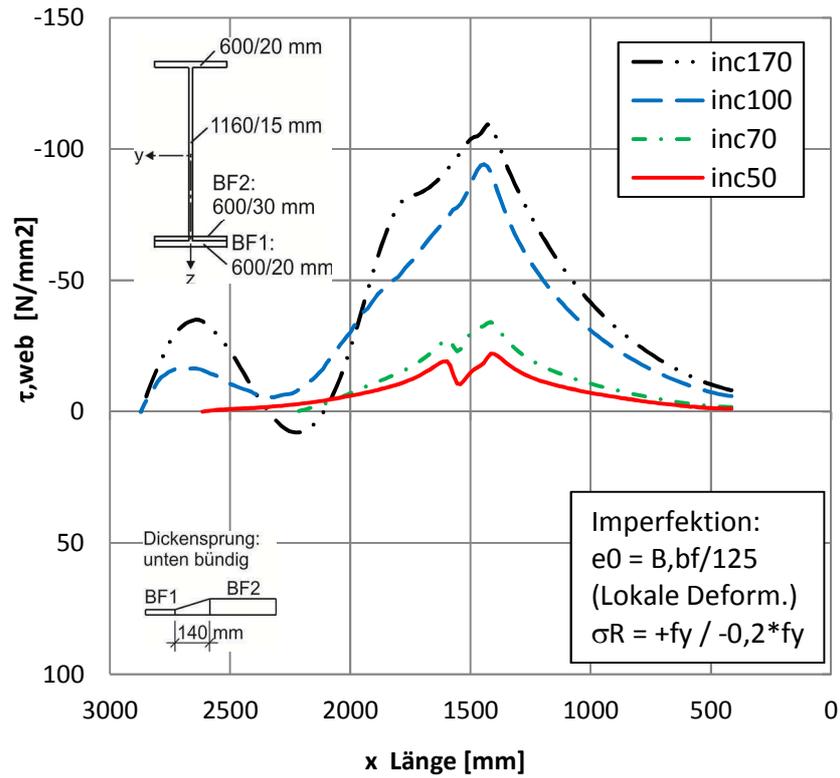


Abbildung 98: $h=1200\text{mm}$, UB, $t_1/t_2=1.5$, $\alpha=10$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 10$, e_0

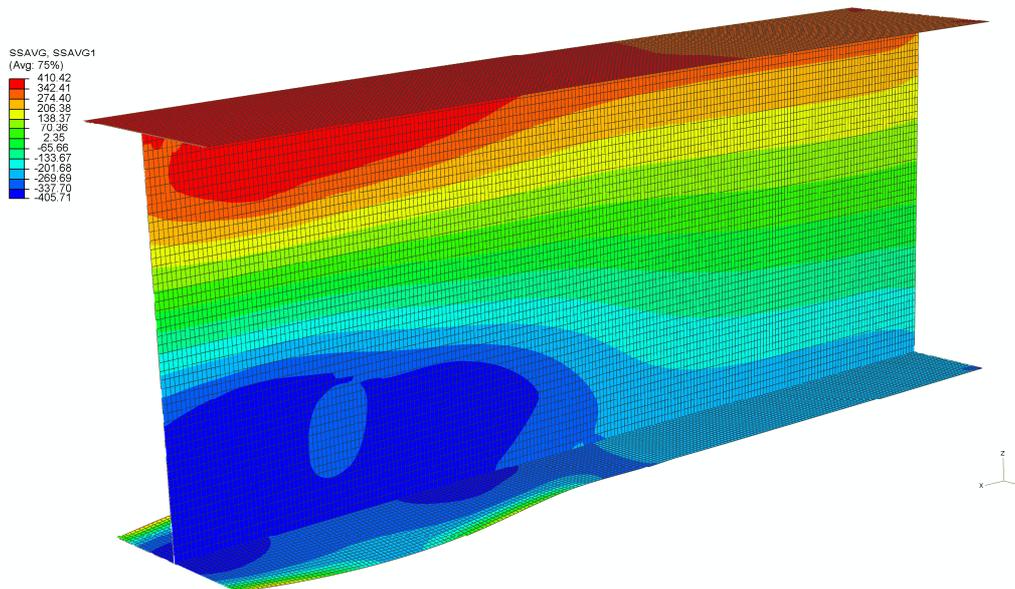


Abbildung 99: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/100$, ST, INC 235

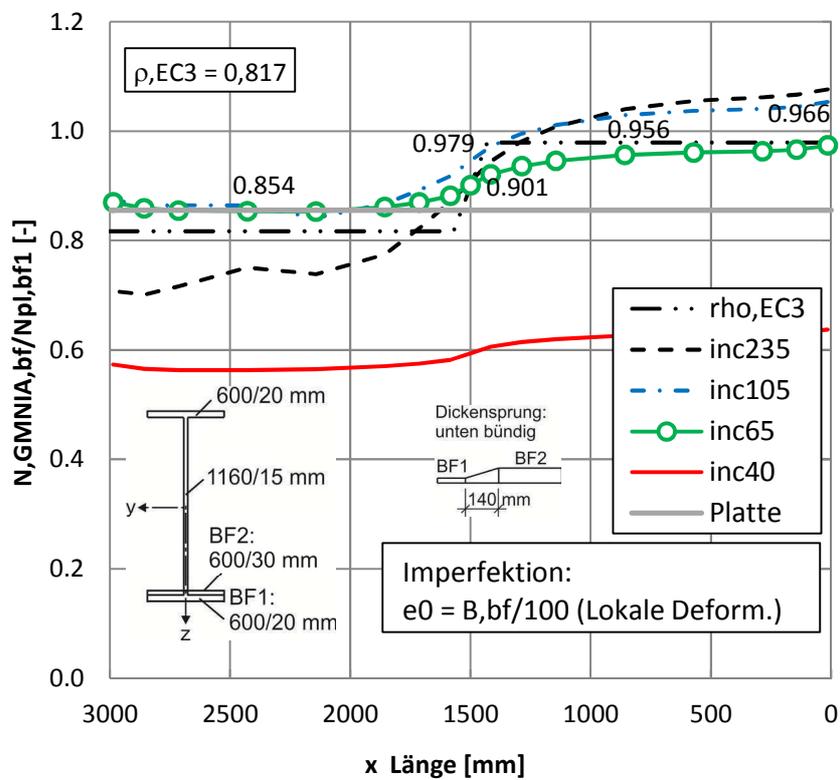


Abbildung 100: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=10$, Untergurtkräfte mit geom. Imperfektion

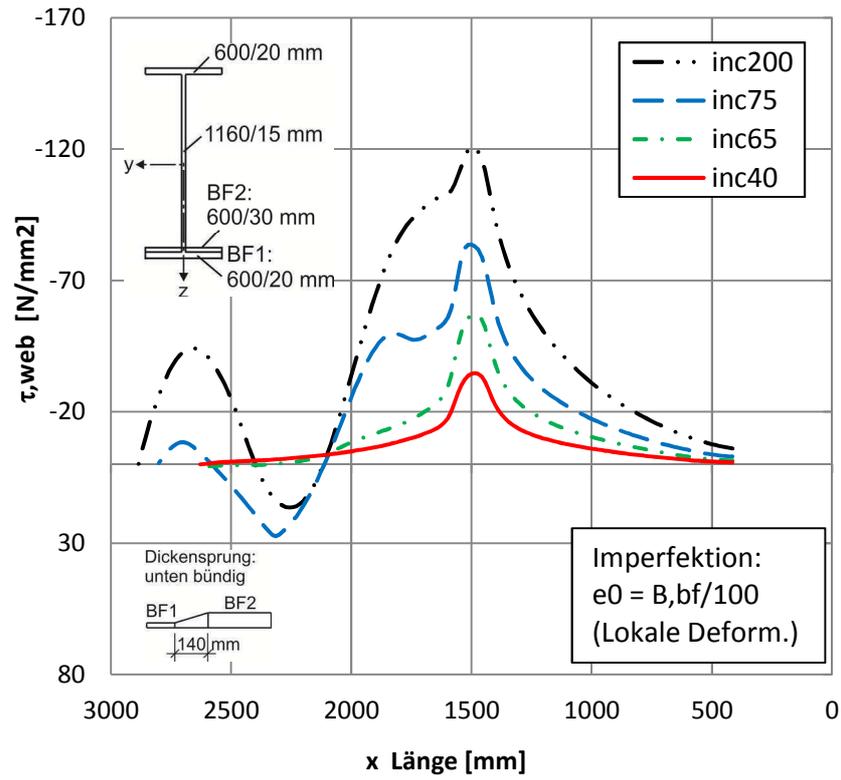


Abbildung 101: $h=1200\text{mm}$, UB, $t_1/t_2=1.5$, $\alpha=10$, Schubspannungen mit geom. Imperfektion

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 10$, $e_0 + \sigma_R$, Steife

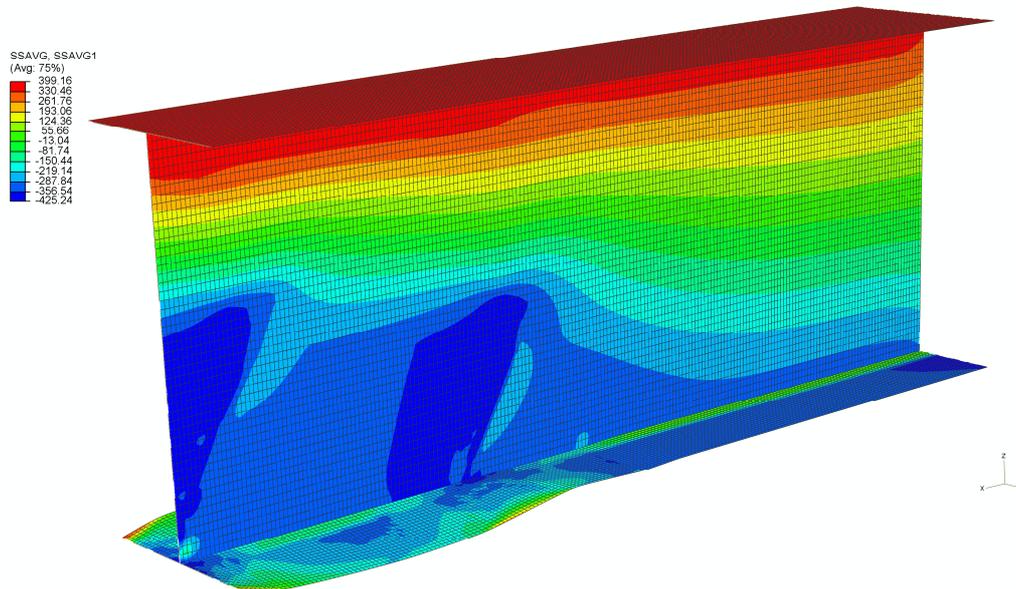


Abbildung 102: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=10$, $B/125$, σ_R , ST, INC 350

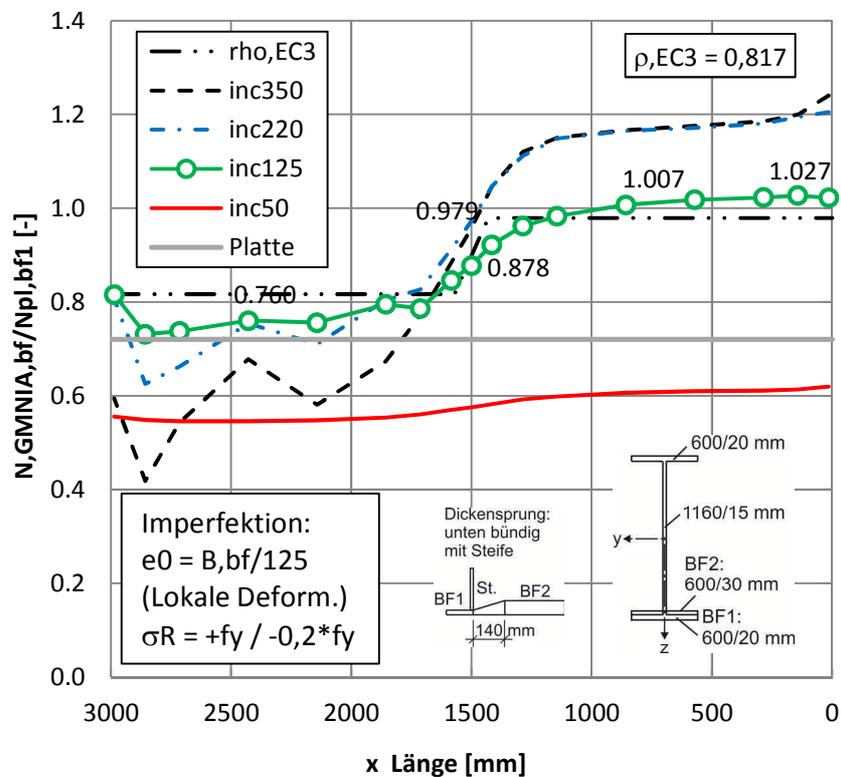


Abbildung 103: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=10$, Untergurtrkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife

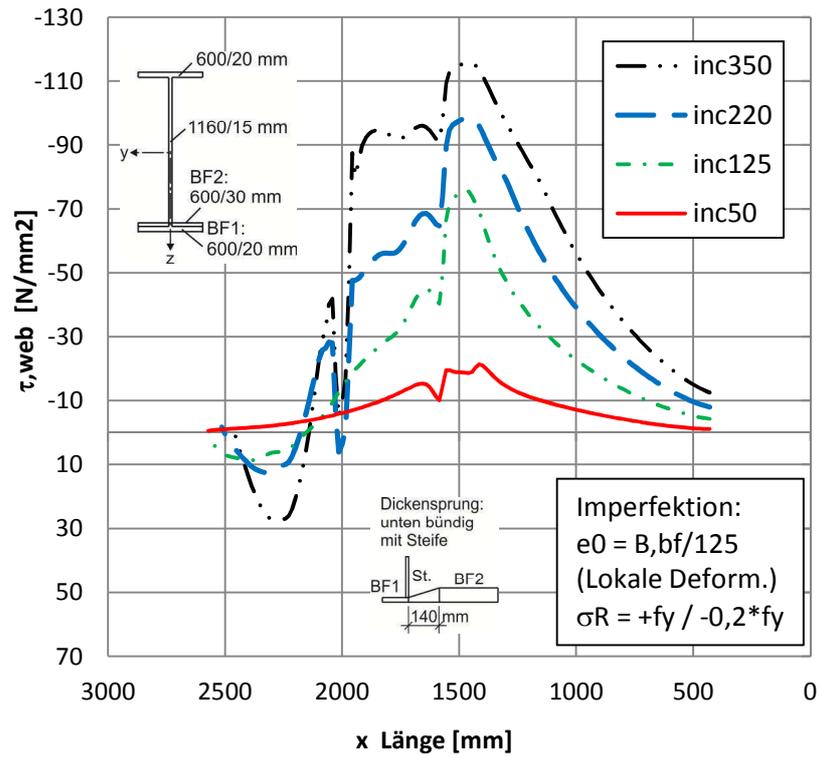


Abbildung 104: $h=1200\text{mm}$, UB, $t_1/t_2=1.5$, $\alpha=10$, Schubspannungen mit geom. Imperfektion und Eigenspannungen, mit Steife

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 10$, e_0 , Steife

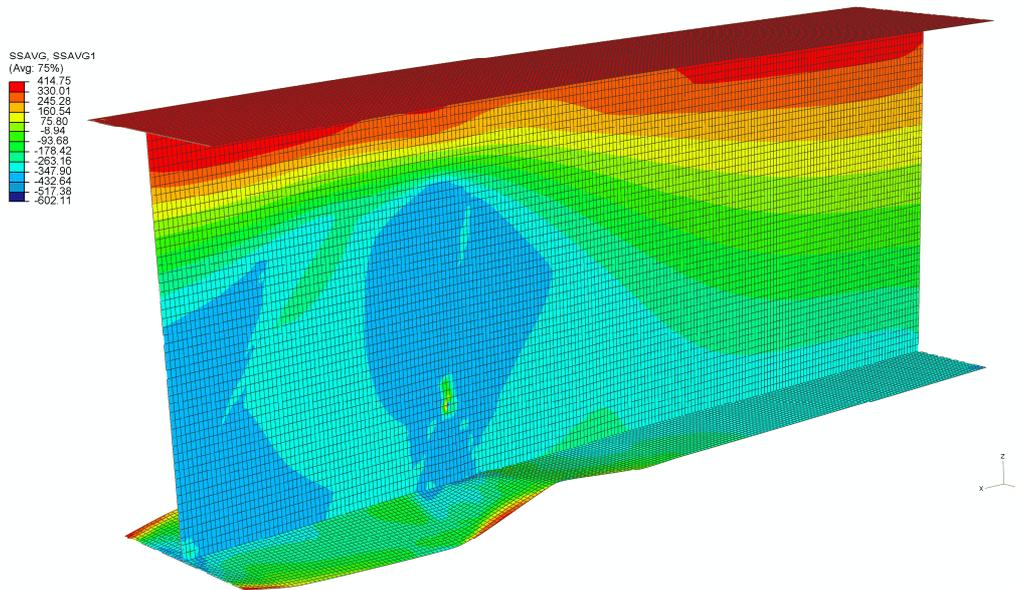


Abbildung 105: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=10$, B/100, ST, INC 410

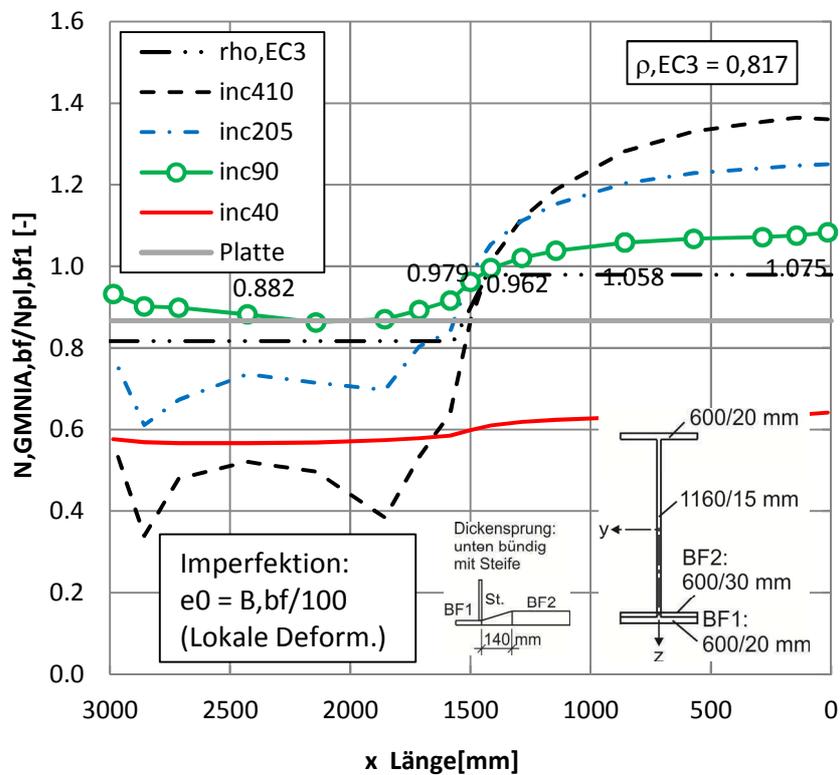


Abbildung 106: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=10$, Untergurkräfte mit geom. Imperfektion, mit Steife

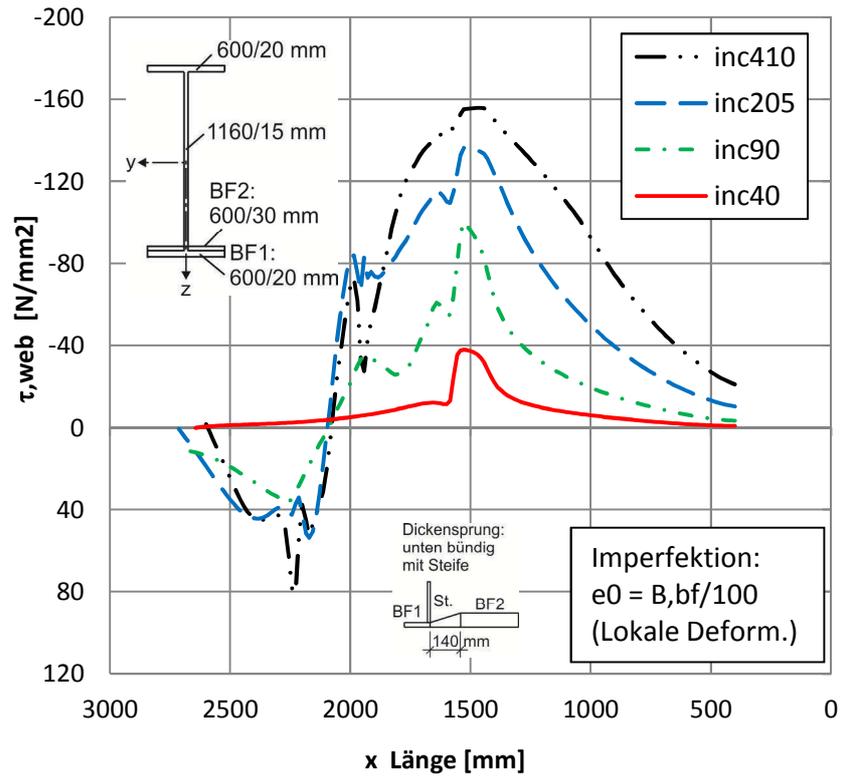


Abbildung 107: $h=1200\text{mm}$, UB, $t_1/t_2=1.5$, $\alpha=10$, Schubspannungen mit geom. Imperfektion, mit Steife

6.3.3. Träger mit Untergurtdickensprung oben bündig $t1/t2 = 1.5$ - „Fall 3“

➤ $H = 1200 \text{ mm}$, OB , $t1/t2 = 1.5$, $\alpha = 20$

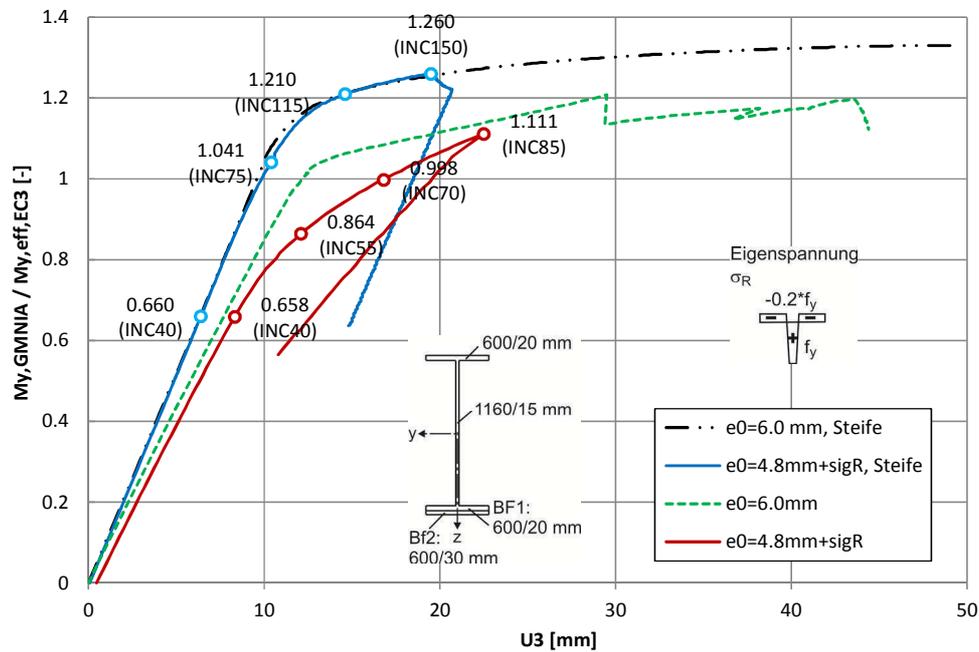


Abbildung 108: Lastverschiebungskurven, $h=1200$, OB , $t1/t2=1.5$, $\alpha=20$

| Case | My | My,GMNIA / | Nbf | Nbf,GMNIA / |
|--|---------|------------|----------|-------------|
| | [kNm] | My,eff,EC3 | | |
| | | [-] | [kN] | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha 20$, $t1/t2=1.5$, $e_0^{125} + \sigma_R$ | 5985.00 | 1.111 | -3311.85 | 0.777 |
| H1200, $\alpha 20$, $t1/t2=1.5$, e_0^{100} | 6327.00 | 1.175 | -3692.63 | 0.867 |
| H1200, $\alpha 20$, $t1/t2=1.5$, $e_0^{125} + \sigma_R$, ST | 6786.01 | 1.260 | -3253.82 | 0.764 |
| H1200, $\alpha 20$, $t1/t2=1.5$, e_0^{100} , ST | 7029.01 | 1.305 | -3419.52 | 0.803 |

Tabelle 22: Vergleiche Träger $H = 1200 \text{ mm}$, OB , $t1/t2 = 1.5$, $alpha = 20$

➤ $H = 1200 \text{ mm}$, OB , $t1/t2 = 1.5$, $\alpha = 20$, $e_0 + \sigma_R$

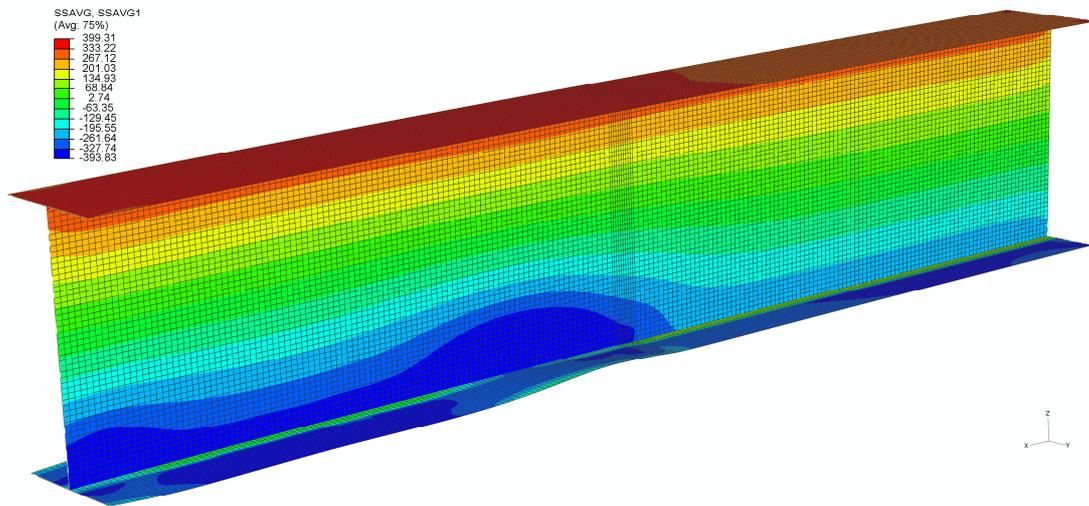


Abbildung 109: $h=1200\text{mm}$, OB , $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , $INC 85$

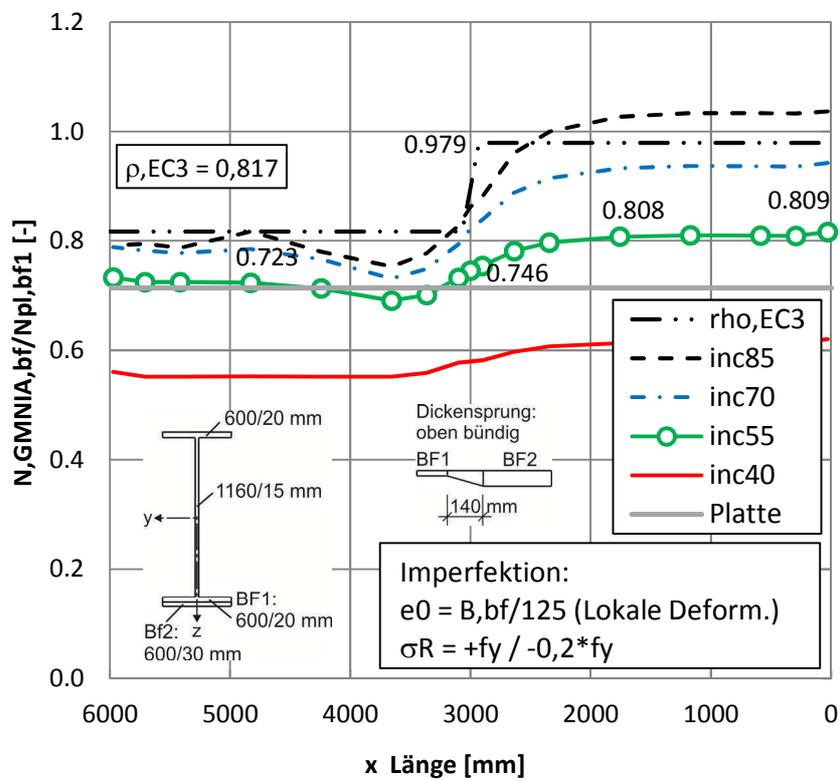


Abbildung 110: $h=1200\text{mm}$, OB , $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen

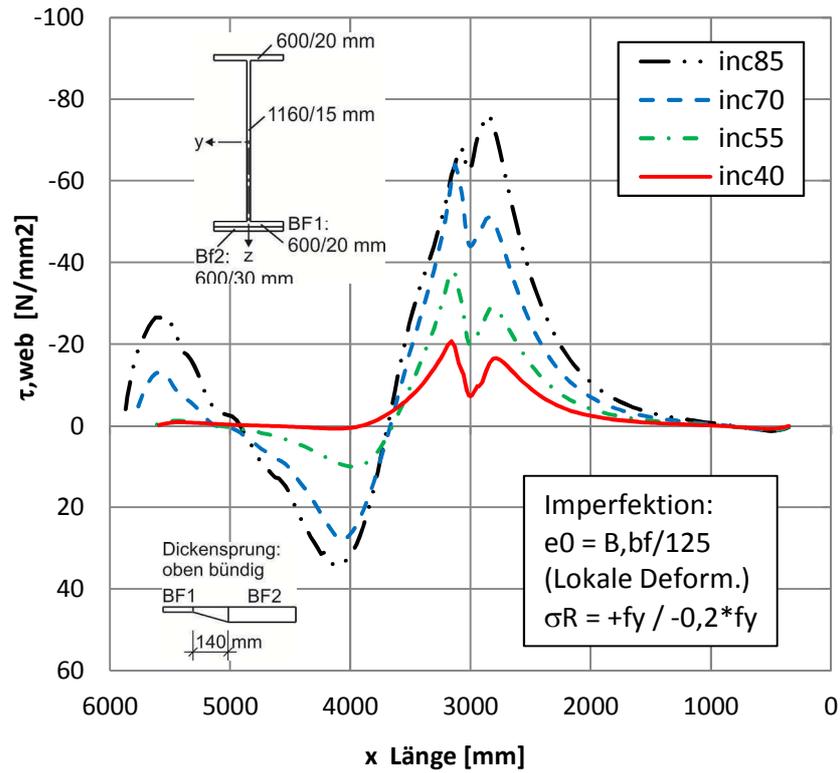


Abbildung 111: $h=1200\text{mm}$, OB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 1200 \text{ mm}$, OB , $t1/t2 = 1.5$, $\alpha = 20$, e_0

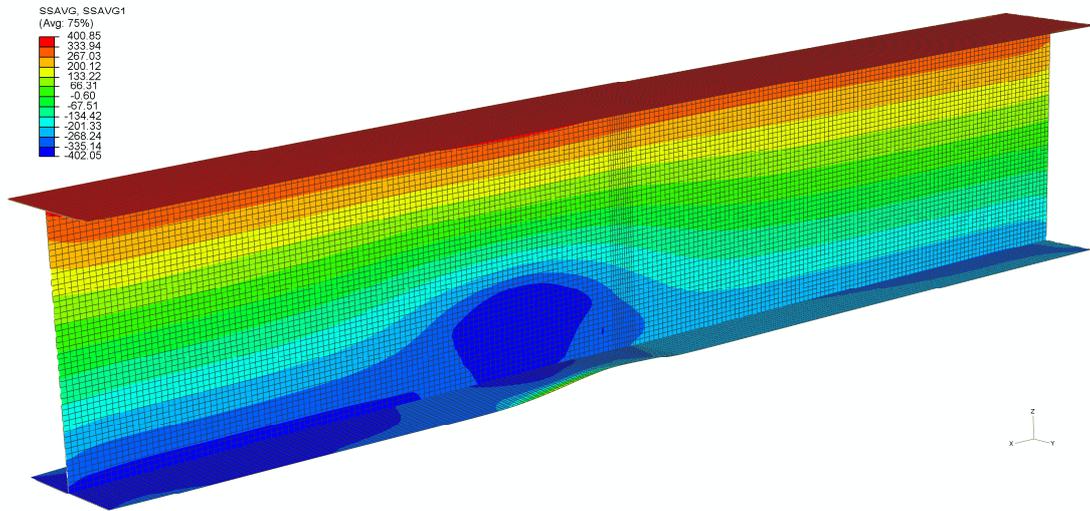


Abbildung 112: $h=1200\text{mm}$, OB , $t1/t2=1.5$, $\alpha=20$, $B/100$, $INC 100$

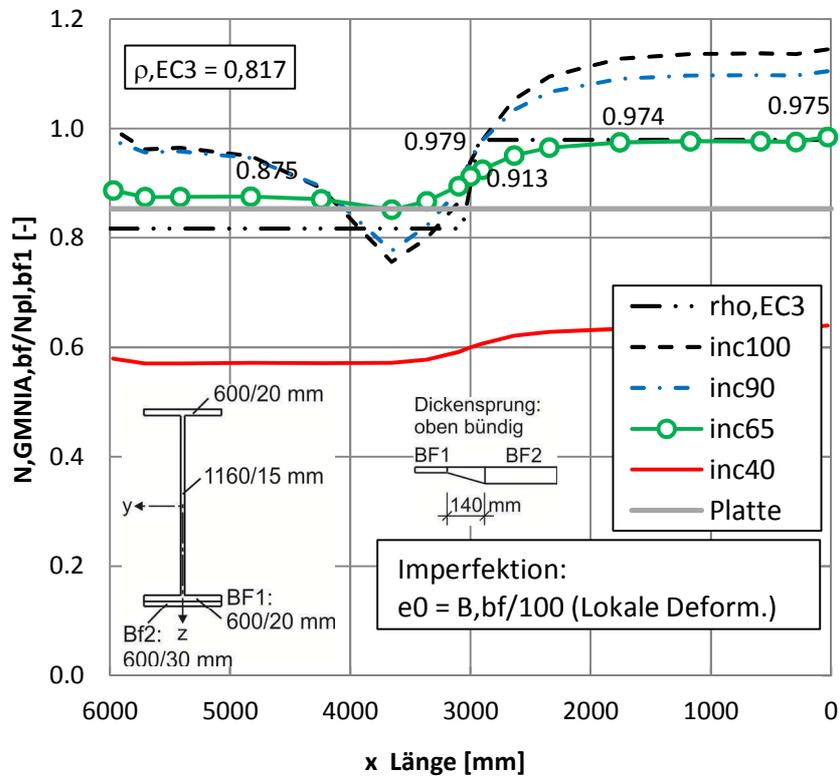


Abbildung 113: $h=1200\text{mm}$, OB , $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion

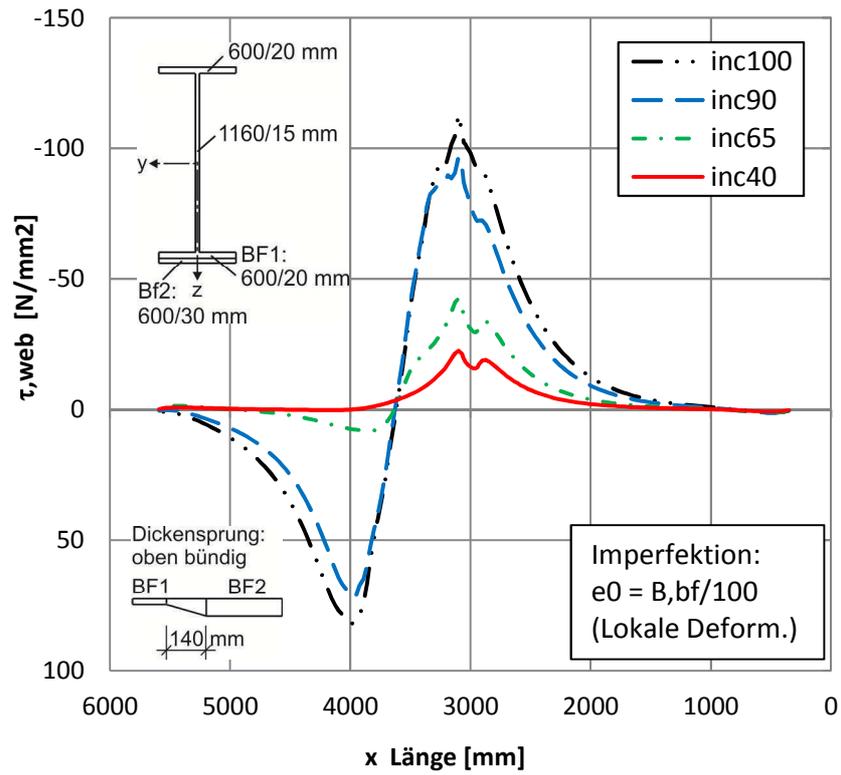


Abbildung 114: $h=1200$ mm, OB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion

➤ $H = 1200 \text{ mm}$, OB , $t1/t2 = 1.5$, $\alpha = 20$, $e_0 + \sigma_R$, *Steife*

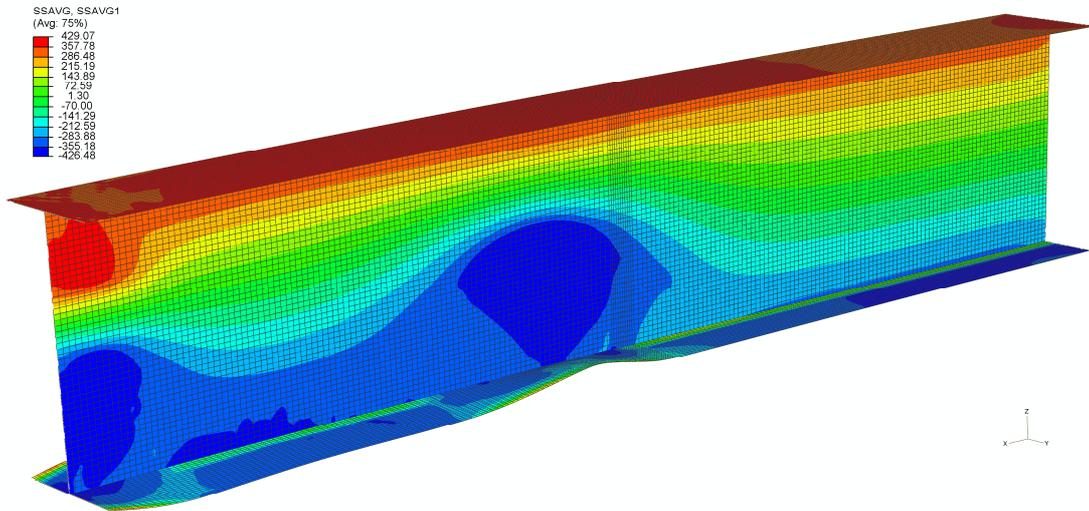


Abbildung 115: $h=1200\text{mm}$, OB , $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , ST , $INC 150$

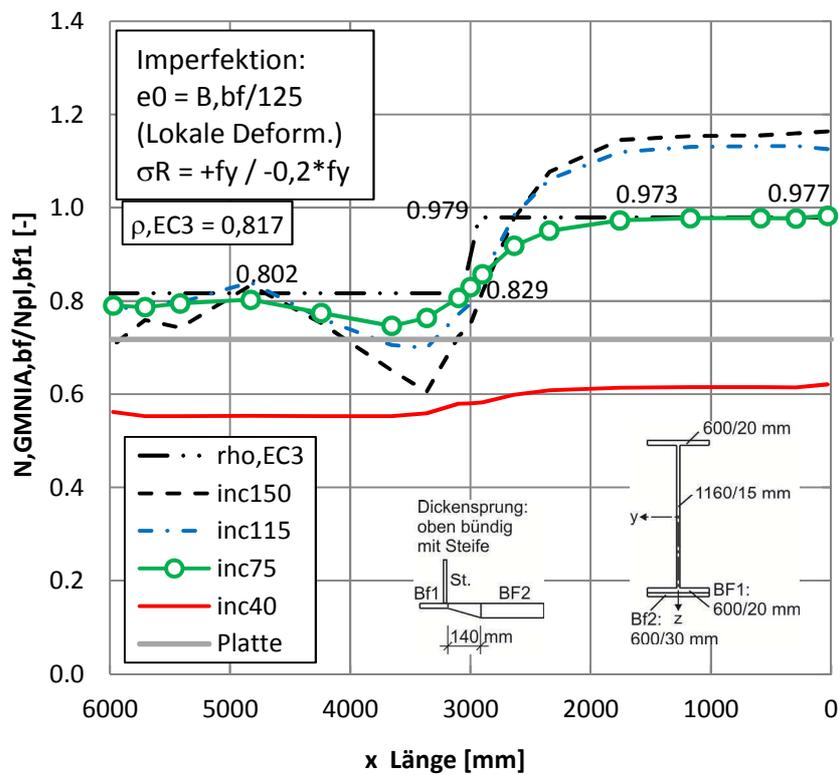


Abbildung 116: $h=1200\text{mm}$, OB , $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen, mit *Steife*

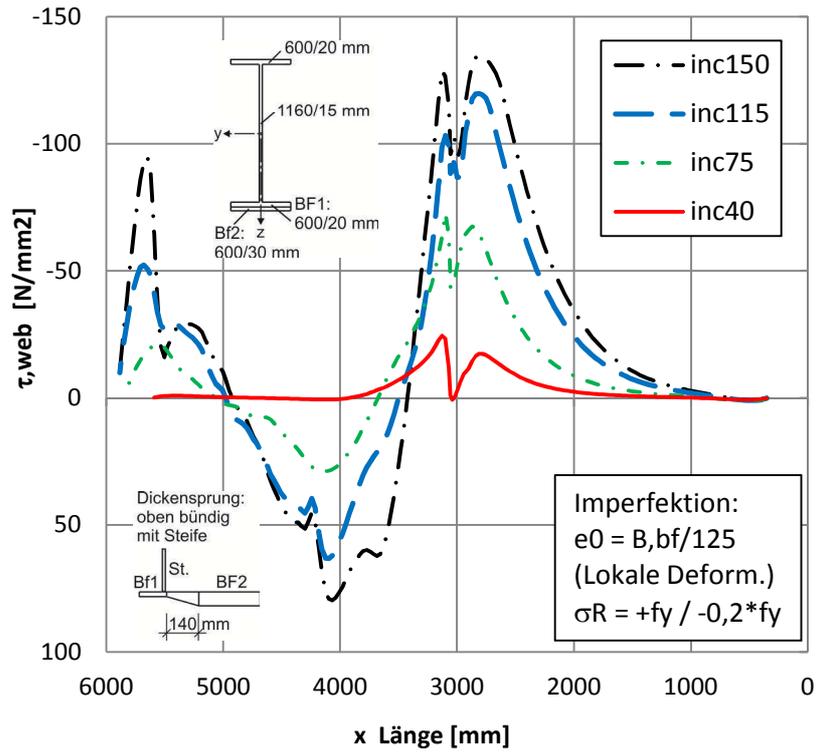


Abbildung 117: $h=1200\text{mm}$, OB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen, mit Steife

➤ $H = 1200 \text{ mm}$, OB , $t1/t2 = 1.5$, $\alpha = 20$, e_0 , *Steife*

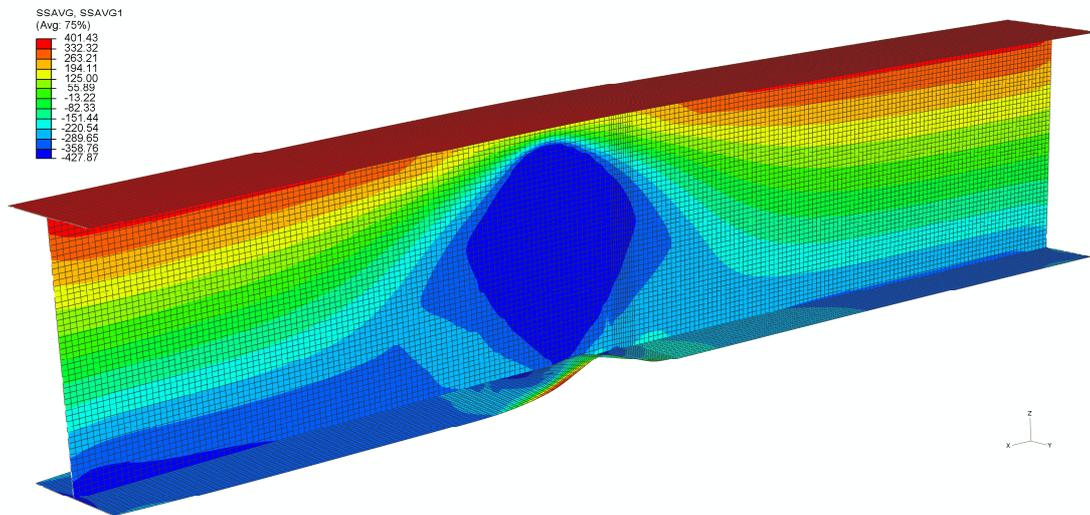


Abbildung 118: $h=1200\text{mm}$, OB , $t1/t2=1.5$, $\alpha=20$, $B/100$, ST , $INC 285$

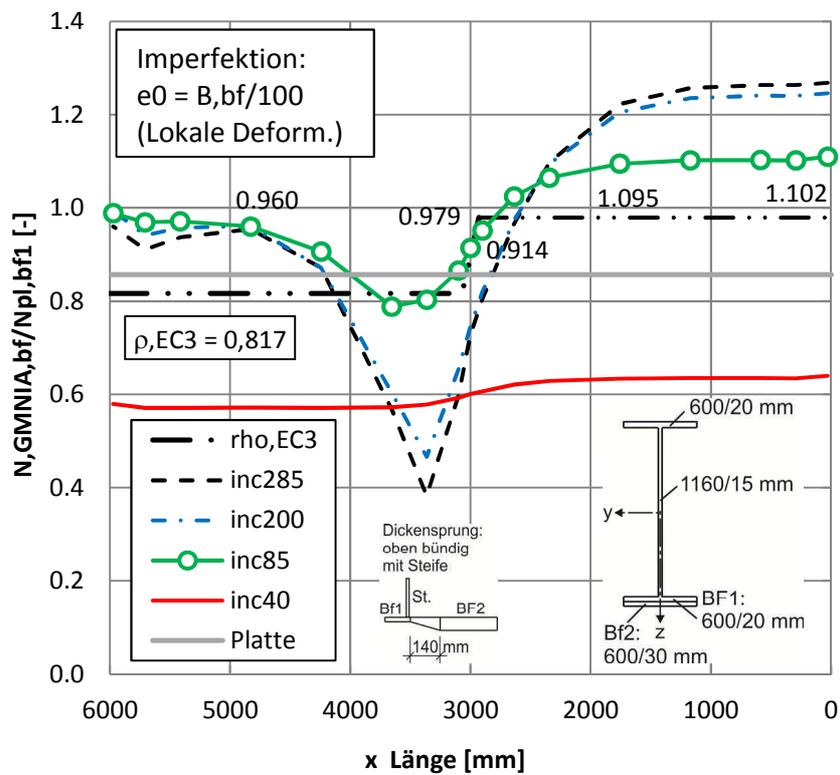


Abbildung 119: $h=1200\text{mm}$, OB , $t1/t2=1.5$, $\alpha=20$, *Untergurtkräfte mit geom. Imperfektion, mit Steife*

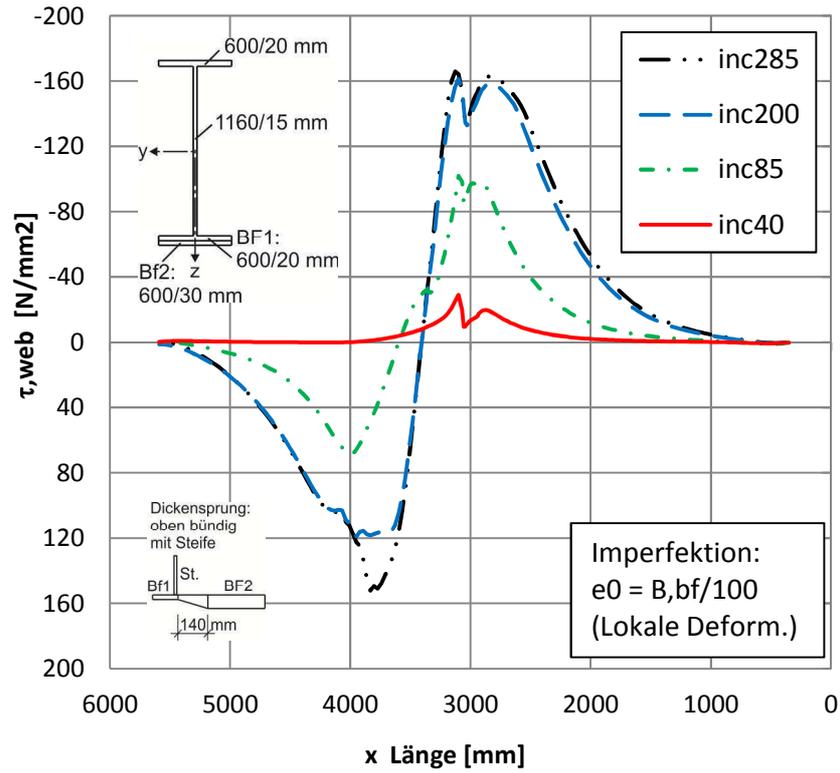


Abbildung 120: $h=1200mm, OB, t_1/t_2=1.5, \alpha=20$, Schubspannungen mit geom. Imperfektion, mit Steife

6.3.4. Träger mit Untergurtdickensprung zentrisch $t_1/t_2 = 1.5$ - „Fall 4“

➤ $H = 1200 \text{ mm}$, Z , $t_1/t_2 = 1.5$, $\alpha = 20$

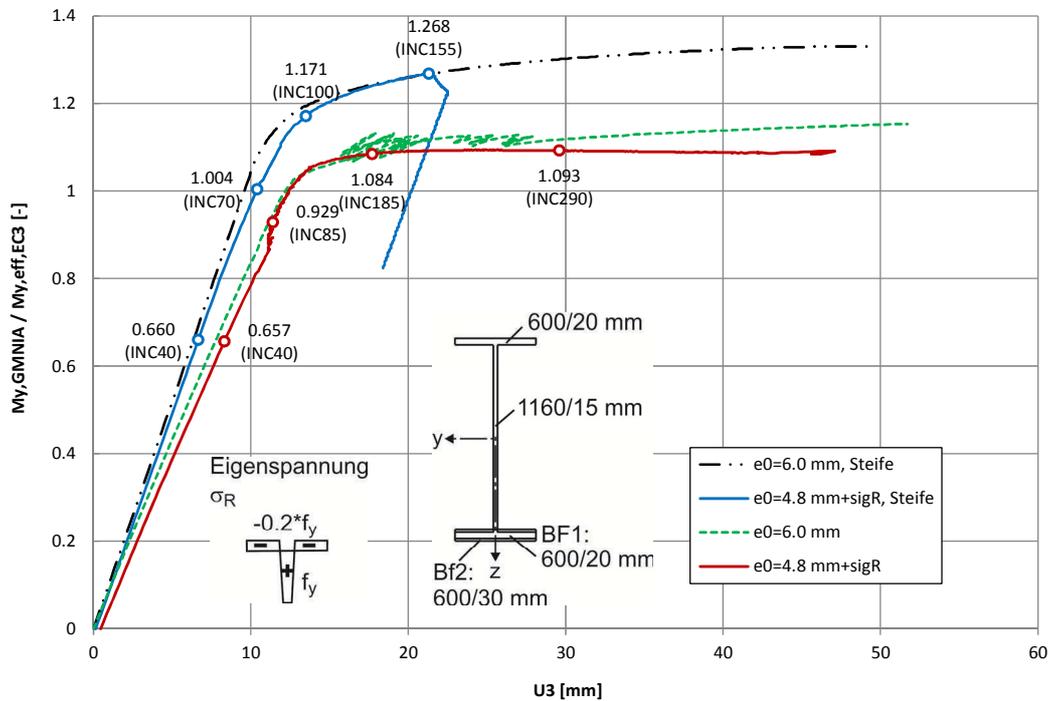


Abbildung 121: Lastverschiebungskurven, $h=1200$, Z , $t_1/t_2=1.5$, $\alpha=20$

| Case | My | My,GMNIA / | Nbf | Nbf,GMNIA / |
|--|---------|------------|----------|-------------|
| | [kNm] | My,eff,EC3 | | |
| | | [-] | | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125} + \sigma R$ | 5841.00 | 1.084 | -3015.58 | 0.708 |
| H1200, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} | 6831.01 | 1.268 | -3687.58 | 0.866 |
| H1200, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125} + \sigma R$, ST | 6831.01 | 1.268 | -3204.28 | 0.752 |
| H1200, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} , ST | 7011.01 | 1.302 | -3063.34 | 0.719 |

Tabelle 23: Vergleiche Träger $H = 1200 \text{ mm}$, Z , $t_1/t_2 = 1.5$, $\alpha = 20$

➤ $H = 1200 \text{ mm}$, Z , $t1/t2 = 1.5$, $\alpha = 20$, $e_0 + \sigma_R$

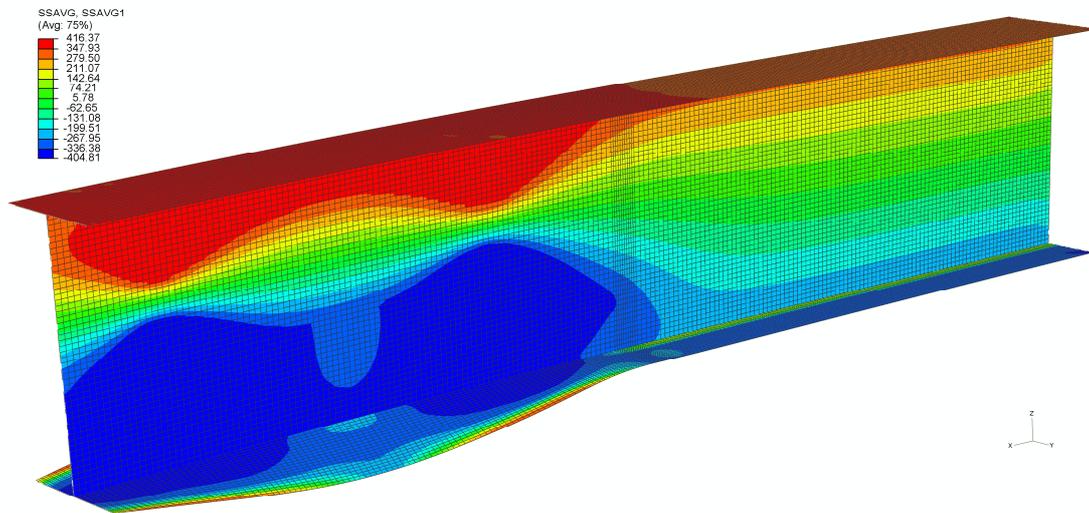


Abbildung 122: $h=1200\text{mm}$, Z , $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , INC 290

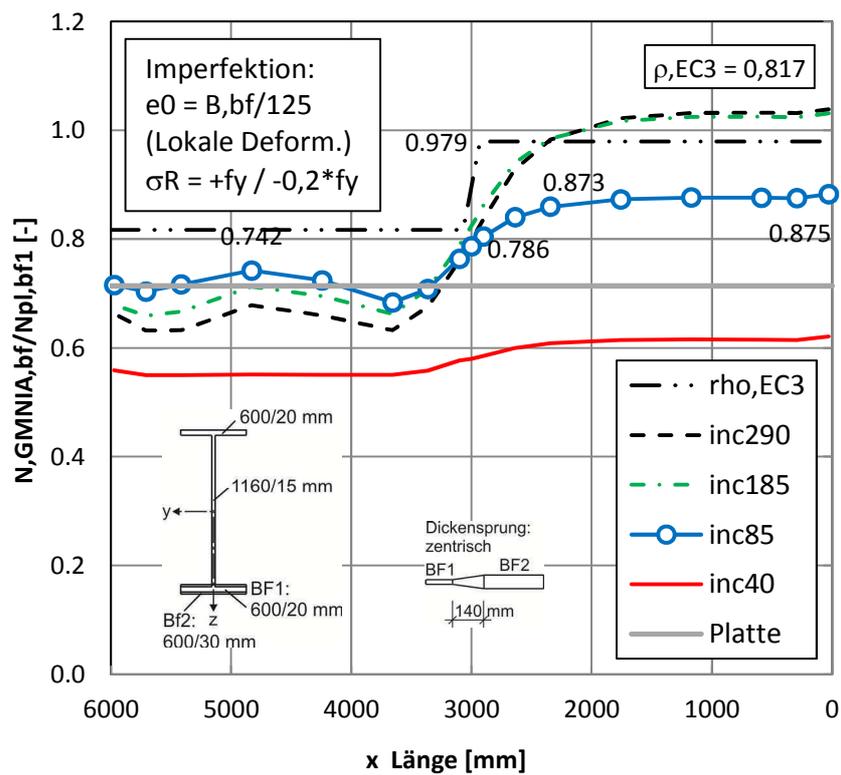


Abbildung 123: $h=1200\text{mm}$, Z , $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen

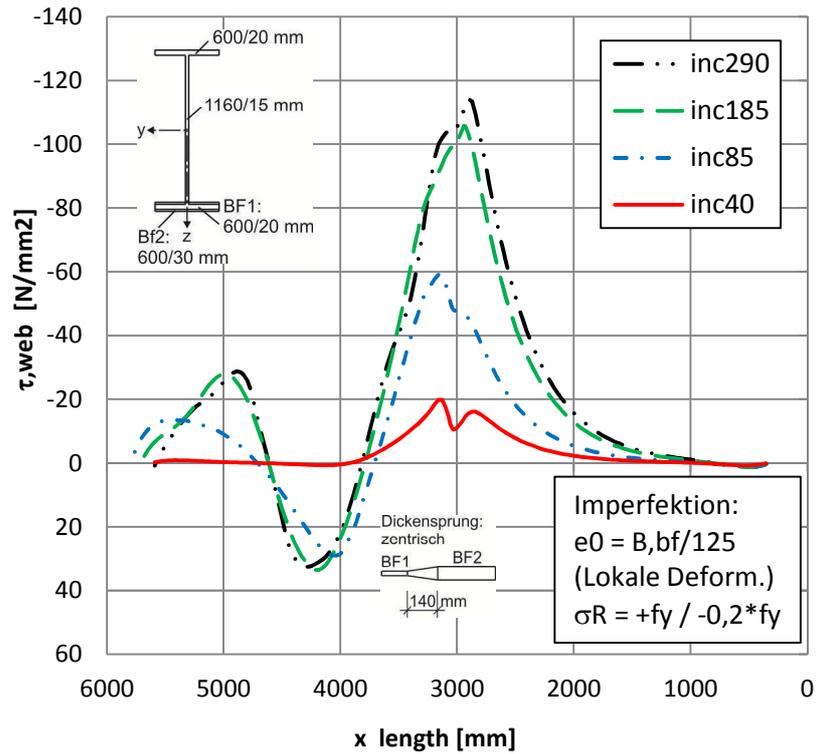


Abbildung 124: $h=1200\text{mm}$, Z, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 1200 \text{ mm}$, Z , $t1/t2 = 1.5$, $\alpha = 20$, e_0

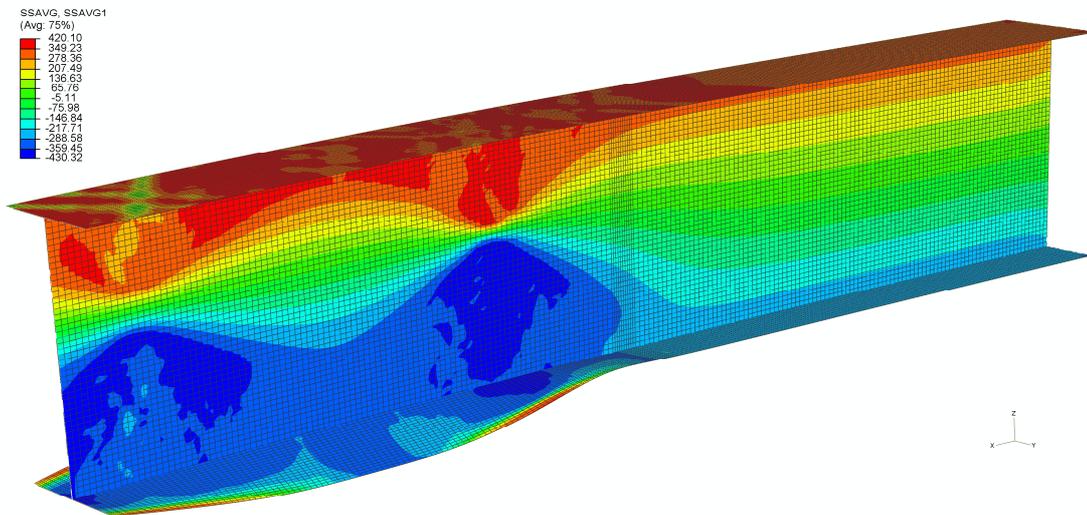


Abbildung 125: $h=1200\text{mm}$, Z , $t1/t2=1.5$, $\alpha=20$, $B/100$, $INC 300$

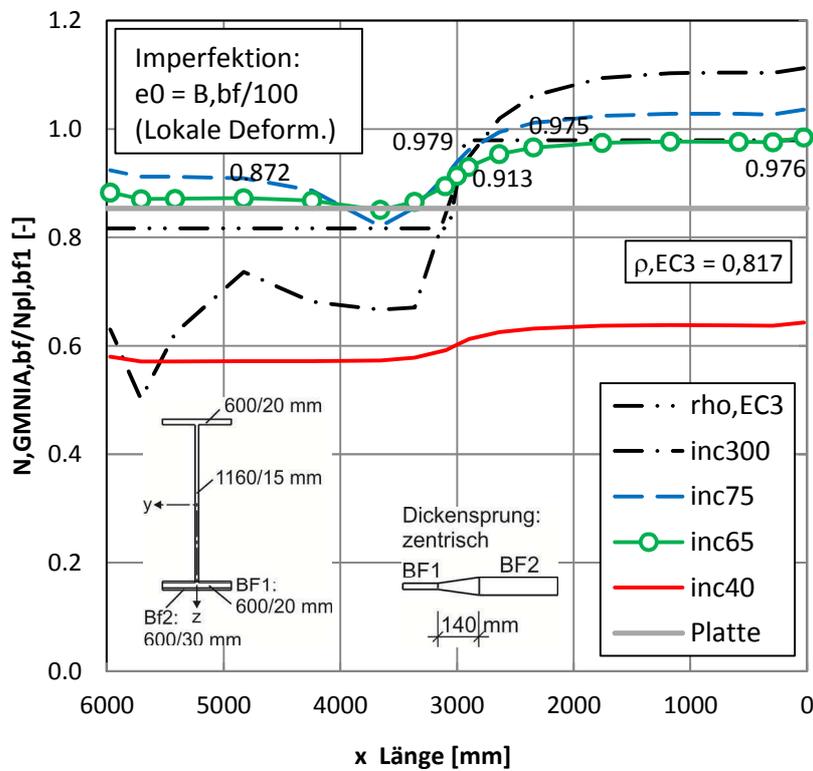


Abbildung 126: $h=1200\text{mm}$, Z , $t1/t2=1.5$, $\alpha=20$, Untergurkräfte mit geom. Imperfektion

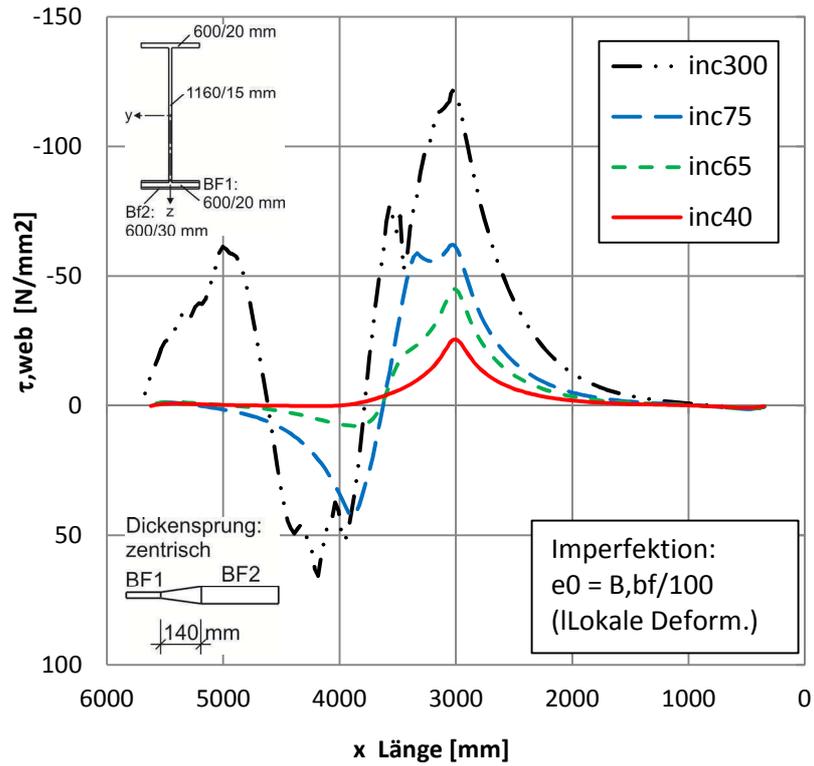


Abbildung 127: $h=1200\text{mm}$, Z , $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion

➤ $H = 1200 \text{ mm}$, Z , $t1/t2 = 1.5$, $\alpha = 20$, $e_0 + \sigma_R$, Steife

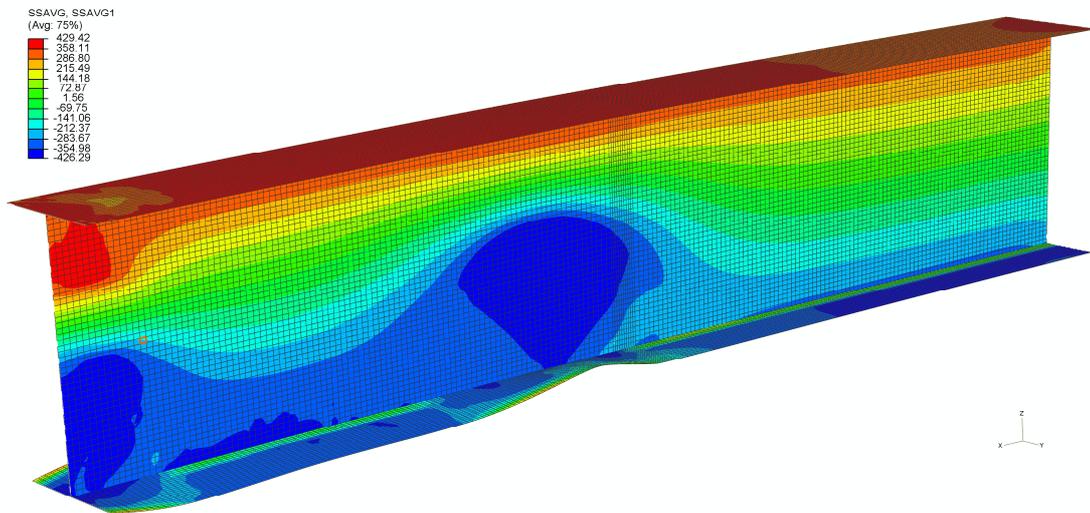


Abbildung 128: $h=1200\text{mm}$, Z , $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , ST , $INC 155$

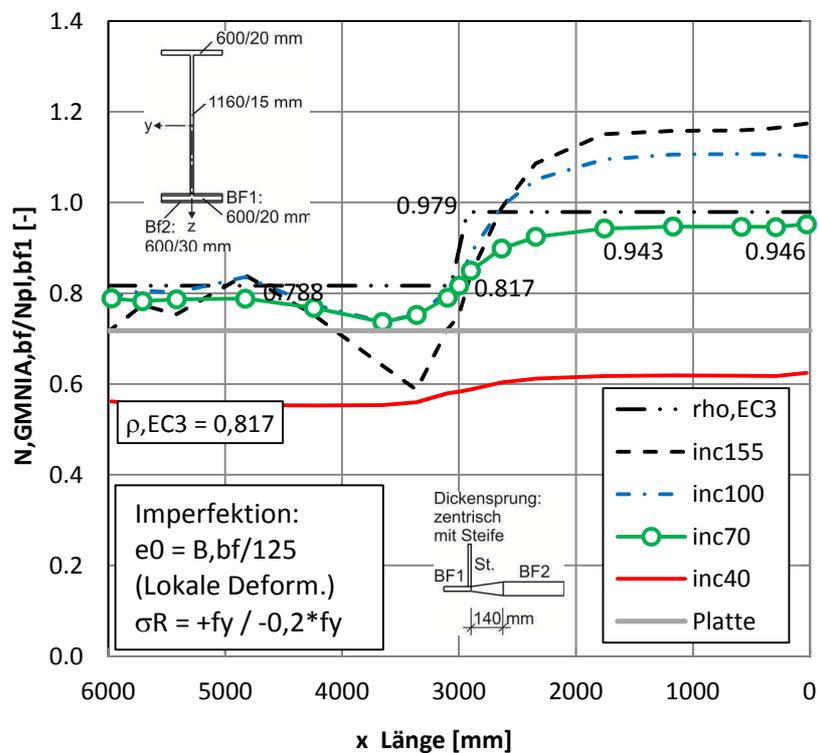


Abbildung 129: $h=1200\text{mm}$, Z , $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife

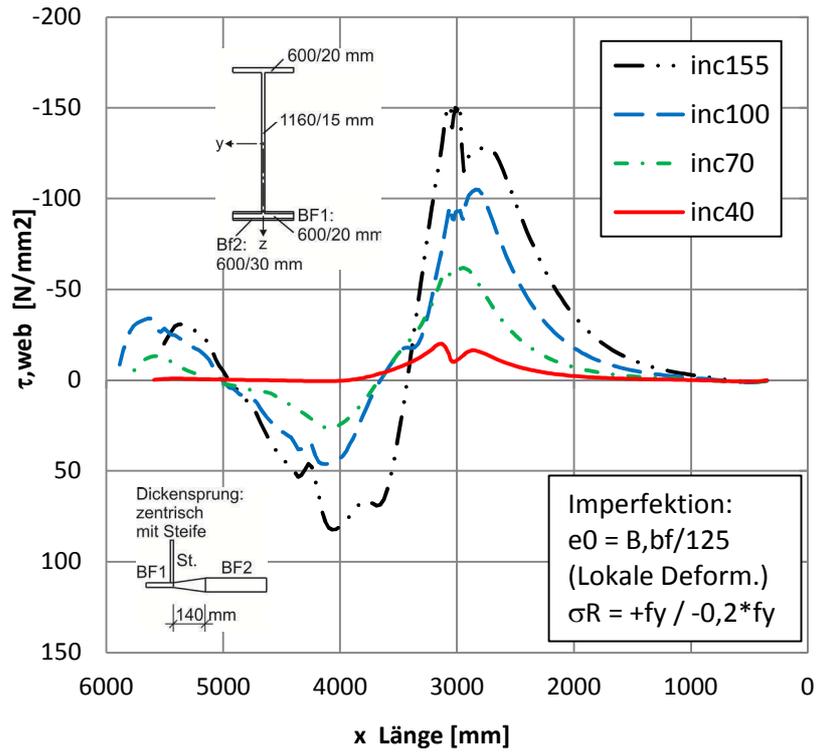


Abbildung 130: $h=1200$ mm, Z , $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen, mit Steife

➤ $H = 1200 \text{ mm}$, Z , $t1/t2 = 1.5$, $\alpha = 20$, e_0 , Steife

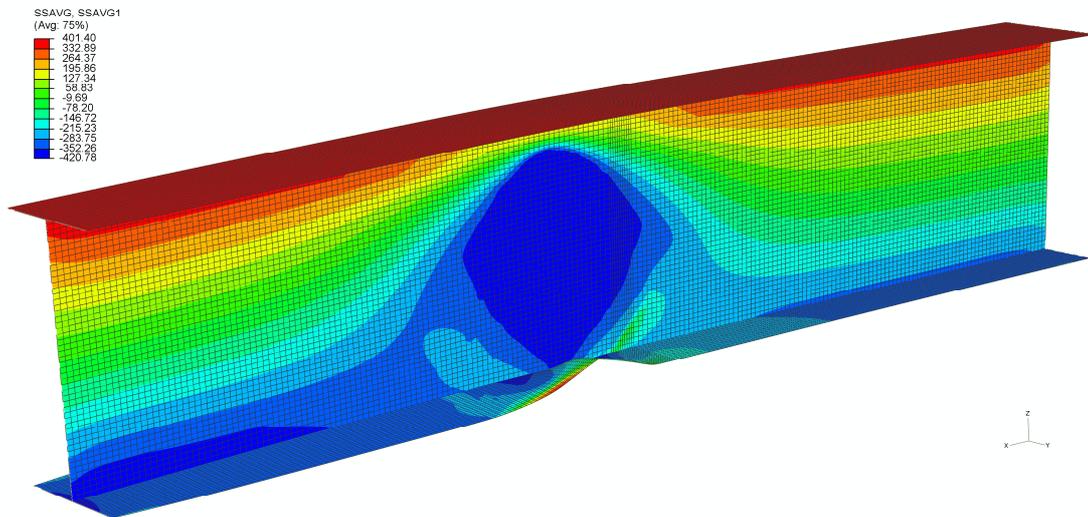


Abbildung 131: $h=1200\text{mm}$, Z , $t1/t2=1.5$, $\alpha=20$, $B/100$, ST , $INC 270$

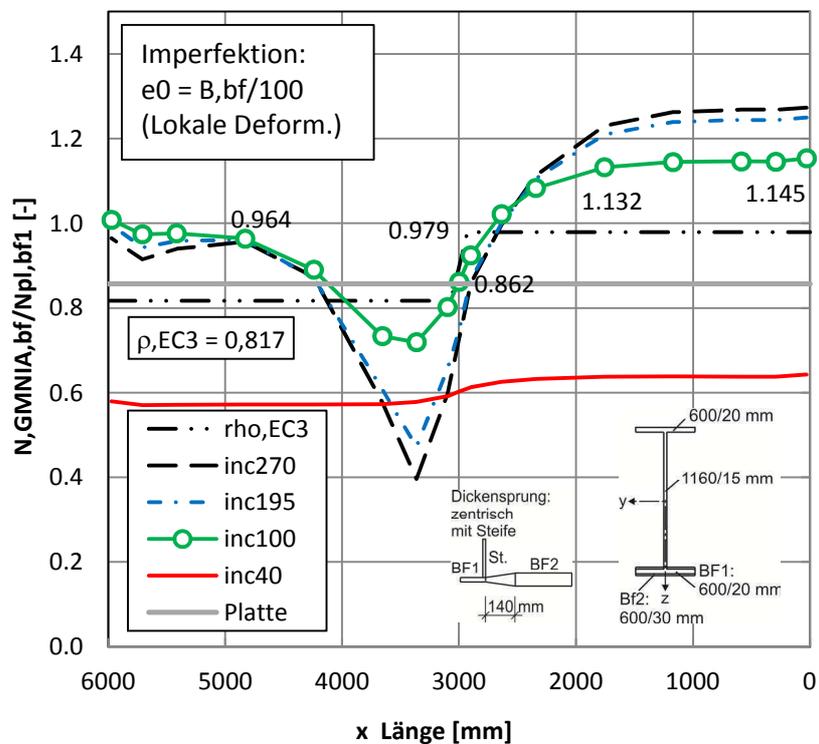


Abbildung 132: $h=1200\text{mm}$, Z , $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion, mit Steife

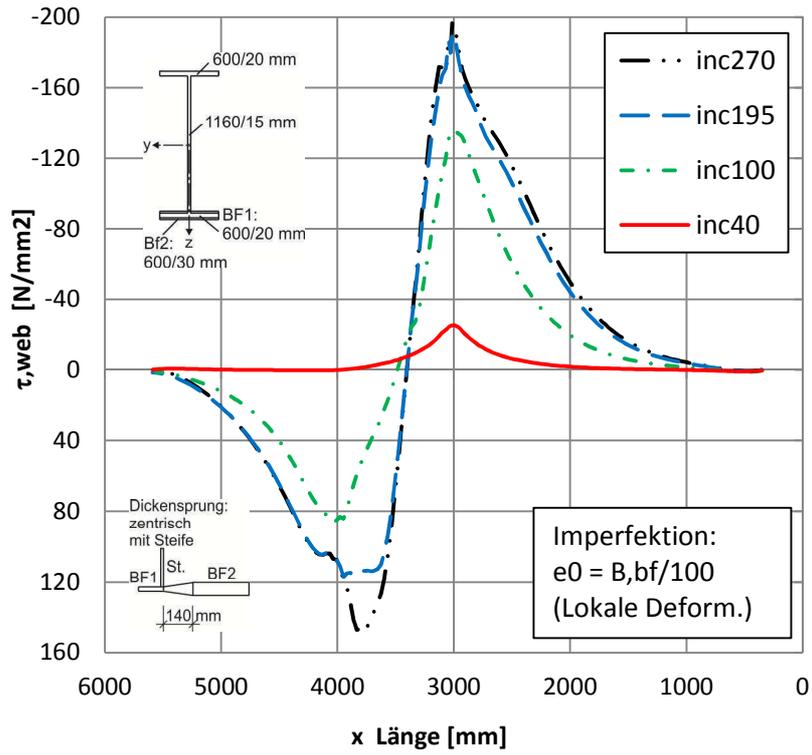


Abbildung 133: $h=1200\text{mm}$, Z , $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion, mit Steife

6.3.5. Träger mit Untergurtdickensprung unten bündig $t1/t2 = 3.0$ - „Fall 5“

➤ $H = 1200 \text{ mm}$, UB , $t1/t2 = 3.0$, $\alpha = 20$

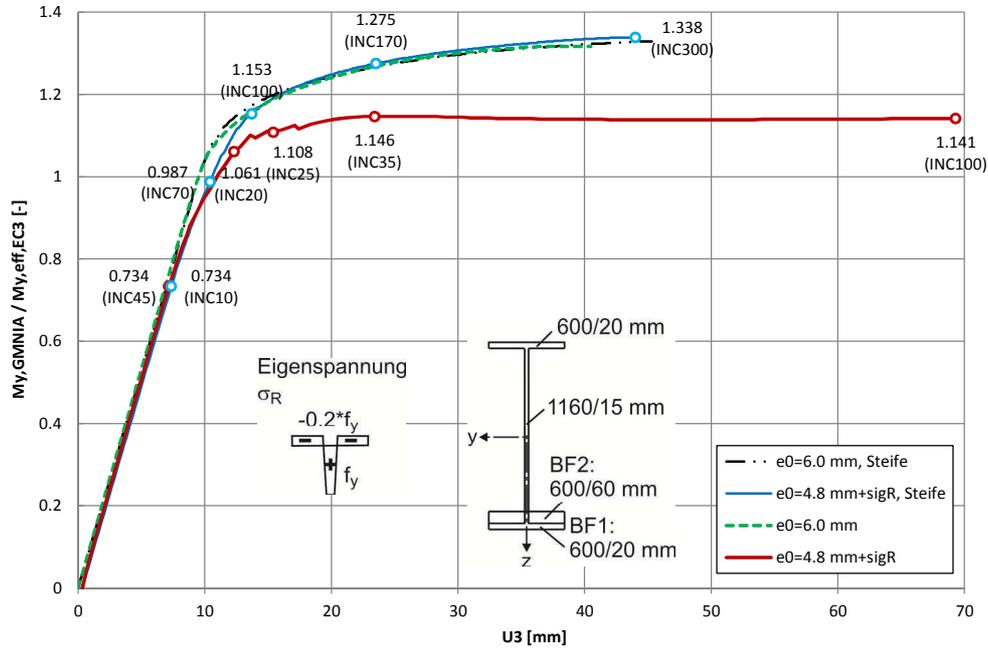


Abbildung 134: Lastverschiebungskurven, $h=1200$, UB , $t1/t2=3.0$, $\alpha=20$

| Case | My | My,GMNIA / | Nbf | Nbf,GMNIA / |
|--|---------|------------|----------|-------------|
| | [kNm] | My,eff,EC3 | | |
| | | [-] | [kN] | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma_R$ | 6174.00 | 1.146 | -3283.67 | 0.771 |
| H1200, $\alpha 20$, $t1/t2=3.0$, e_0^{100} | 6849.01 | 1.272 | -3758.18 | 0.882 |
| H1200, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma_R$, ST | 6867.01 | 1.275 | -3259.51 | 0.765 |
| H1200, $\alpha 20$, $t1/t2=3.0$, e_0^{100} , ST | 6858.01 | 1.273 | -3755.44 | 0.882 |

Tabelle 24: Vergleiche Träger $H = 1200 \text{ mm}$, UB , $t1/t2 = 3.0$, $\alpha = 20$

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$

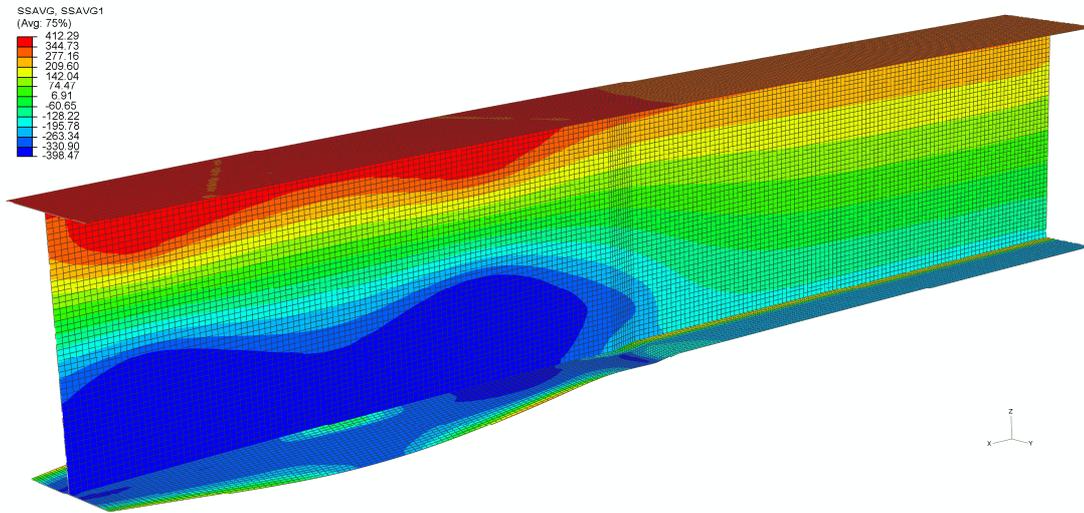


Abbildung 135: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , INC 100

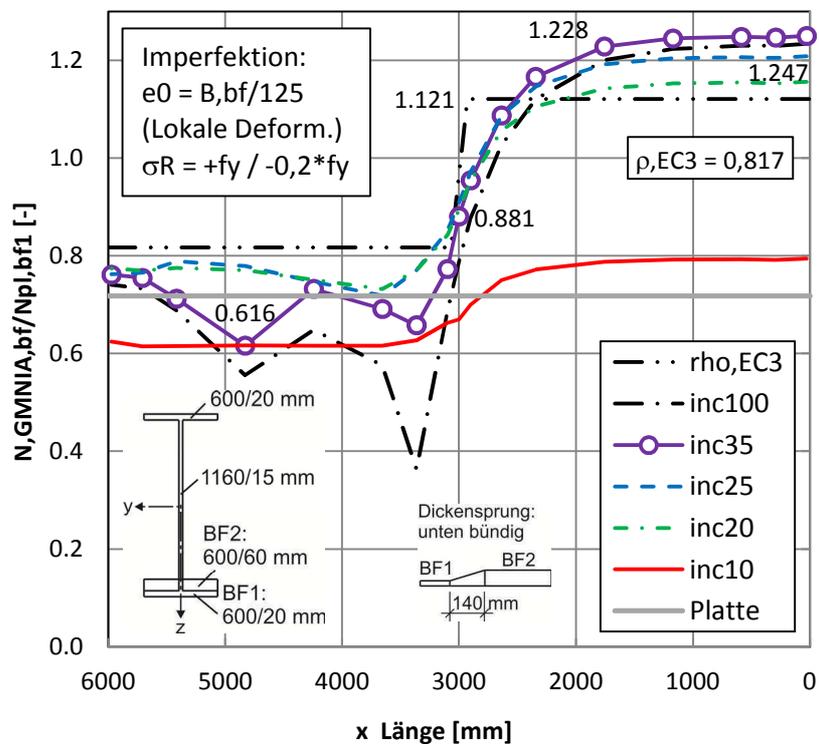


Abbildung 136: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen

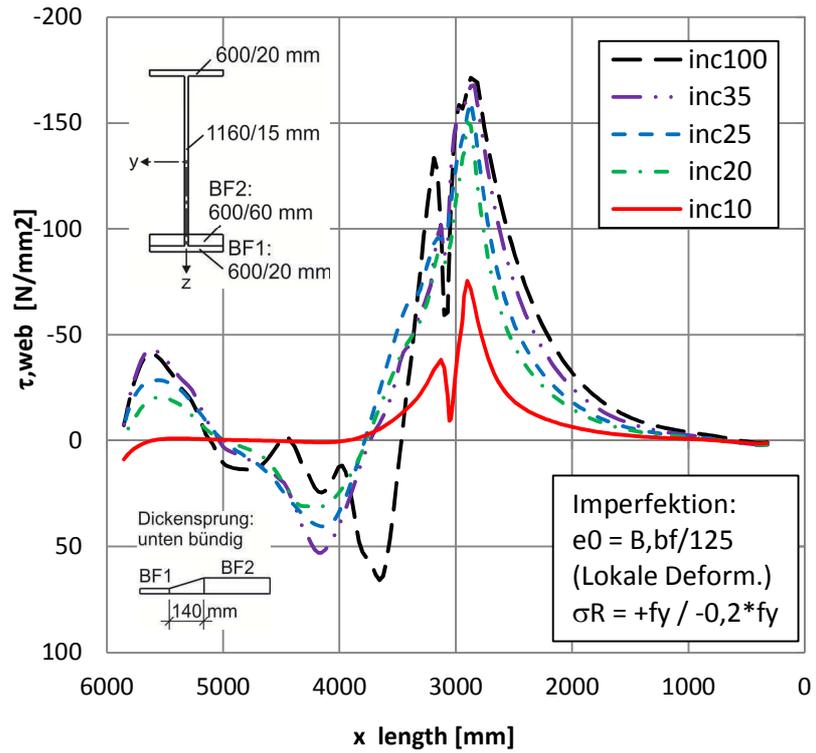


Abbildung 137: $h=1200\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, e_0

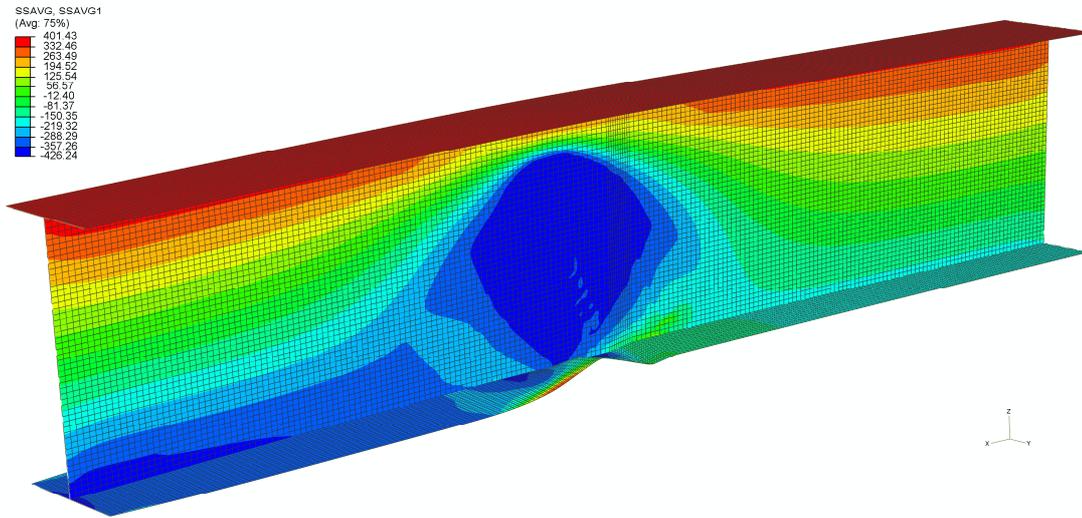


Abbildung 138: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/100$, INC 270

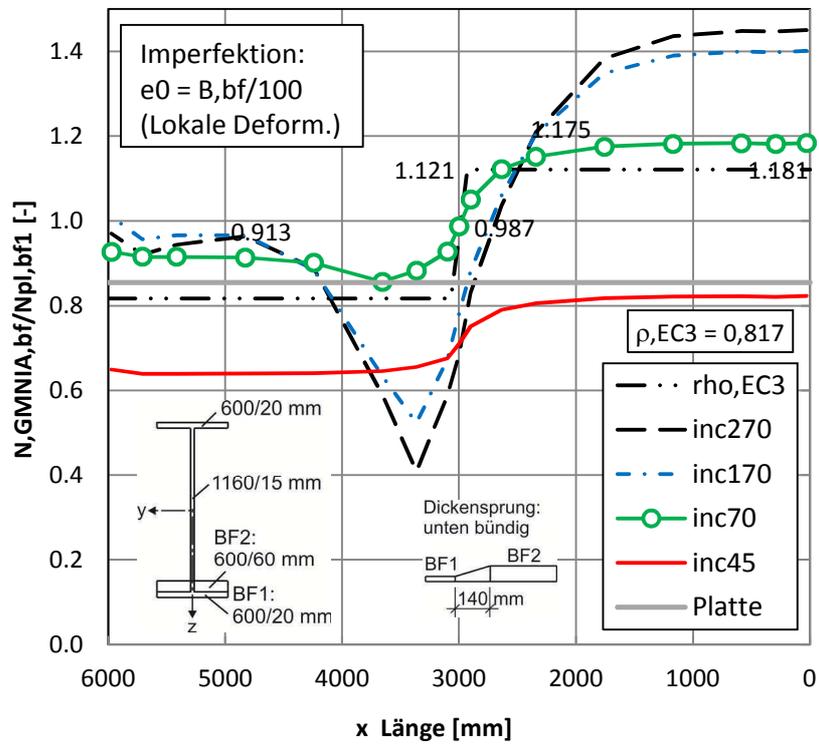


Abbildung 139: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion

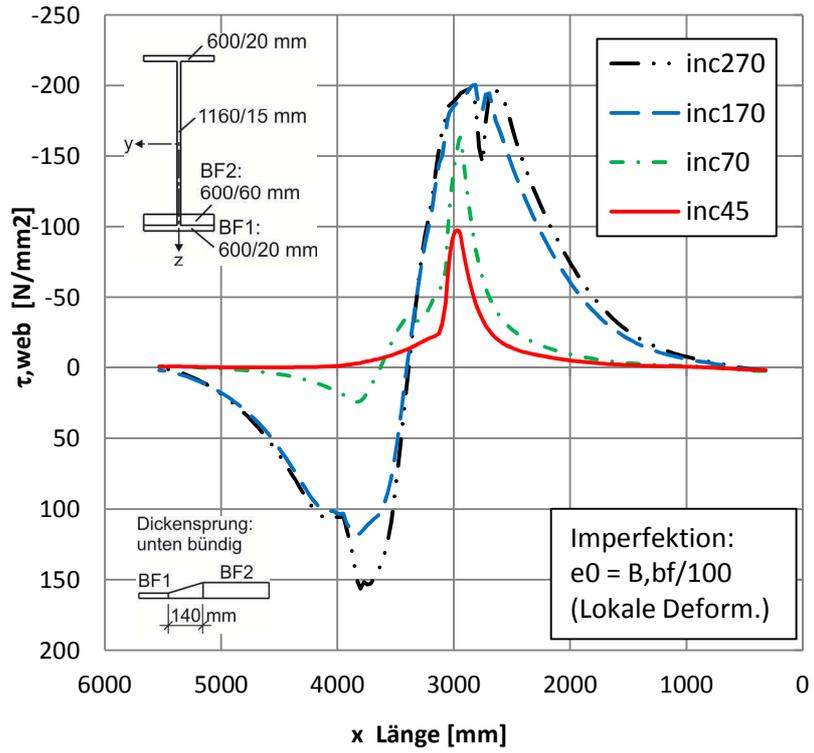


Abbildung 140: $h=1200\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$, Steife

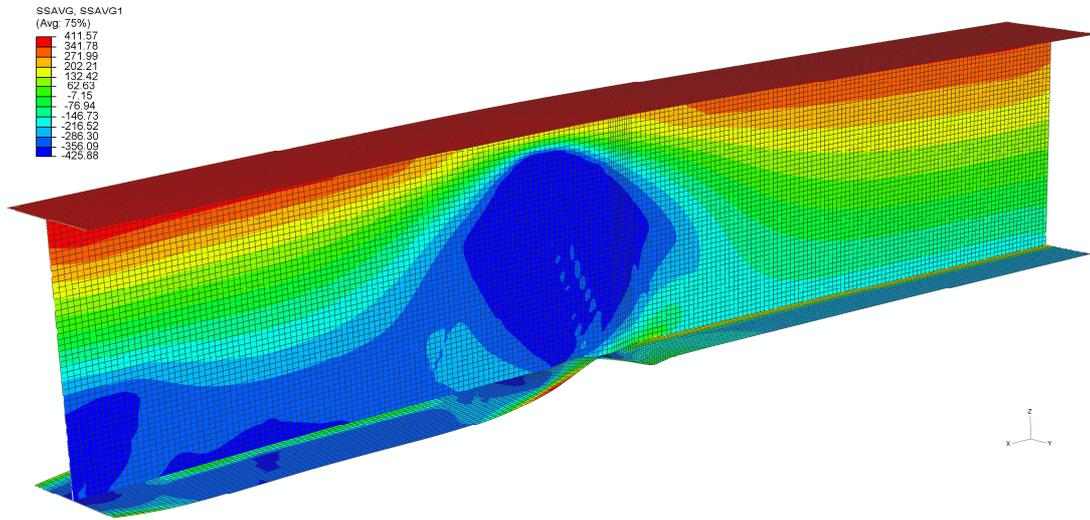


Abbildung 141: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , ST, INC 300

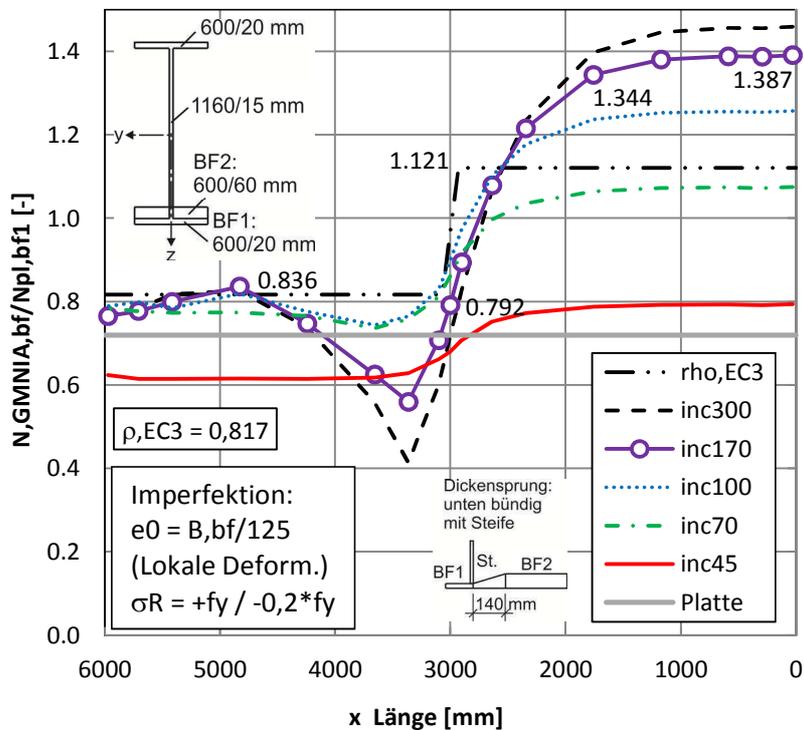


Abbildung 142: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtrkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife

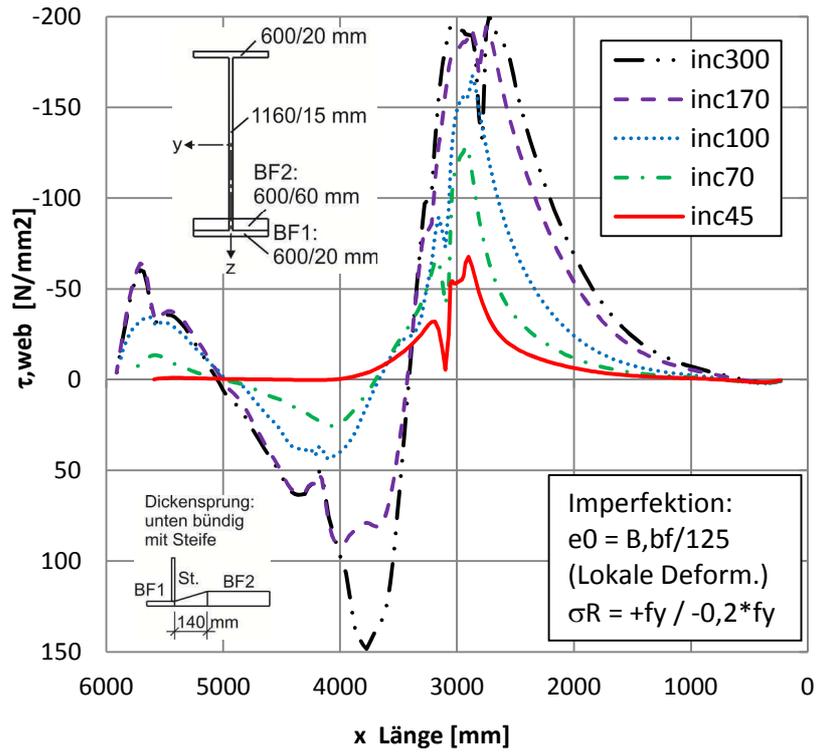


Abbildung 143: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen, mit Steife

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, e_0 , Steife

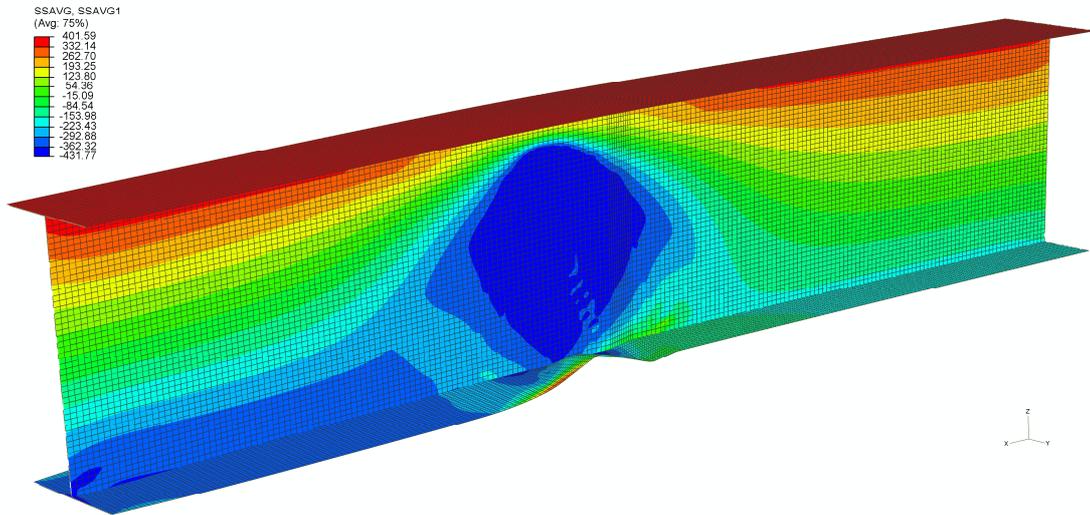


Abbildung 144: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/100$, ST, INC 270

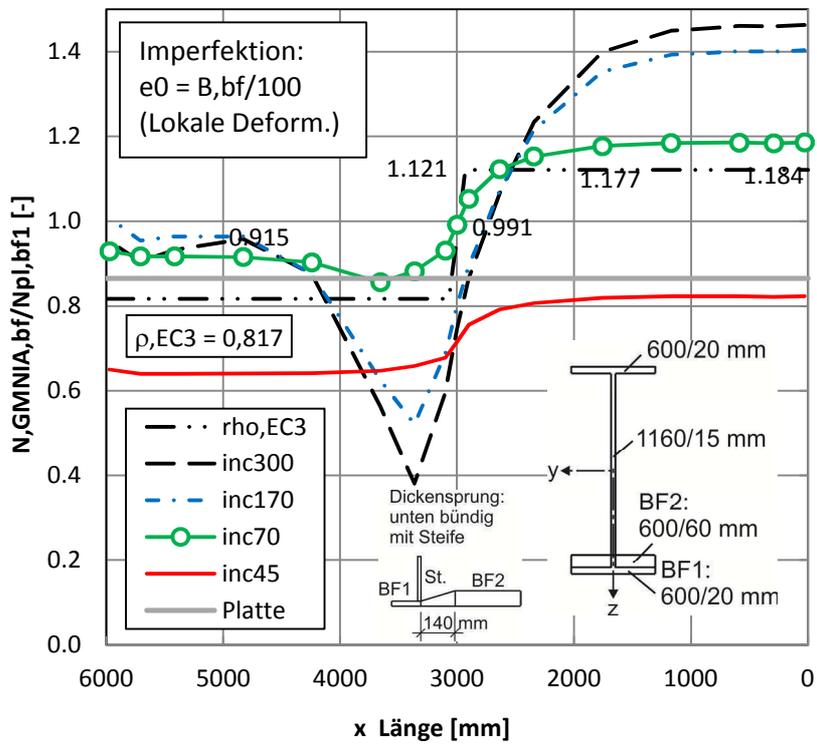


Abbildung 145: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion, mit Steife

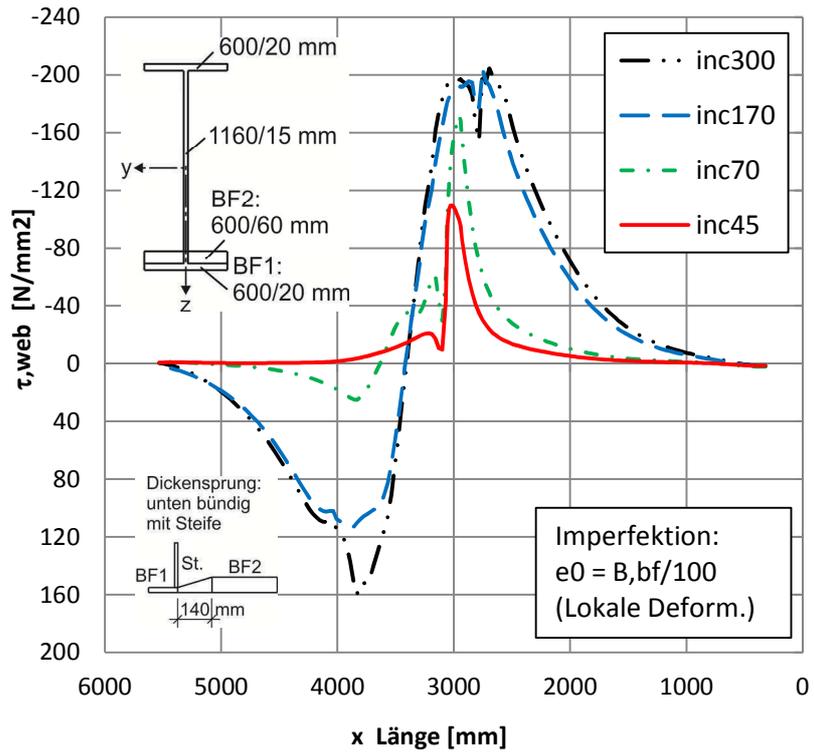


Abbildung 146: $h=1200mm$, UB, $t1/t2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion, mit Steife

➤ $H = 1200 \text{ mm}$, UB , $t_1/t_2 = 3.0$, $\alpha = 10$

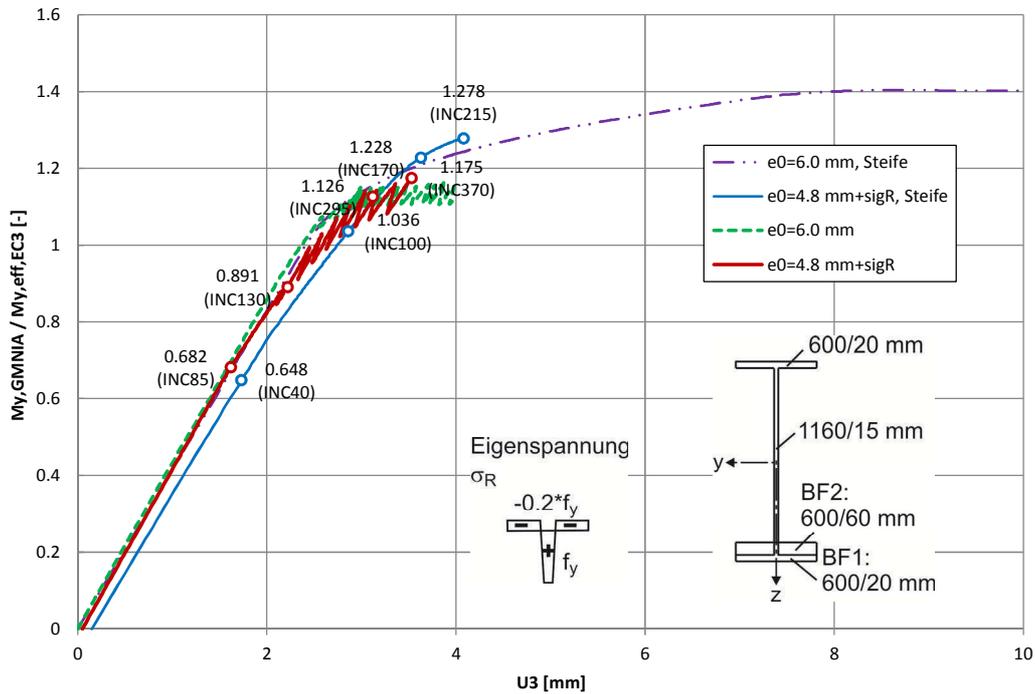


Abbildung 147: Lastverschiebungskurven, $h=1200$, UB , $t_1/t_2=3.0$, $\alpha=10$

| Case | My | My,GMNIA / | Nbf | Nbf,GMNIA / |
|--|---------|------------|----------|-------------|
| | [kNm] | My,eff,EC3 | | |
| | | [-] | | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.04 | 0.817 |
| H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125} + \sigma R$ | 6327.00 | 1.175 | -3627.62 | 0.852 |
| H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} | 6066.00 | 1.126 | -3886.32 | 0.912 |
| H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125} + \sigma R$, ST | 6885.01 | 1.278 | -3376.05 | 0.792 |
| H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} , ST | 7560.01 | 1.404 | -3846.32 | 0.903 |

Tabelle 25: Vergleiche Träger $H = 1200 \text{ mm}$, UB , $t_1/t_2 = 3.0$, $\alpha = 10$

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 10$, $e_0 + \sigma_R$

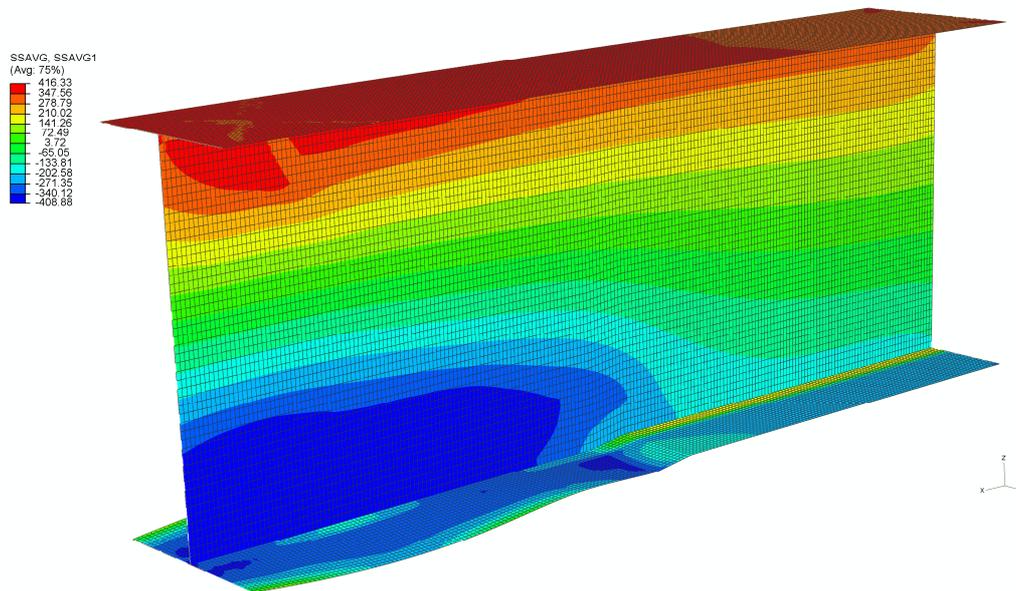


Abbildung 148: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=10$, $B/125$, σ_R , INC 370

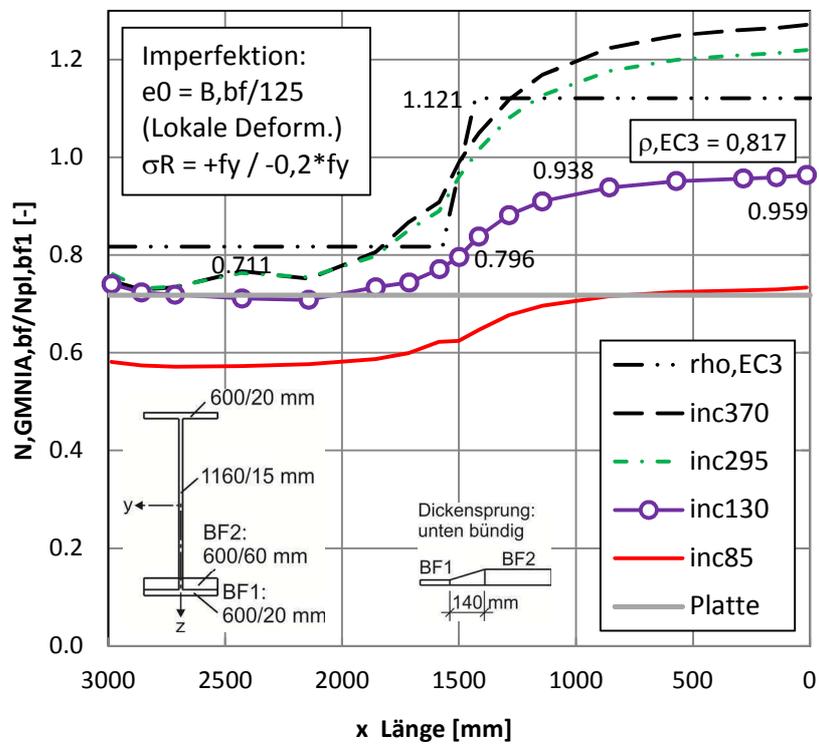


Abbildung 149: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=10$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen

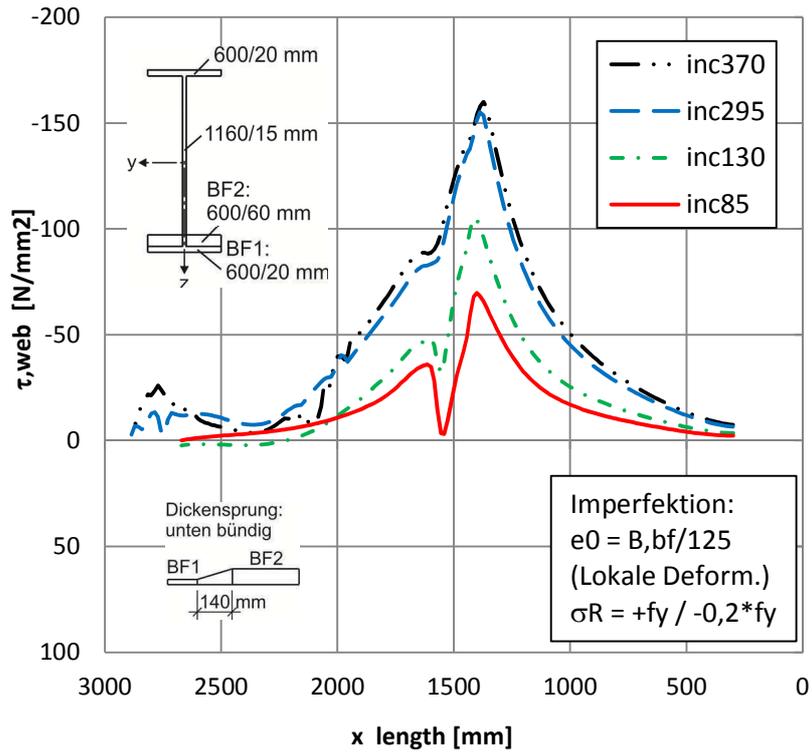


Abbildung 150: $h=1200\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=10$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 10$, e_0

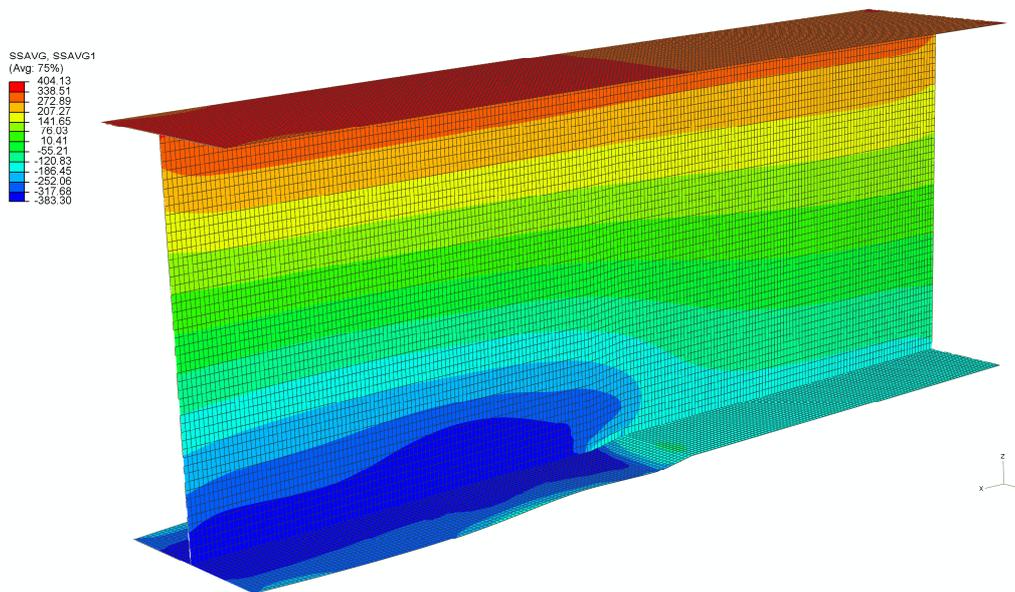


Abbildung 151: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=10$, $B/100$, INC 210

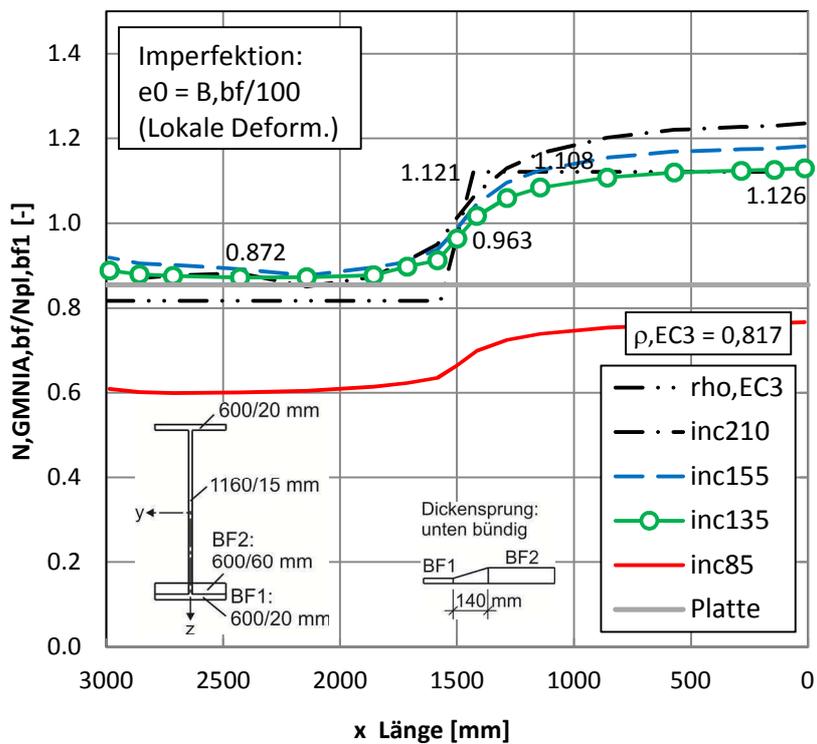


Abbildung 152: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=10$, Untergurtkräfte mit geom. Imperfektion

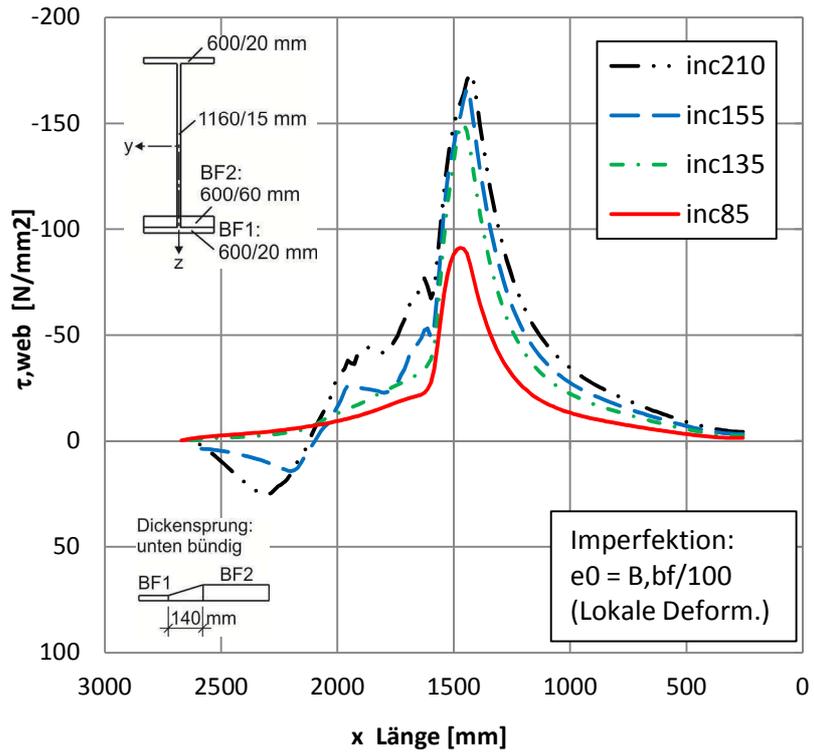


Abbildung 153: $h=1200\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=10$, Schubspannungen mit geom. Imperfektion

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 10$, $e_0 + \sigma_R$, Steife

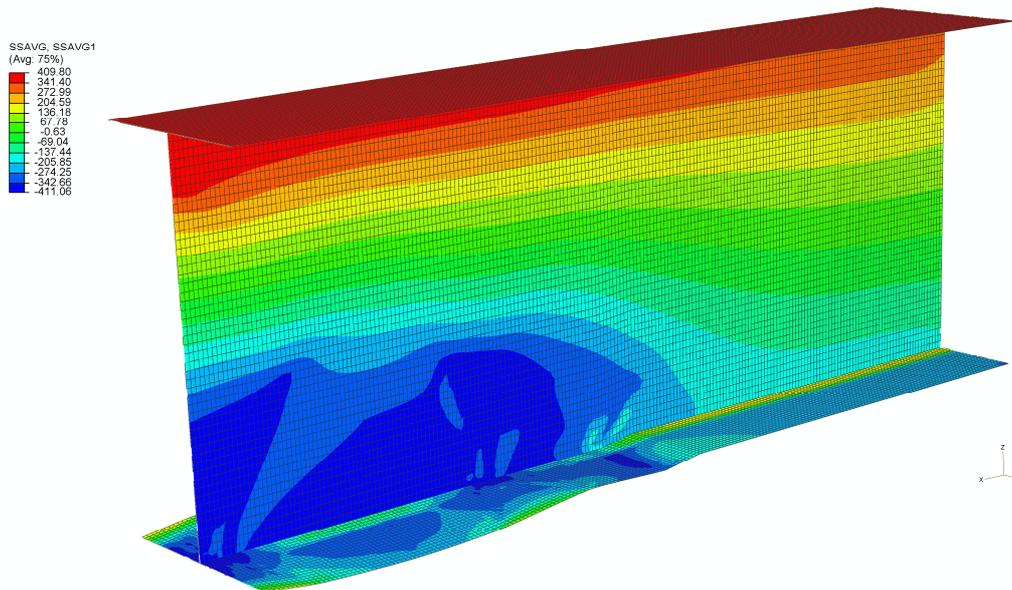


Abbildung 154: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=10$, $B/125$, σ_R , ST, INC 215

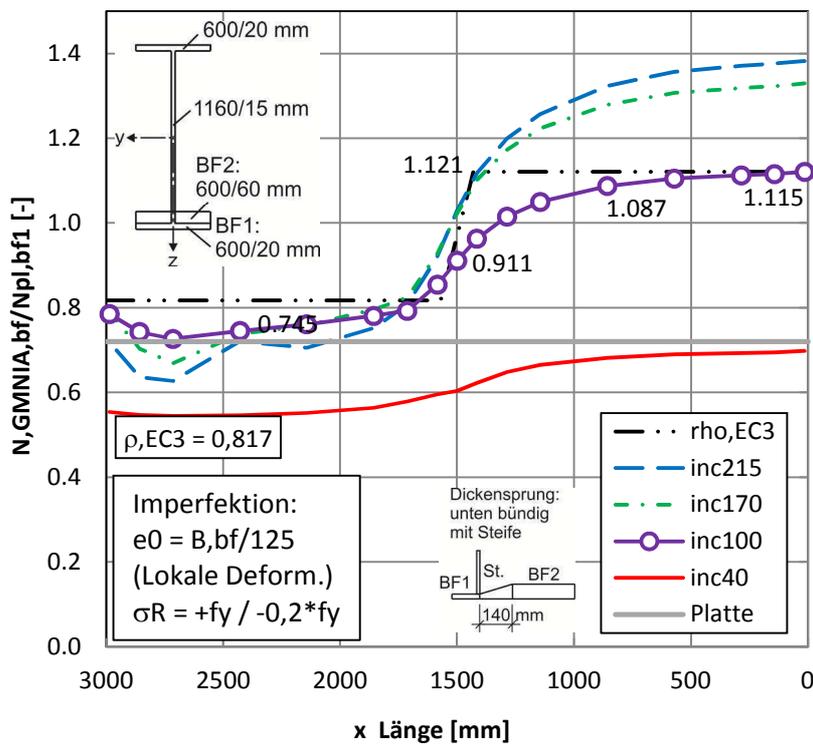


Abbildung 155: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=10$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife

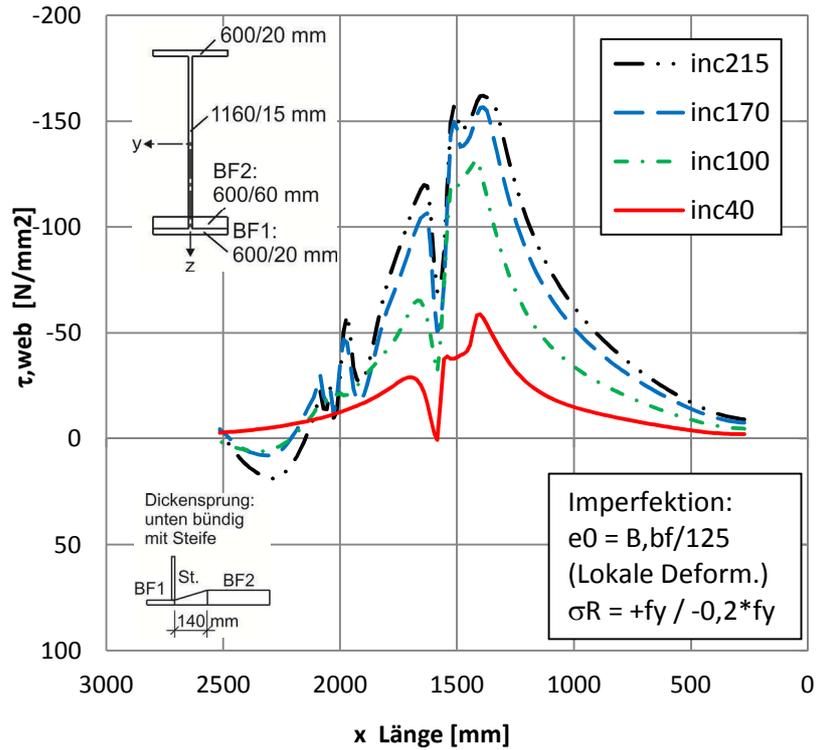


Abbildung 156: $h=1200$ mm, UB, $t_1/t_2=3.0$, $\alpha=10$, Schubspannungen mit geom. Imperfektion und Eigenspannungen, mit Steife

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 10$, e_0 , Steife

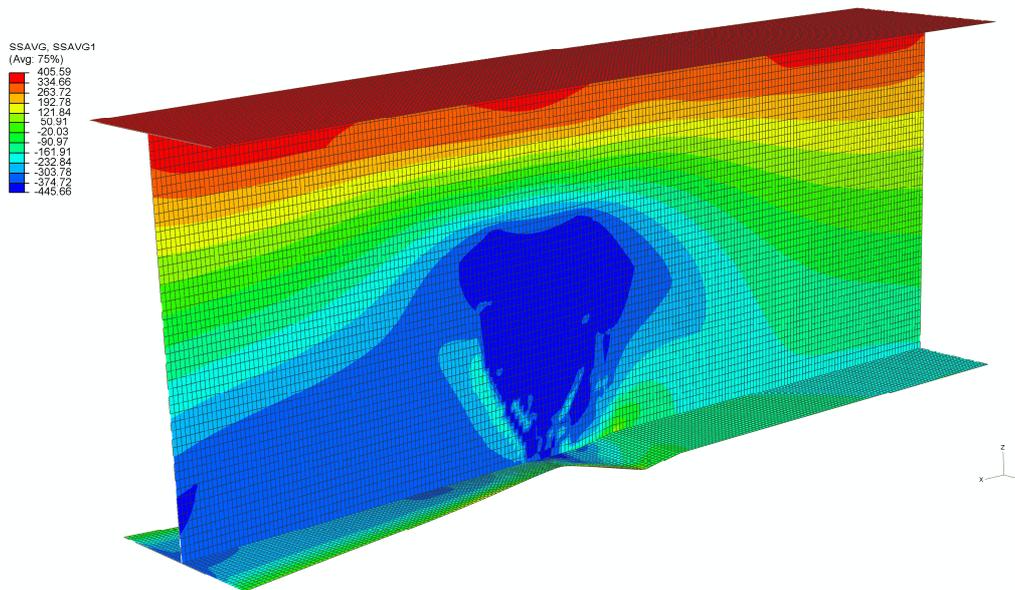


Abbildung 157: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=10$, B/100, ST, INC 445

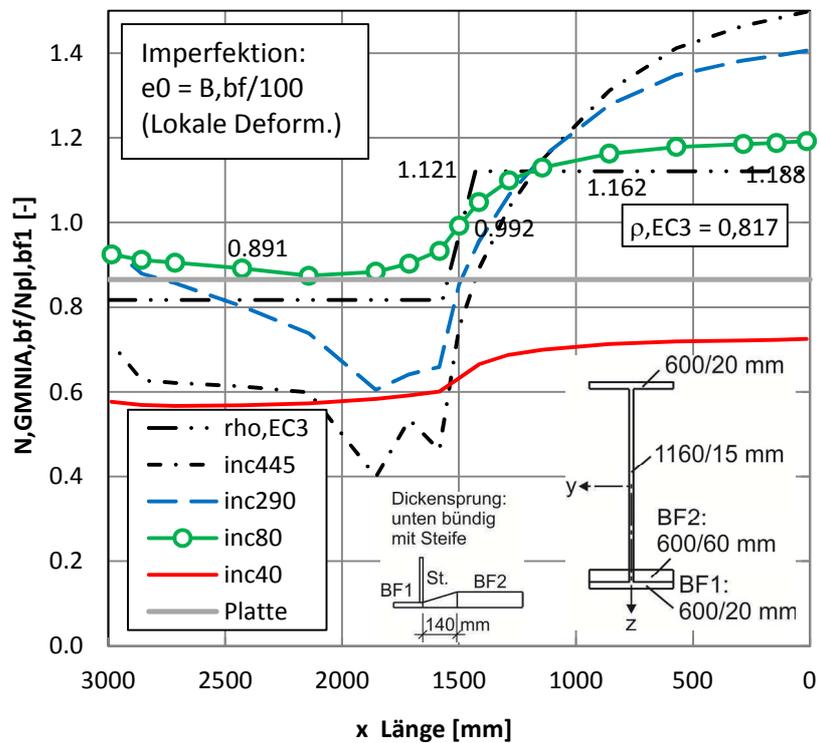


Abbildung 158: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=10$, Untergurtkräfte mit geom. Imperfektion, mit Steife

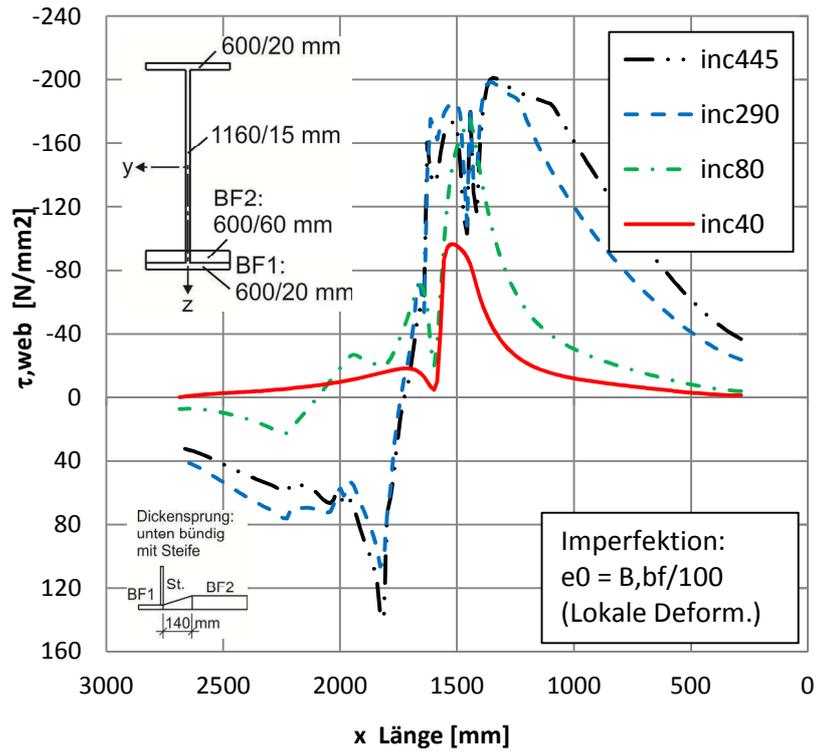


Abbildung 159: $h=1200mm$, UB, $t1/t2=3.0$, $\alpha=10$, Schubspannungen mit geom. Imperfektion, mit Steife

6.3.6. Träger mit Untergurtdickensprung oben bündig $t1/t2 = 3.0$ - „Fall 6“

➤ $H = 1200 \text{ mm}$, OB , $t1/t2 = 3.0$, $\alpha = 20$

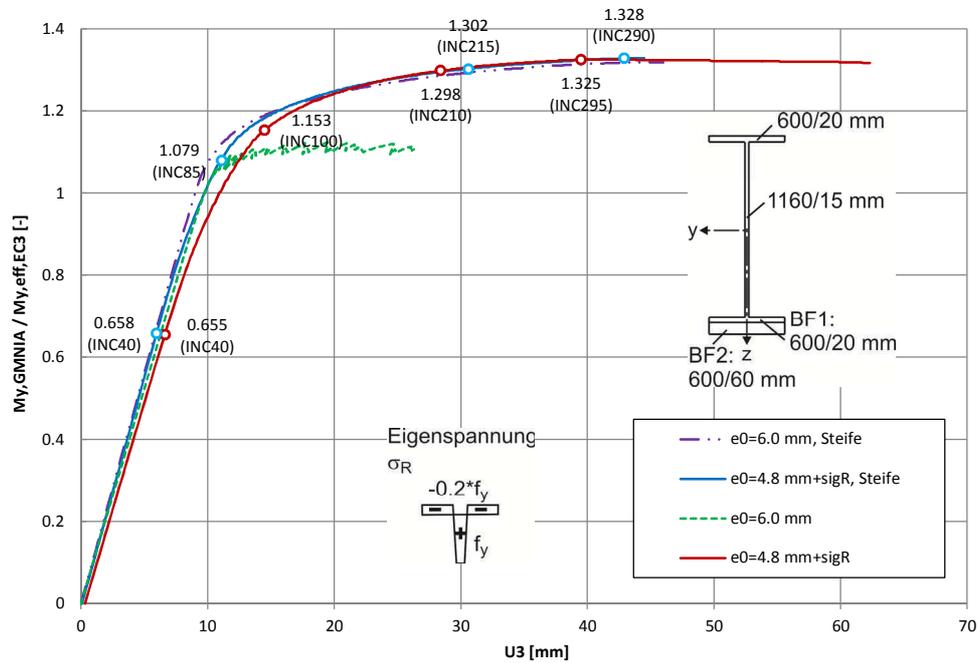


Abbildung 160: Lastverschiebungskurven, $h=1200$, OB , $t1/t2=3.0$, $\alpha=20$

| Case | My | My,GMNIA / | Nbf | Nbf,GMNIA / |
|--|---------|------------|----------|-------------|
| | [kNm] | My,eff,EC3 | | |
| | | [-] | [kN] | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma R$ | 6993.01 | 1.298 | -3314.61 | 0.778 |
| H1200, $\alpha 20$, $t1/t2=3.0$, e_0^{100} | 6030.00 | 1.119 | -3717.89 | 0.873 |
| H1200, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma R$, ST | 7011.01 | 1.302 | -3350.54 | 0.787 |
| H1200, $\alpha 20$, $t1/t2=3.0$, e_0^{100} , ST | 6993.01 | 1.298 | -3463.57 | 0.813 |

Tabelle 26: Vergleiche Träger $H = 1200 \text{ mm}$, OB , $t1/t2 = 3.0$, $\alpha = 20$

➤ $H = 1200 \text{ mm}$, OB , $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$

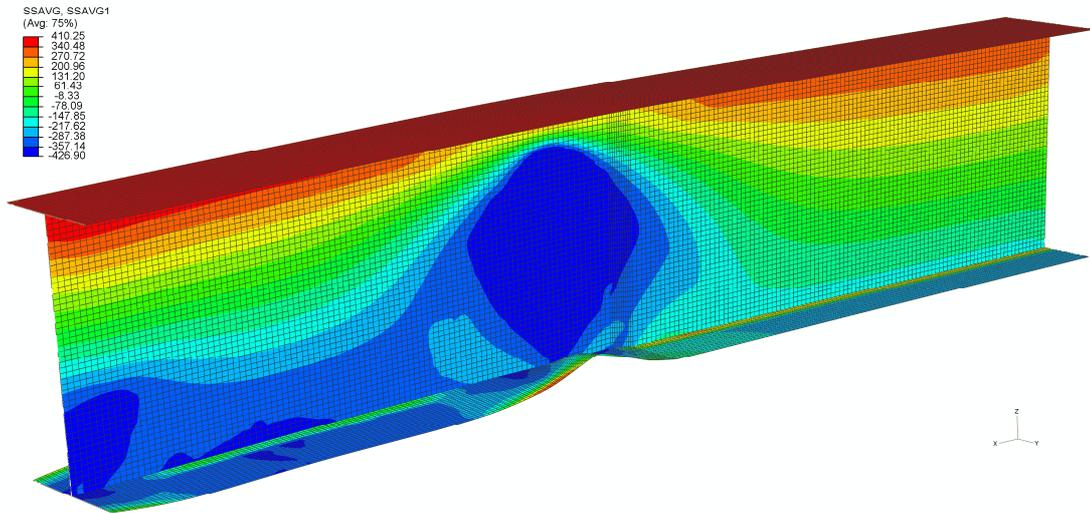


Abbildung 161: $h=1200\text{mm}$, OB , $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , $INC 295$

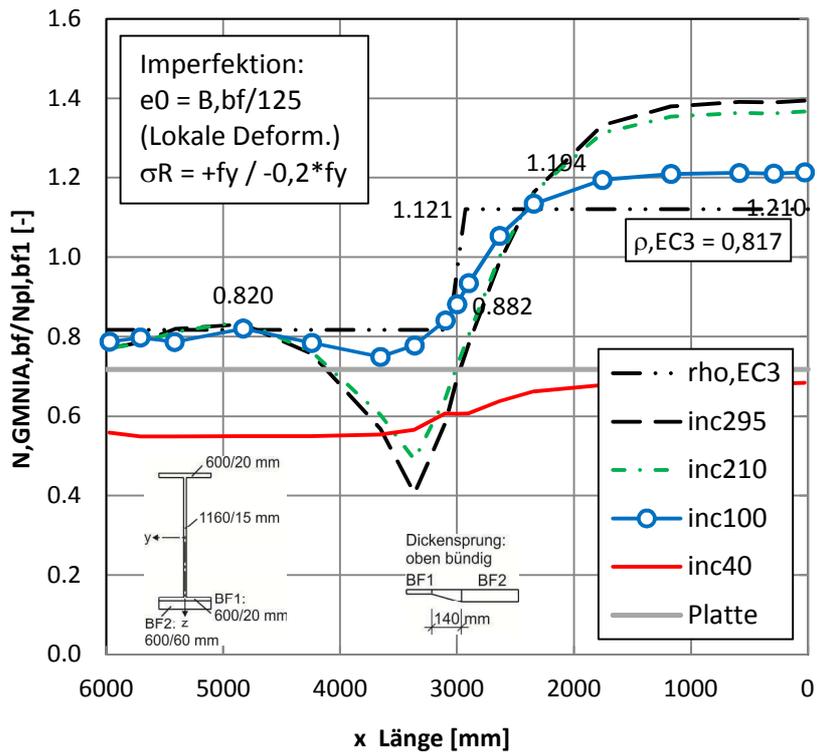


Abbildung 162: $h=1200\text{mm}$, OB , $t1/t2=3.0$, $\alpha=20$, Untergurtr fte mit geom. Imperfektion und Eigenspannungen

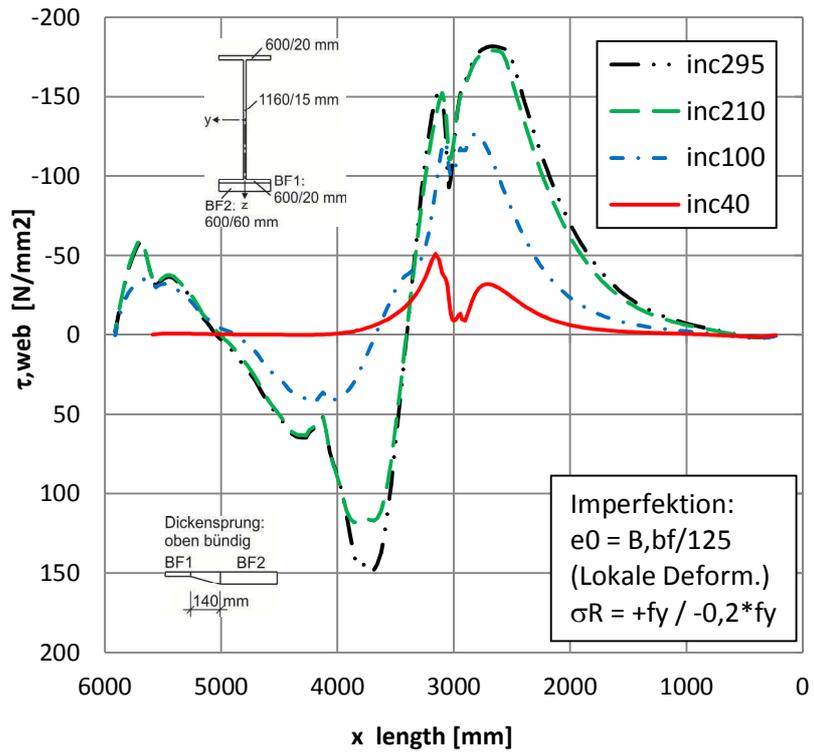


Abbildung 163: $h=1200\text{mm}$, OB, $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 1200 \text{ mm}$, OB , $t1/t2 = 3.0$, $\alpha = 20$, e_0

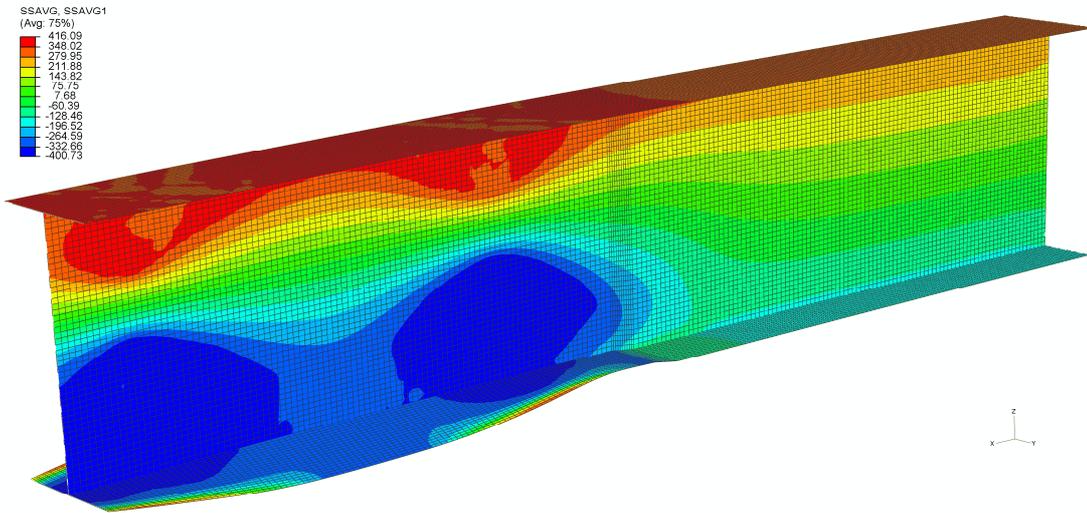


Abbildung 164: $h=1200\text{mm}$, OB , $t1/t2=3.0$, $\alpha=20$, $B/100$, $INC 245$

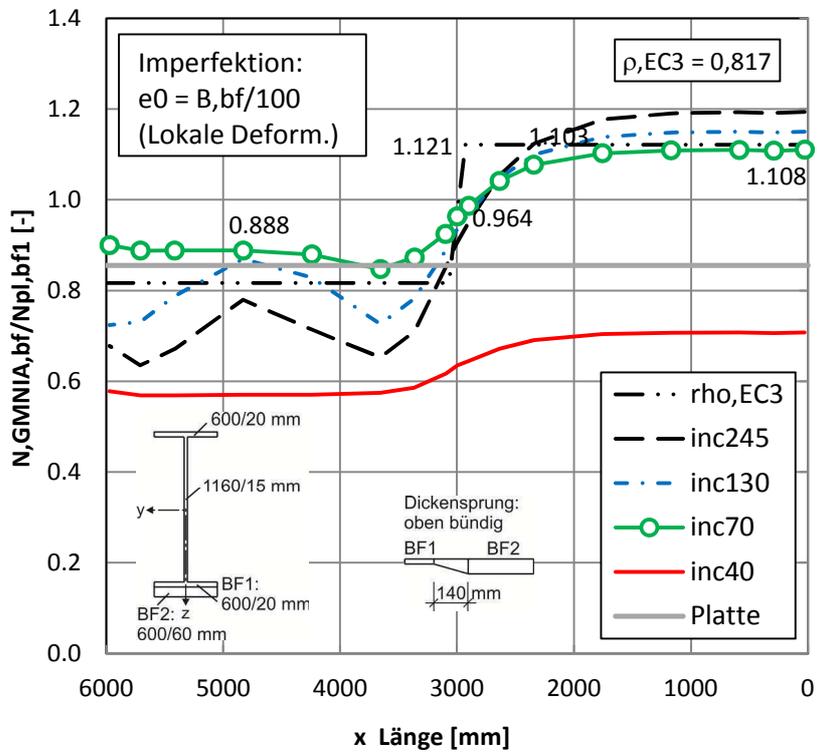


Abbildung 165: $h=1200\text{mm}$, OB , $t1/t2=3.0$, $\alpha=20$, Untergurkräfte mit geom. Imperfektion

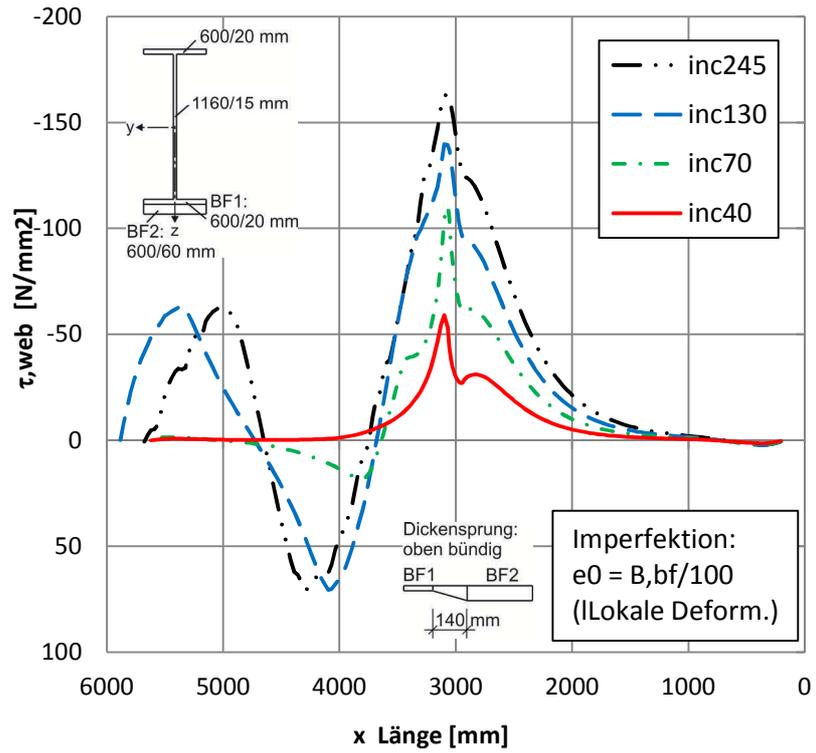


Abbildung 166: $h=1200\text{mm}$, OB , $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion

➤ $H = 1200 \text{ mm}$, OB , $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$, *Steife*

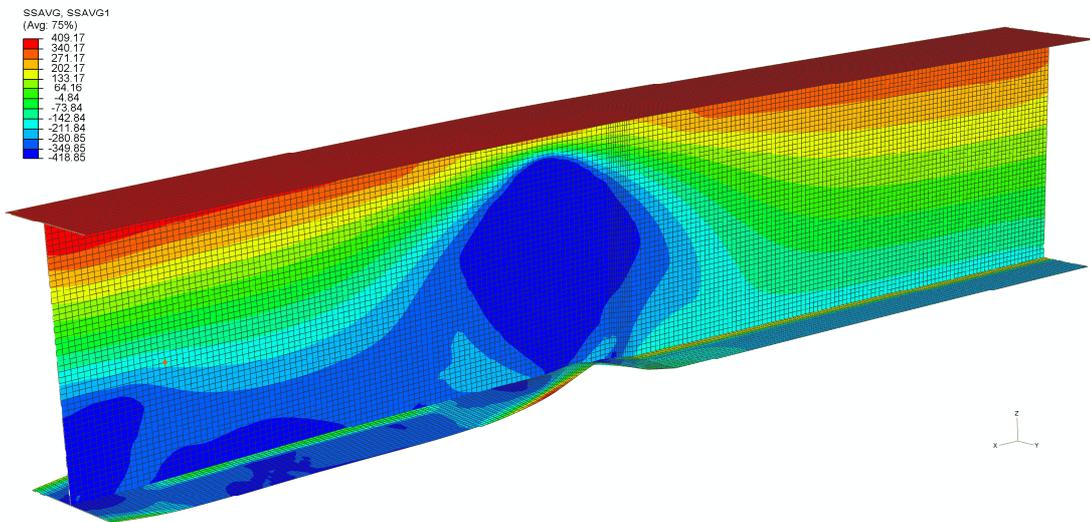


Abbildung 167: $h=1200\text{mm}$, OB , $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , ST , $INC 290$

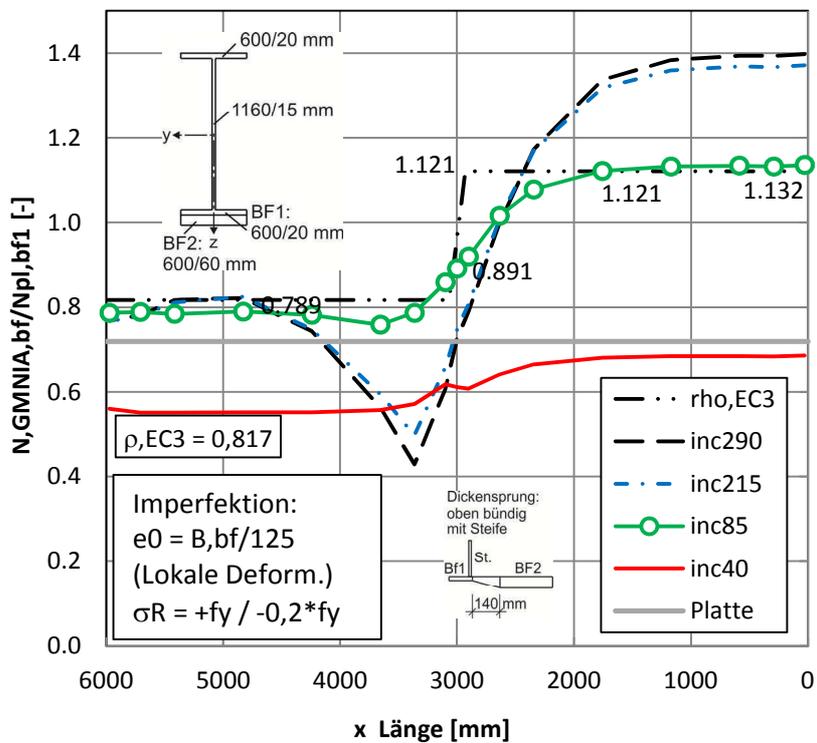


Abbildung 168: $h=1200\text{mm}$, OB , $t1/t2=3.0$, $\alpha=20$, *Untergurtkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife*

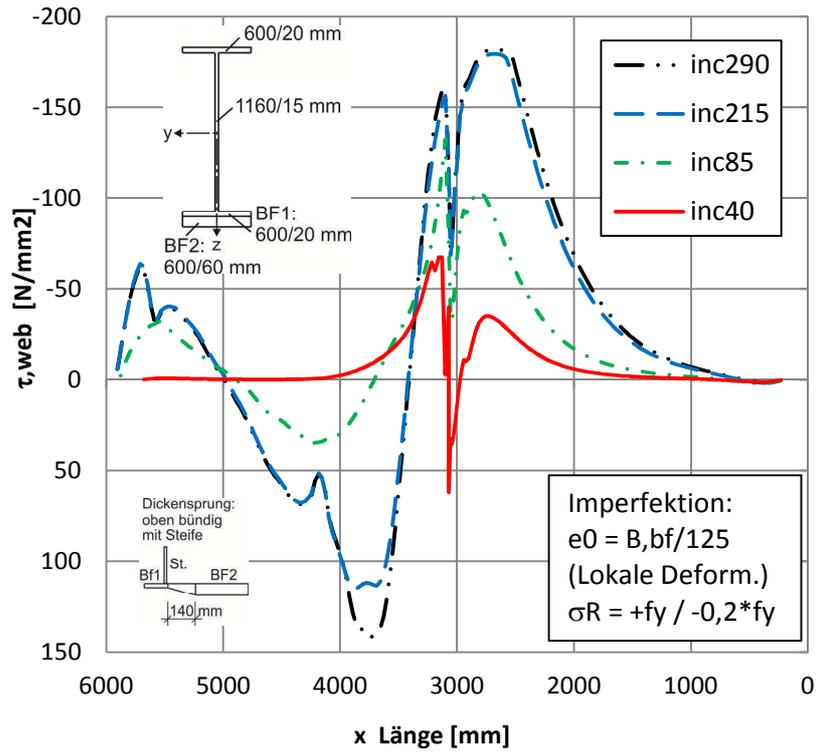


Abbildung 169: $h=1200\text{mm}$, OB, $t_1/t_2=3,0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen, mit Steife

➤ $H = 1200 \text{ mm}$, OB , $t1/t2 = 3.0$, $\alpha = 20$, e_0 , *Steife*

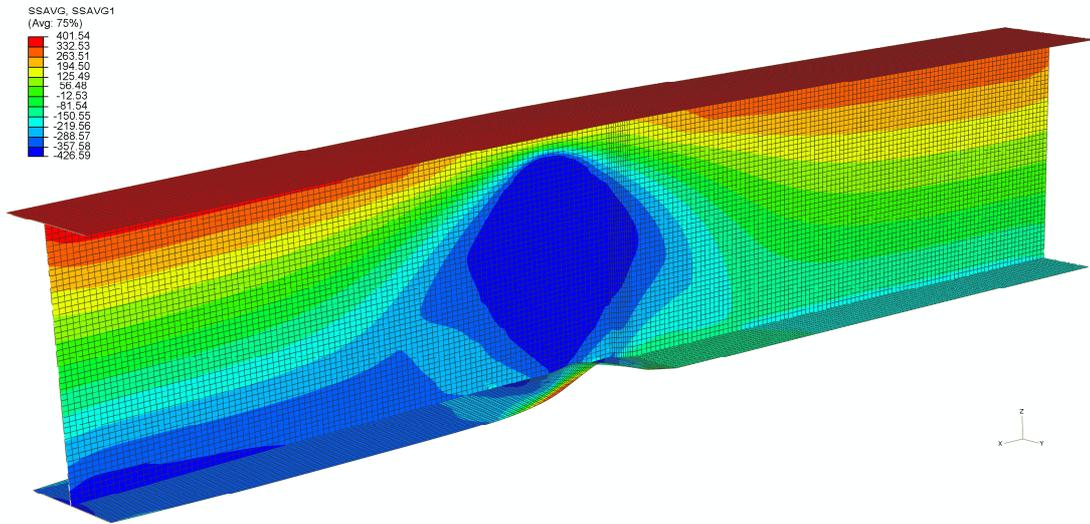


Abbildung 170: $h=1200\text{mm}$, OB , $t1/t2=3.0$, $\alpha=20$, $B/100$, ST , $INC 290$

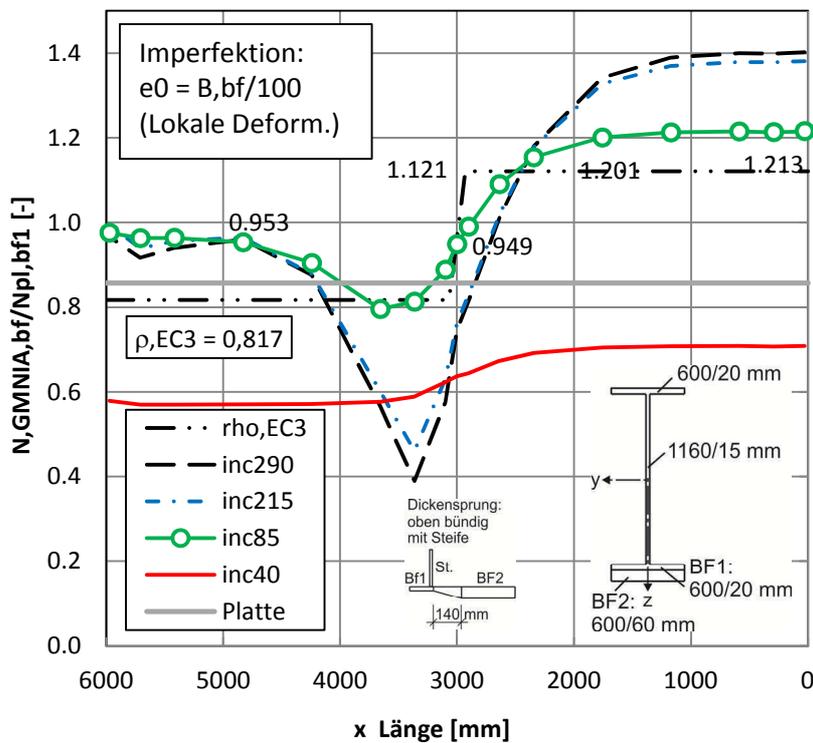


Abbildung 171: $h=1200\text{mm}$, OB , $t1/t2=3.0$, $\alpha=20$, *Untergurtkräfte mit geom. Imperfektion, mit Steife*

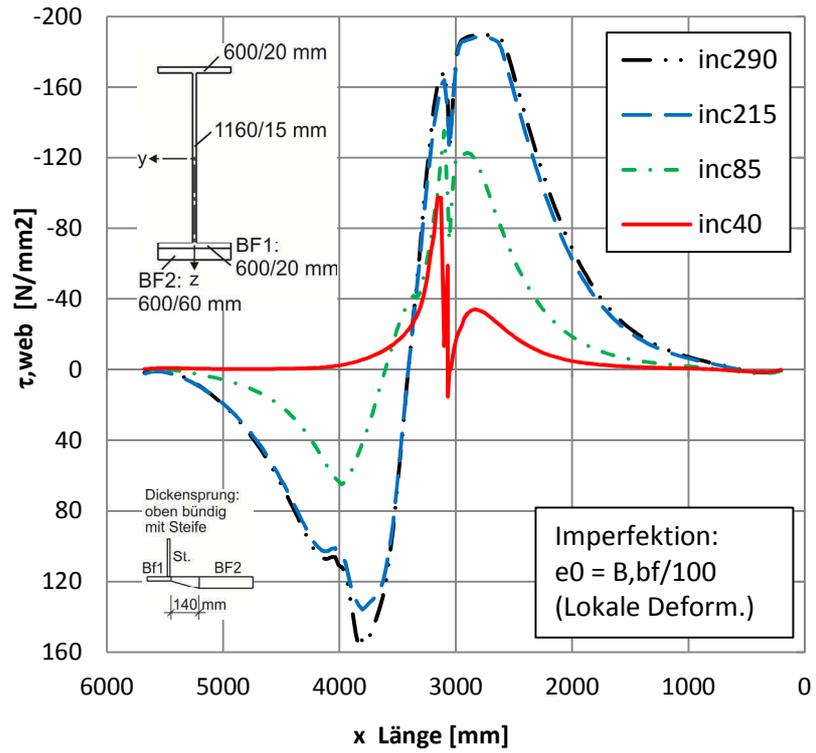


Abbildung 172: $h=1200\text{mm}$, OB, $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion, mit Steife

6.3.7. Träger mit Untergurtdickensprung zentrisch $t1/t2 = 3.0$ - „Fall 7“

➤ $H = 1200 \text{ mm}$, Z , $t1/t2 = 3.0$, $\alpha = 20$

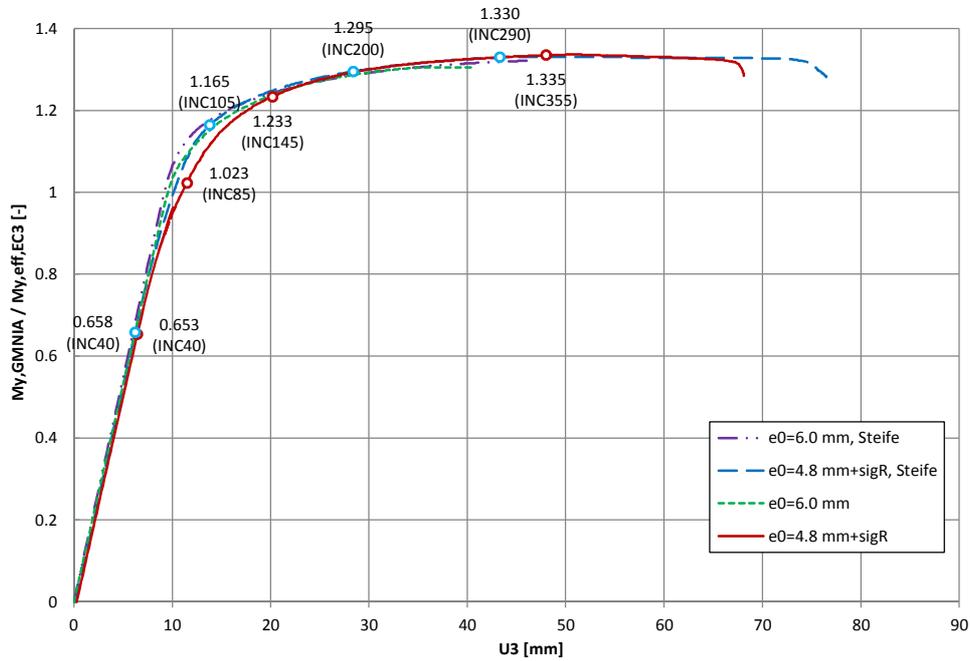


Abbildung 173: Lastverschiebungskurven, $h=1200$, Z , $t1/t2=3.0$, $\alpha=20$

| Case | My | My,GMNIA / | Nbf | Nbf,GMNIA / |
|--|---------|------------|----------|-------------|
| | [kNm] | My,eff,EC3 | | |
| | | [-] | [kN] | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma R$ | 7191.01 | 1.335 | -3260.56 | 0.765 |
| H1200, $\alpha 20$, $t1/t2=3.0$, e_0^{100} | 7029.01 | 1.305 | -3646.76 | 0.856 |
| H1200, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma R$, ST | 7164.01 | 1.330 | -3206.14 | 0.753 |
| H1200, $\alpha 20$, $t1/t2=3.0$, e_0^{100} , ST | 7119.01 | 1.322 | -3467.04 | 0.814 |

Tabelle 27: Vergleiche Träger $H = 1200 \text{ mm}$, Z , $t1/t2 = 3.0$, $\alpha = 20$

➤ $H = 1200 \text{ mm}$, Z , $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$

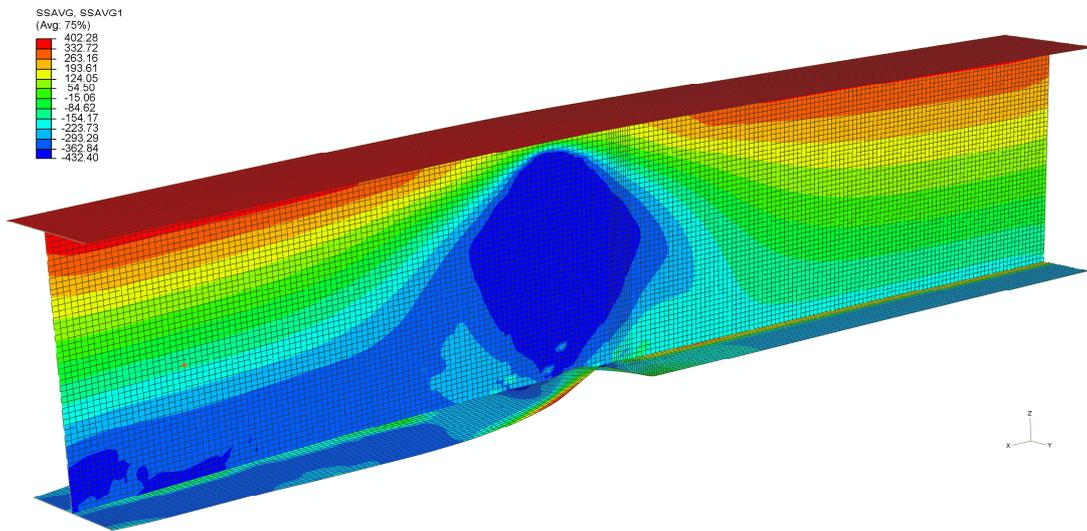


Abbildung 174: $h=1200\text{mm}$, Z , $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , INC 355

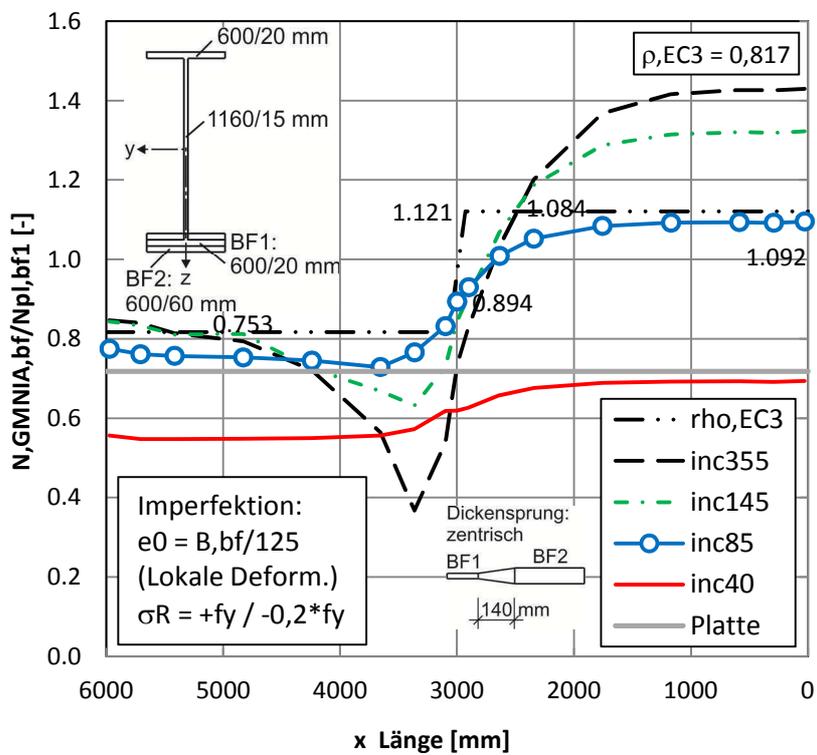


Abbildung 175: $h=1200\text{mm}$, Z , $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen

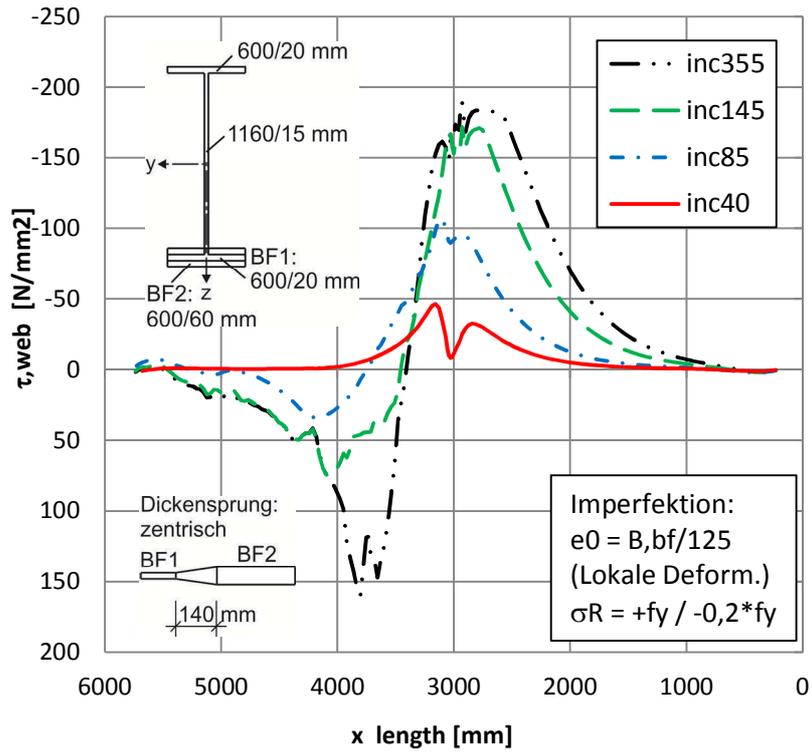


Abbildung 176: $h=1200\text{mm}$, Z, $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 1200 \text{ mm}$, Z , $t1/t2 = 3.0$, $\alpha = 20$, e_0

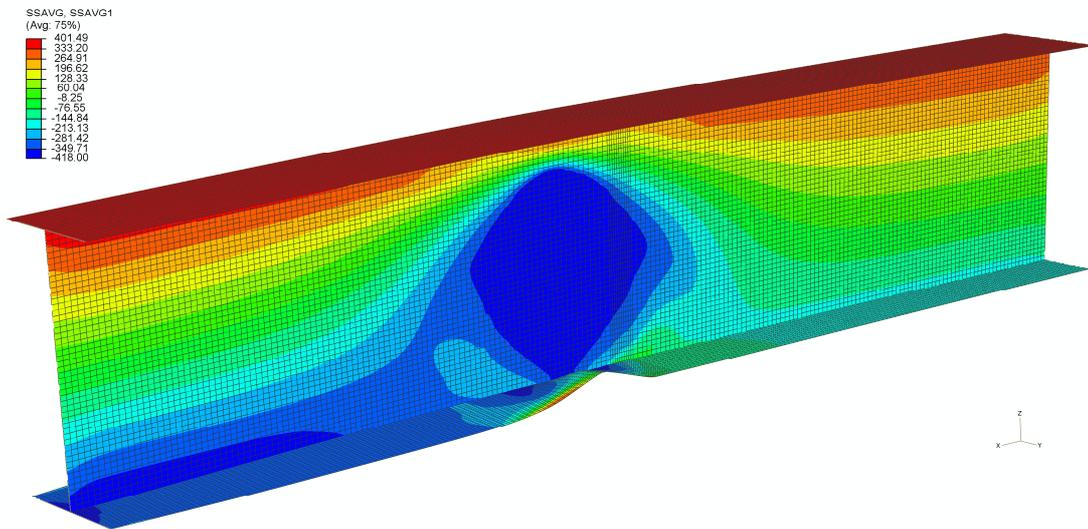


Abbildung 177: $h=1200\text{mm}$, Z , $t1/t2=3.0$, $\alpha=20$, $B/100$, INC 260

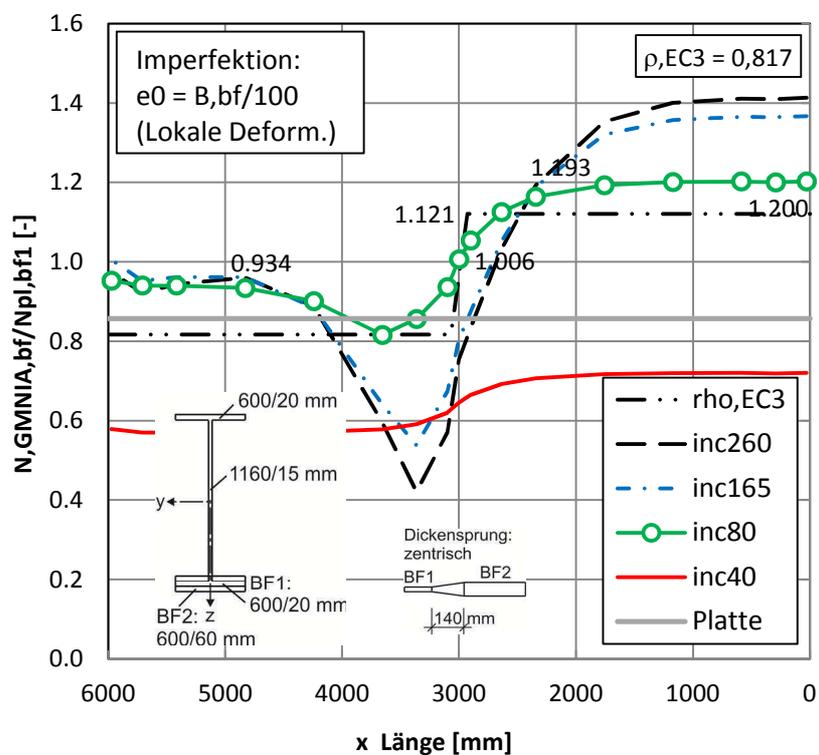


Abbildung 178: $h=1200\text{mm}$, Z , $t1/t2=3.0$, $\alpha=20$, Untergurkräfte mit geom. Imperfektion

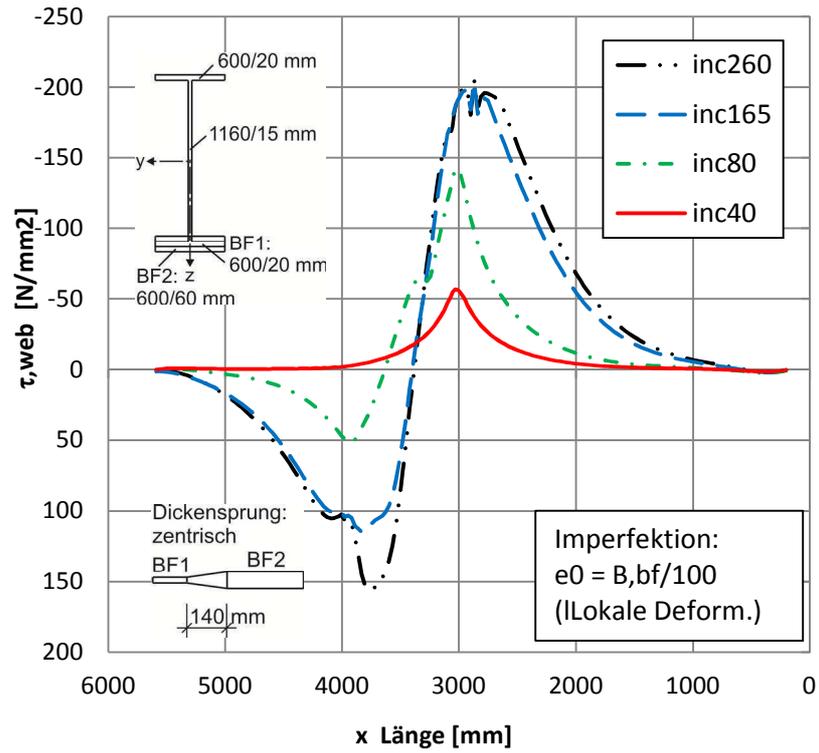


Abbildung 179: $h=1200\text{mm}$, Z , $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion

➤ $H = 1200 \text{ mm}$, Z , $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$, Steife

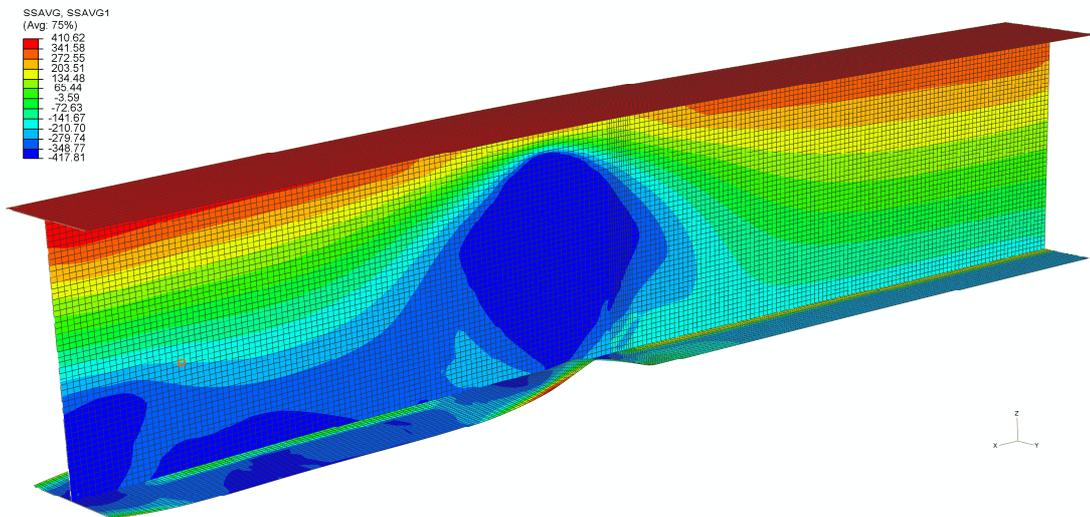


Abbildung 180: $h=1200\text{mm}$, Z , $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , ST , $INC 290$

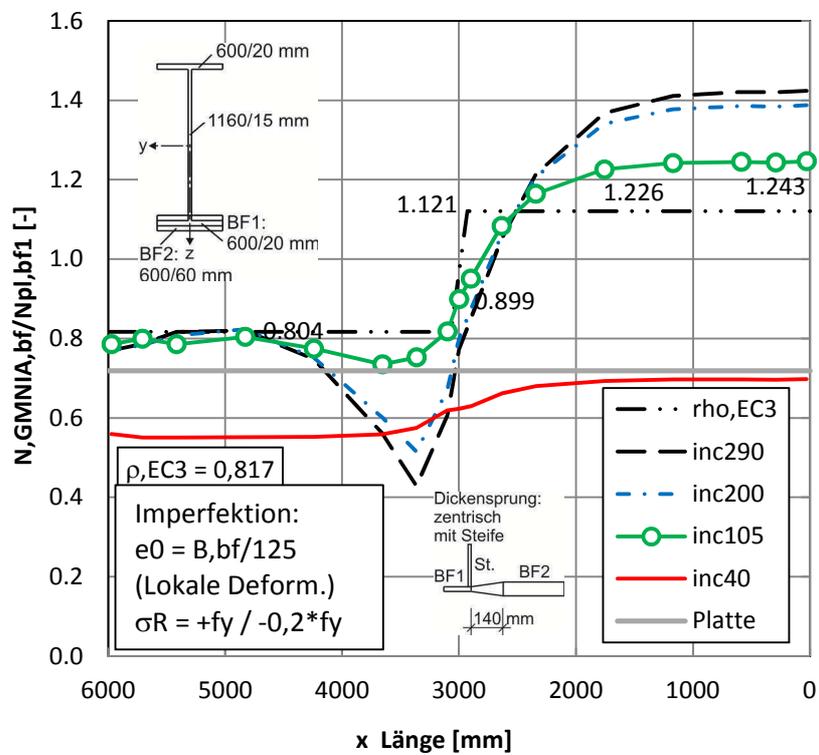


Abbildung 181: $h=1200\text{mm}$, Z , $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife

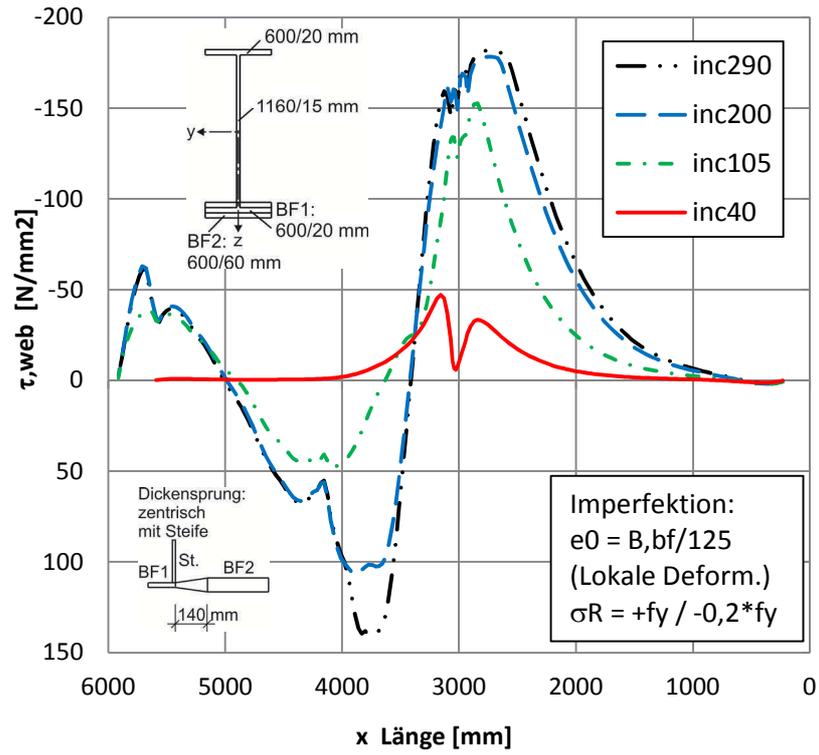


Abbildung 182: $h=1200\text{mm}$, Z , $t_1/t_2=3.0$, $a=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen, mit Steife

➤ $H = 1200 \text{ mm}$, Z , $t1/t2 = 3.0$, $\alpha = 20$, e_0 , Steife

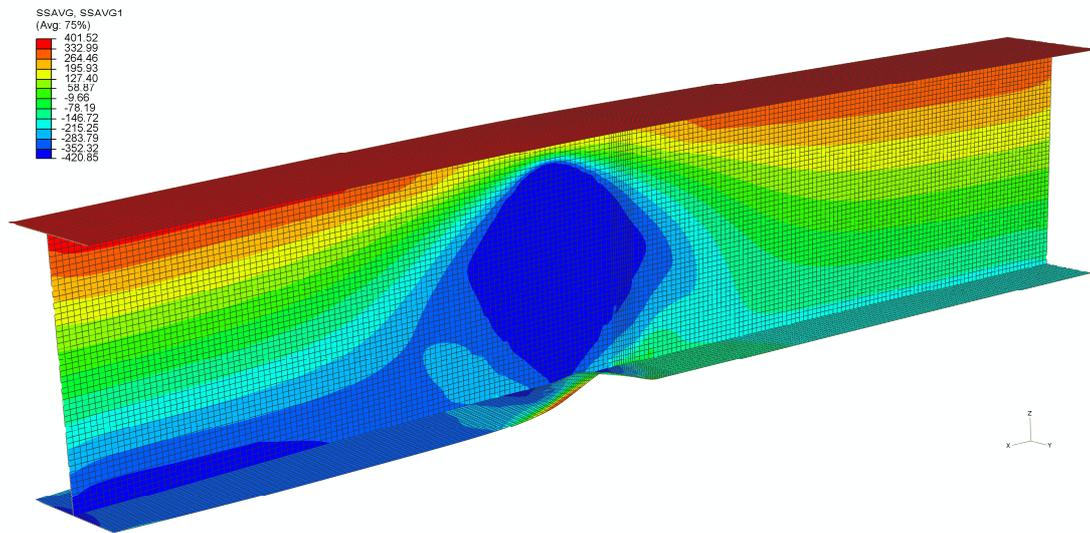


Abbildung 183: $h=1200\text{mm}$, Z , $t1/t2=3.0$, $\alpha=20$, $B/100$, ST , $INC 295$

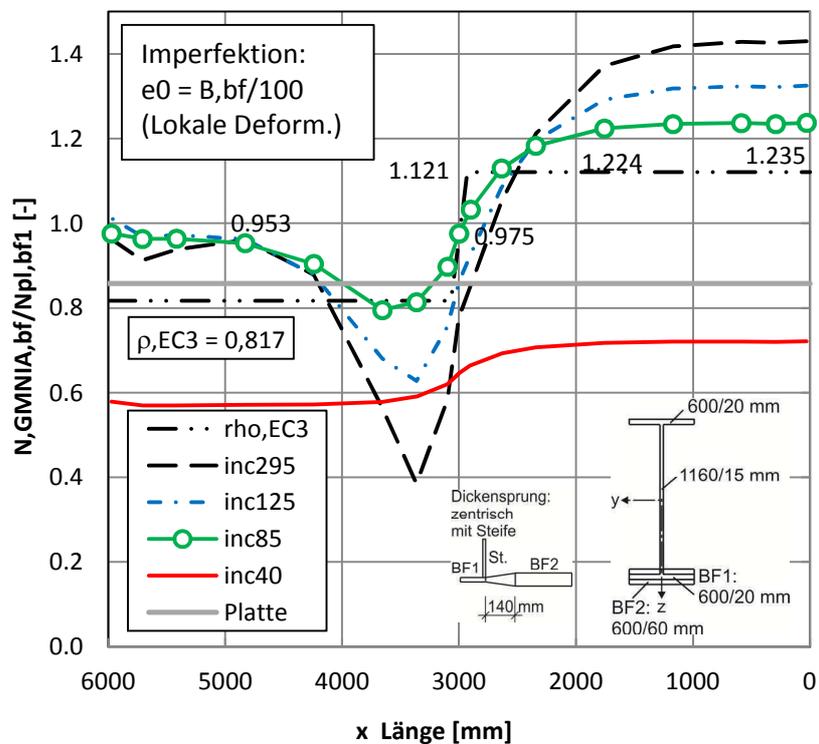


Abbildung 184: $h=1200\text{mm}$, Z , $t1/t2=3.0$, $\alpha=20$, Unterгурkräfte mit geom. Imperfektion, mit Steife

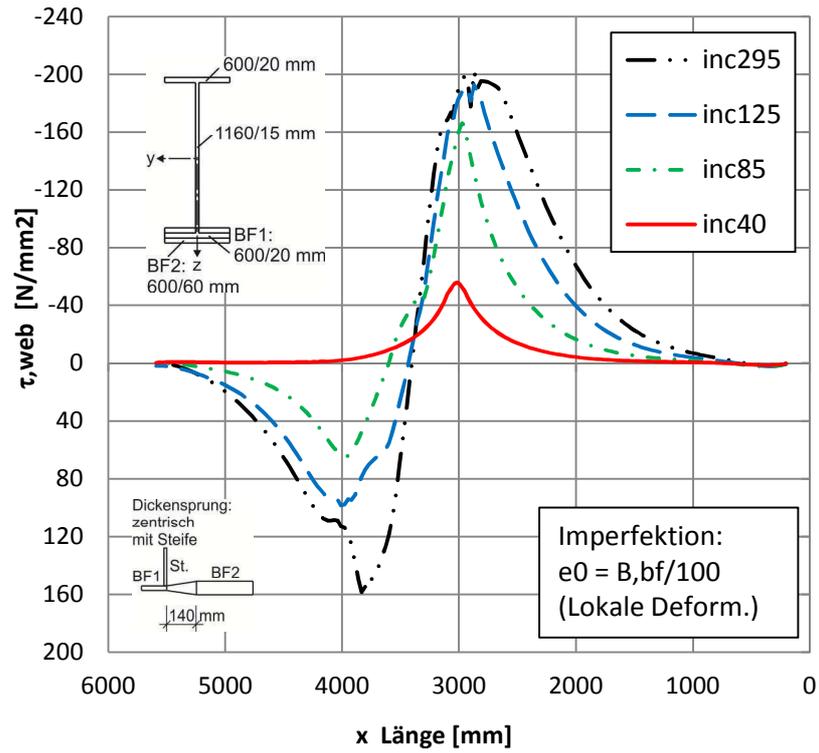


Abbildung 185: $h=1200\text{mm}$, Z , $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion, mit Steife

6.3.8. Träger unten bündig mit geom. Imperfektion i_m $t1/t2 = 3.0$ - „Fall 8“

➤ $H = 1200$ mm, UB, $t1/t2 = 3.0$, $\alpha = 20$, i_m

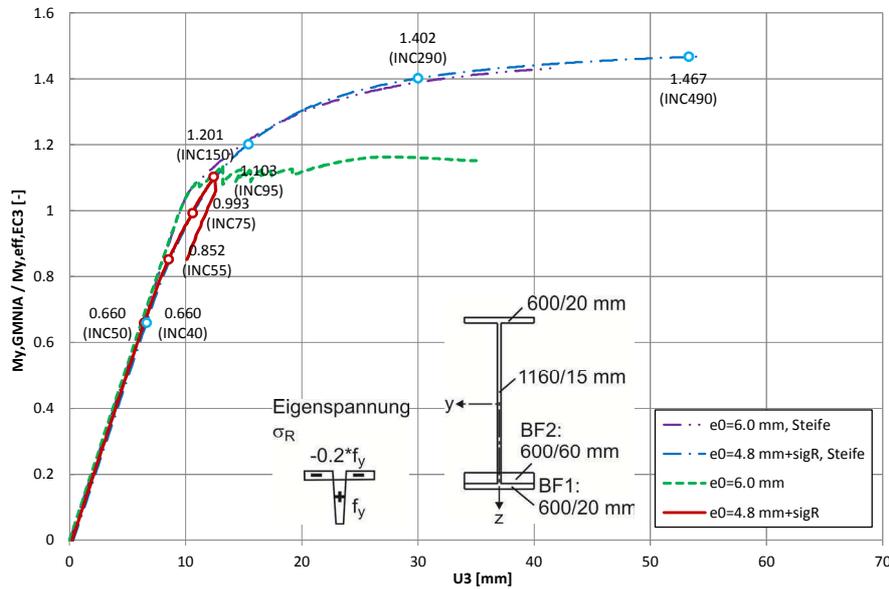


Abbildung 186: Lastverschiebungskurven, $h=1200$, UB, $t1/t2=3.0$, $\alpha=20$, i_m

| Case | My | My,GMNIA / My,eff,EC3 | Nbf | Nbf,GMNIA / Npl,eff,EC3 |
|--|---------|-----------------------|----------|-------------------------|
| | [kNm] | [-] | [kN] | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma R$ | 5940.00 | 1.103 | -3266.08 | 0.767 |
| H1200, $\alpha 20$, $t1/t2=3.0$, e_0^{100} | 6066.00 | 1.126 | -3633.94 | 0.853 |
| H1200, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma R$, ST | 6471.01 | 1.201 | -3222.50 | 0.756 |
| H1200, $\alpha 20$, $t1/t2=3.0$, e_0^{100} , ST | 7317.01 | 1.358 | -3688.98 | 0.866 |

Tabelle 28: Vergleiche Träger $H = 1200$ mm, UB, $t1/t2 = 3.0$, $\alpha = 20$, i_m

| Case | My | My,GMNIA / My,eff,EC3 | Nbf | Nbf,GMNIA / Npl,eff,EC3 |
|--|---------|-----------------------|----------|-------------------------|
| | [kNm] | [-] | [kN] | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma R$ | 6174.00 | 1.146 | -3283.67 | 0.771 |
| H1200, $\alpha 20$, $t1/t2=3.0$, e_0^{100} | 6849.01 | 1.272 | -3758.18 | 0.882 |
| H1200, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma R$, ST | 6867.01 | 1.275 | -3259.51 | 0.765 |
| H1200, $\alpha 20$, $t1/t2=3.0$, e_0^{100} , ST | 6858.01 | 1.273 | -3755.44 | 0.882 |

Tabelle 29: Wiederholung von Tabelle 24, i_k

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$, i_m

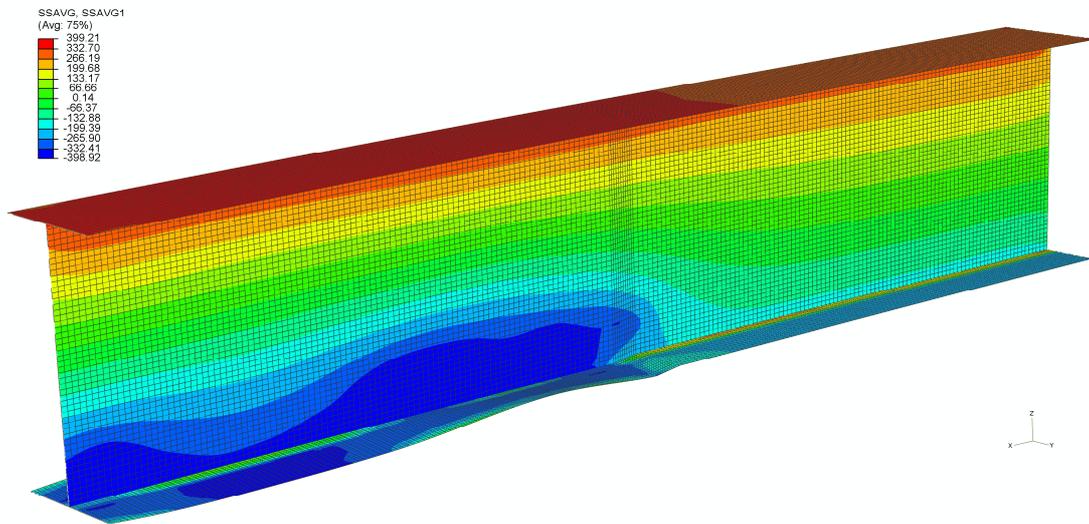


Abbildung 187: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , i_m , INC 95

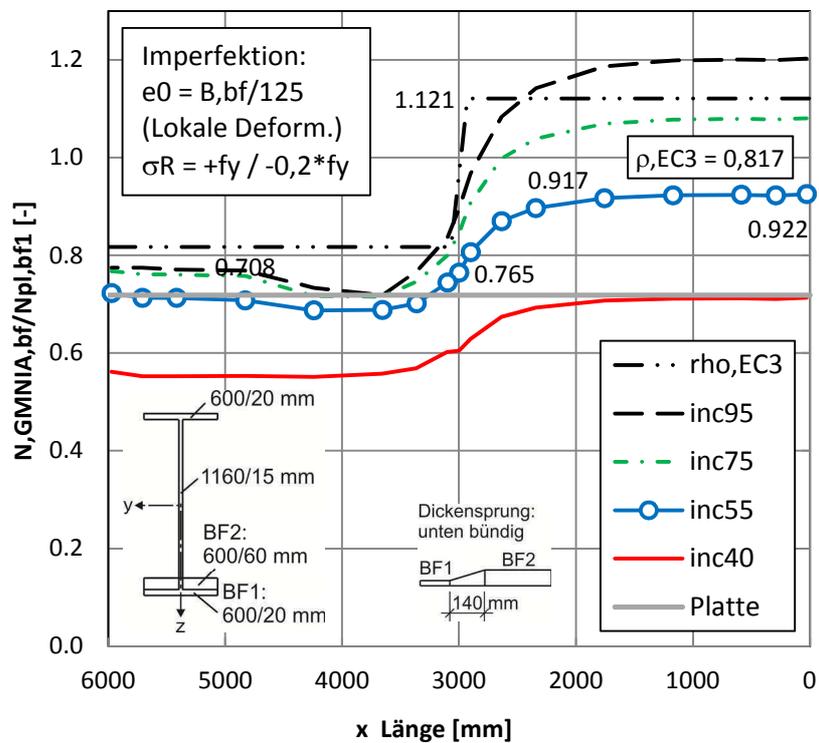


Abbildung 188: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen, i_m

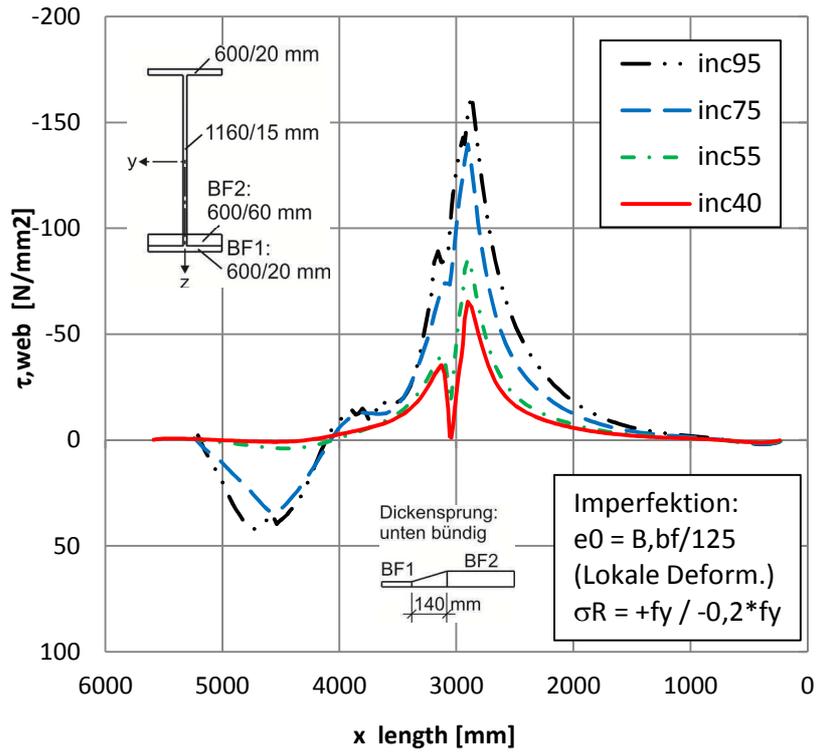


Abbildung 189: $h=1200\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen, i_m

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$, i_m

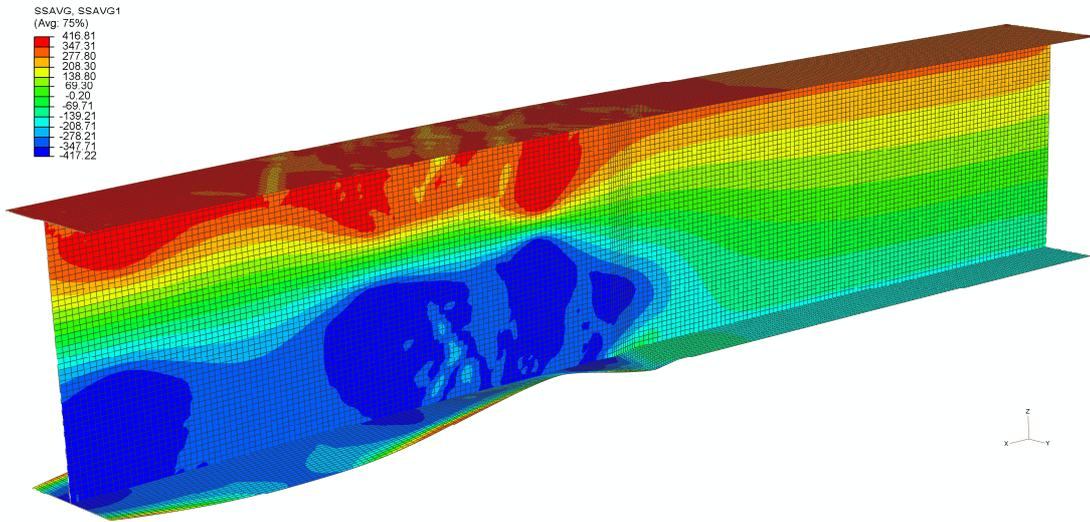


Abbildung 190: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/100$, i_m , INC 260

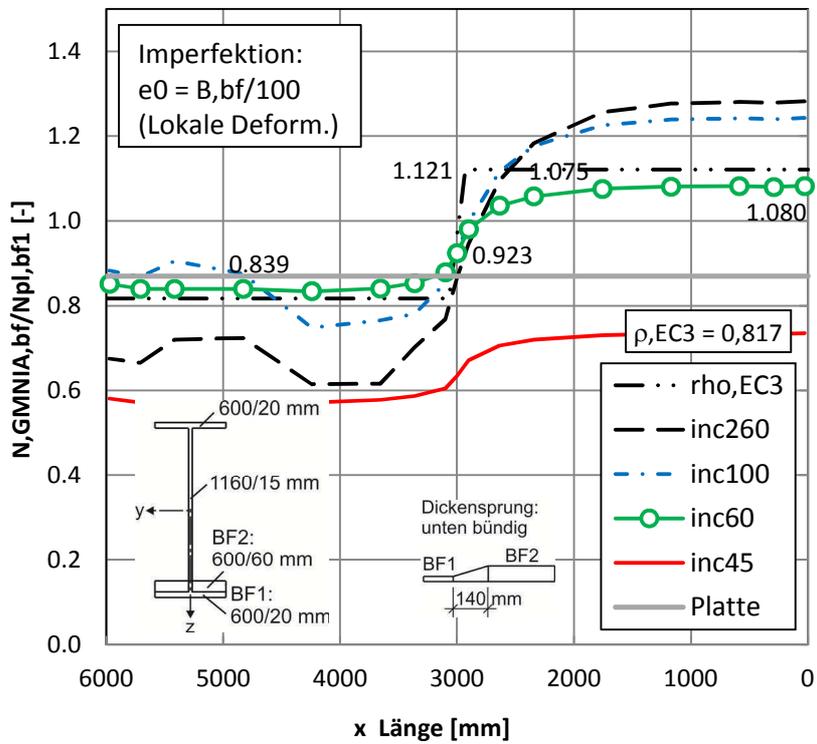


Abbildung 191: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion, i_m

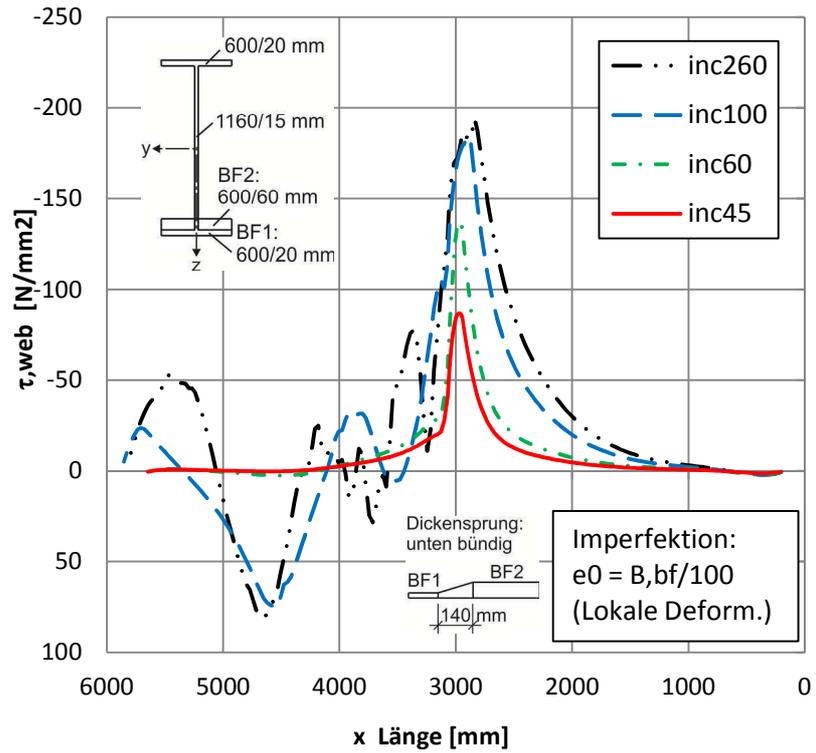


Abbildung 192: $h=1200$ mm, UB, $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion, i_m

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$, Steife, i_m

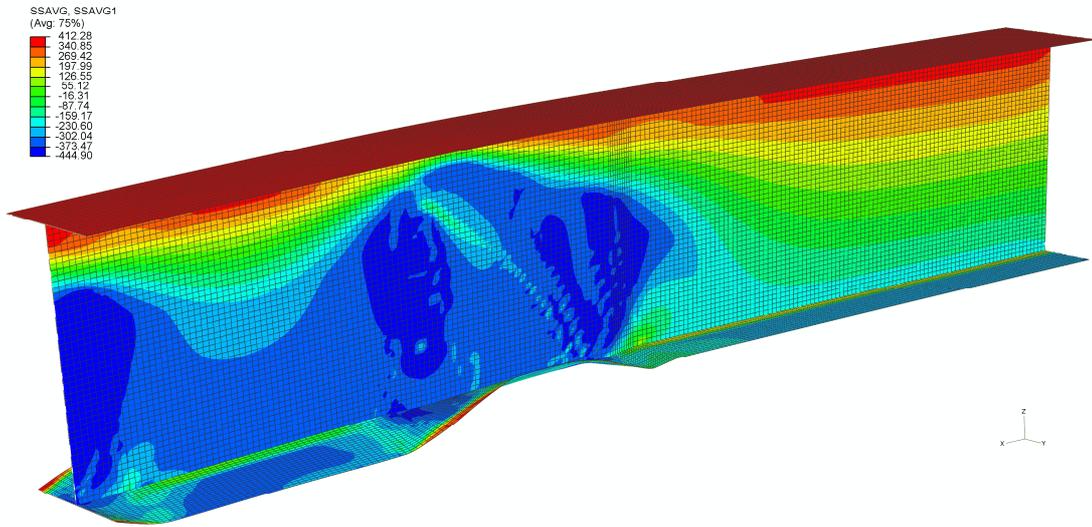


Abbildung 193: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , i_m , ST, INC 490

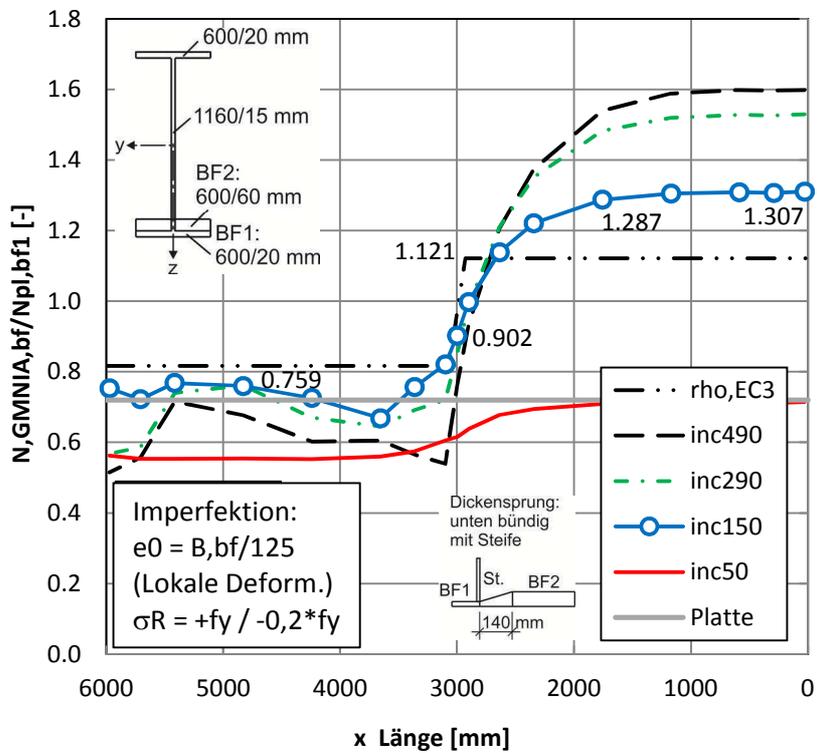


Abbildung 194: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife, i_m

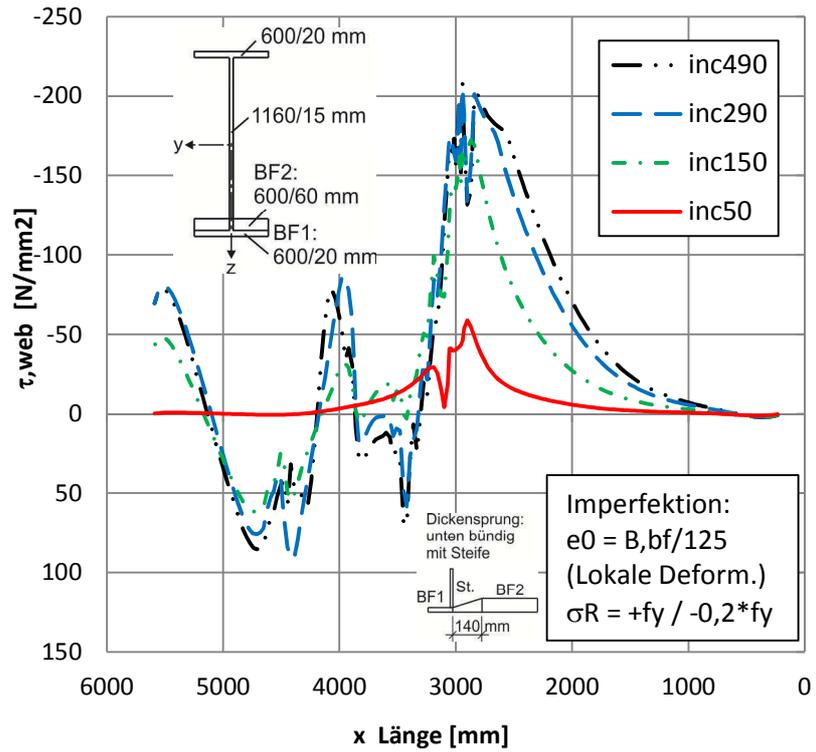


Abbildung 195: $h=1200\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen, mit Steife, i_m

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, e_0 , Steife, i_m

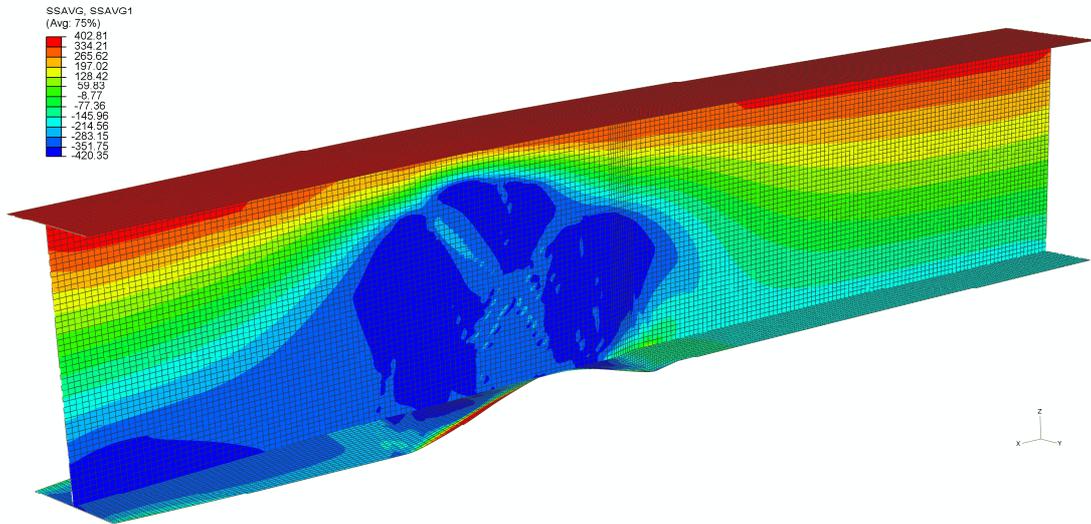


Abbildung 196: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/100$, ST, i_m , INC 300

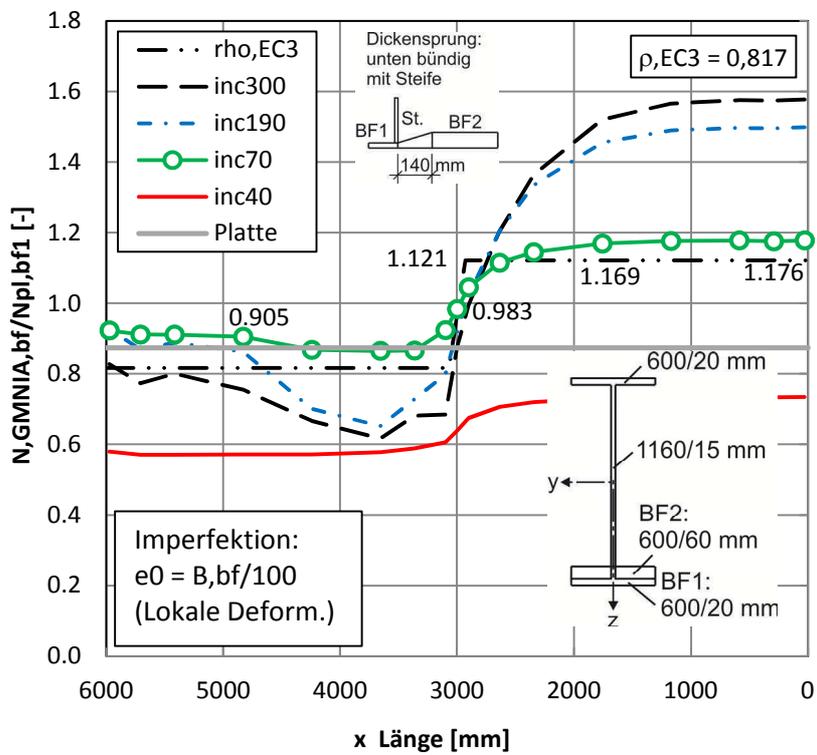


Abbildung 197: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion, mit Steife, i_m

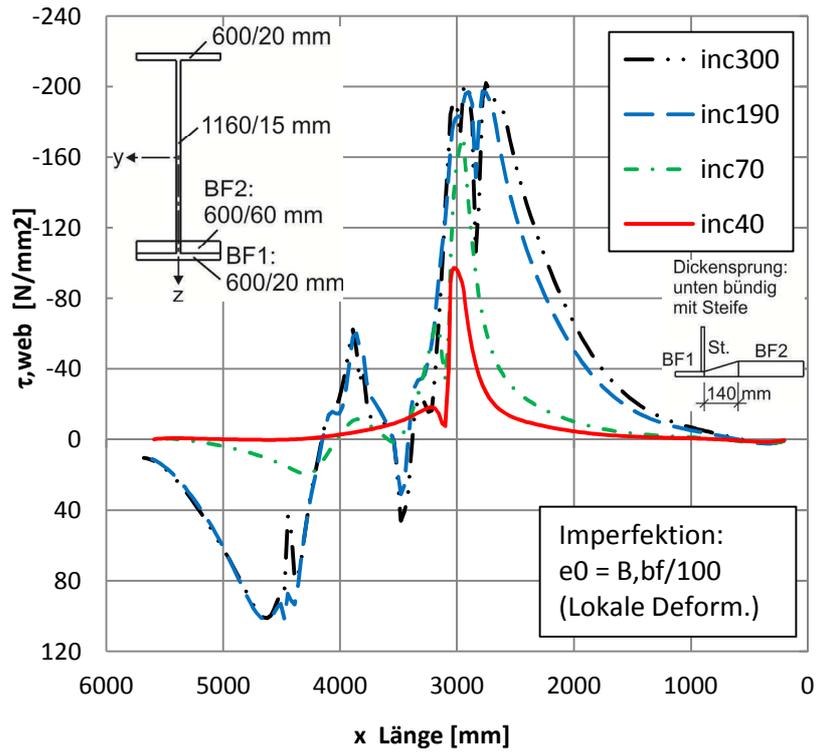


Abbildung 198: $h=1200\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion, mit Steife, i_m

6.4. Träger H = 3910 mm mit konstanter Normalspannung im Gurt

6.4.1. Träger mit Untergurtdickensprung unten bündig $t_1/t_2 = 1.5$ - „Fall 9“

- $H = 3910 \text{ mm}$, UB, $t_1/t_2 = 1.5$, $\alpha = 20$

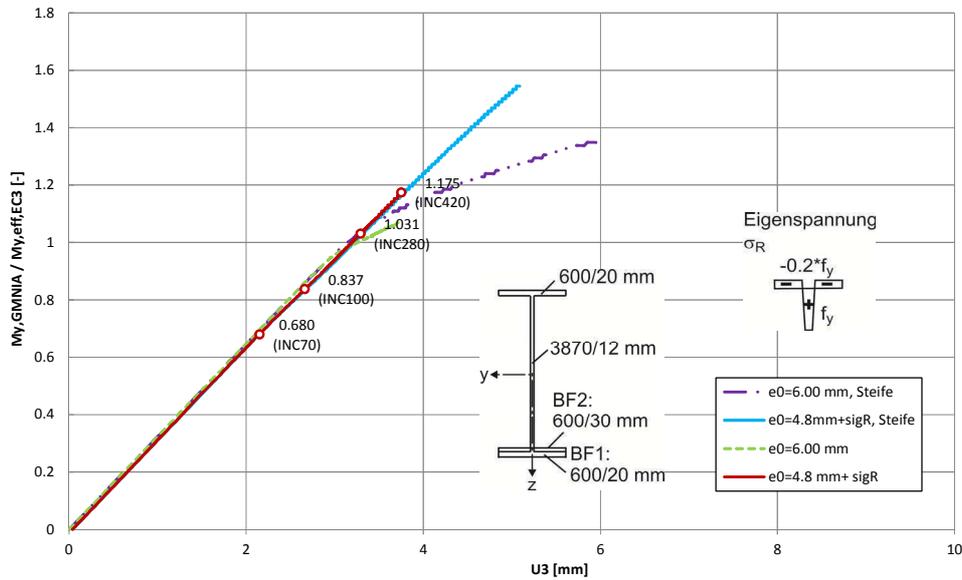


Abbildung 199: Lastverschiebungskurven, $h=3910$, UB, $t_1/t_2=1.5$, $\alpha=20$

| Case | My | My,GMNIA / | Nbf | Nbf,GMNIA / |
|--|----------|------------|----------|-------------|
| | [kNm] | My,eff,EC3 | | |
| | | [-] | [kN] | [-] |
| $M_{pl,RK}$ | 34308.86 | 1.382 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 24825.51 | 1.000 | -3480.03 | 0.817 |
| H3910, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125} + \sigma_R$ | 29159.99 | 1.175 | -3270.72 | 0.768 |
| H3910, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} | 26406.00 | 1.064 | -3637.60 | 0.854 |
| H3910, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125} + \sigma_R$, ST | 31859.99 | 1.283 | -3307.63 | 0.776 |
| H3910, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} , ST | 30239.99 | 1.218 | -3747.01 | 0.880 |

Tabelle 30: Vergleiche Träger $H = 3910 \text{ mm}$, UB, $t_1/t_2 = 1.5$, $\alpha = 20$

➤ $H = 3910 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$, $e_0 + \sigma_R$

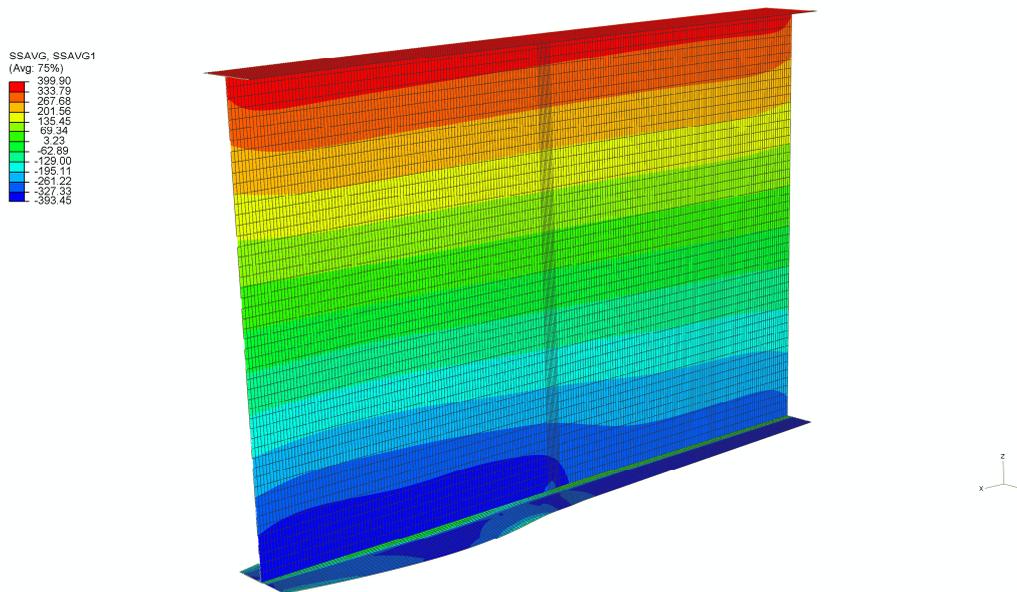


Abbildung 200: $h=3910\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , INC 420

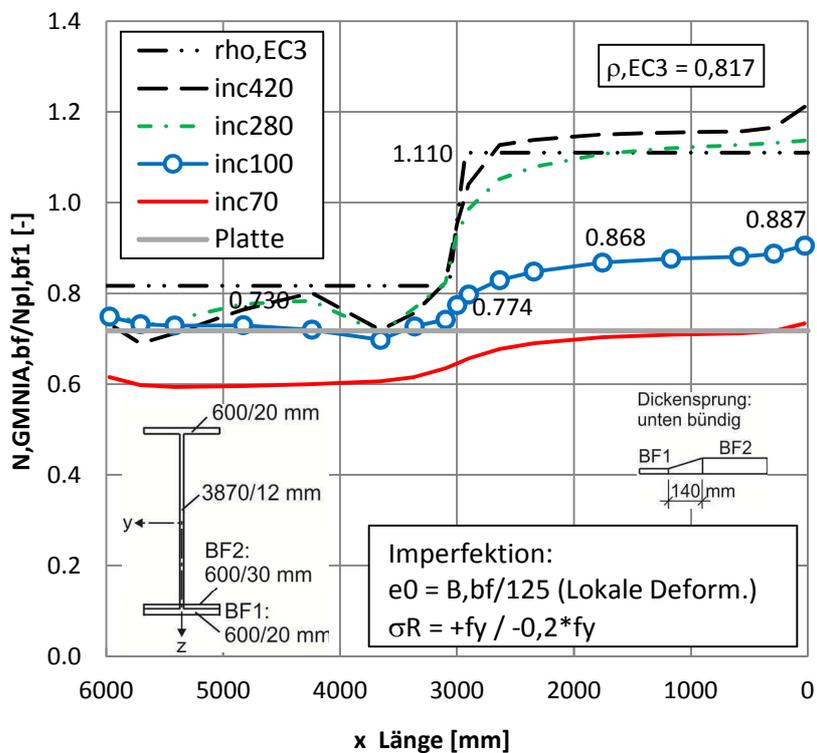


Abbildung 201: $h=3910\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, Untergurkräfte mit geom. Imperfektion und Eigenspannungen

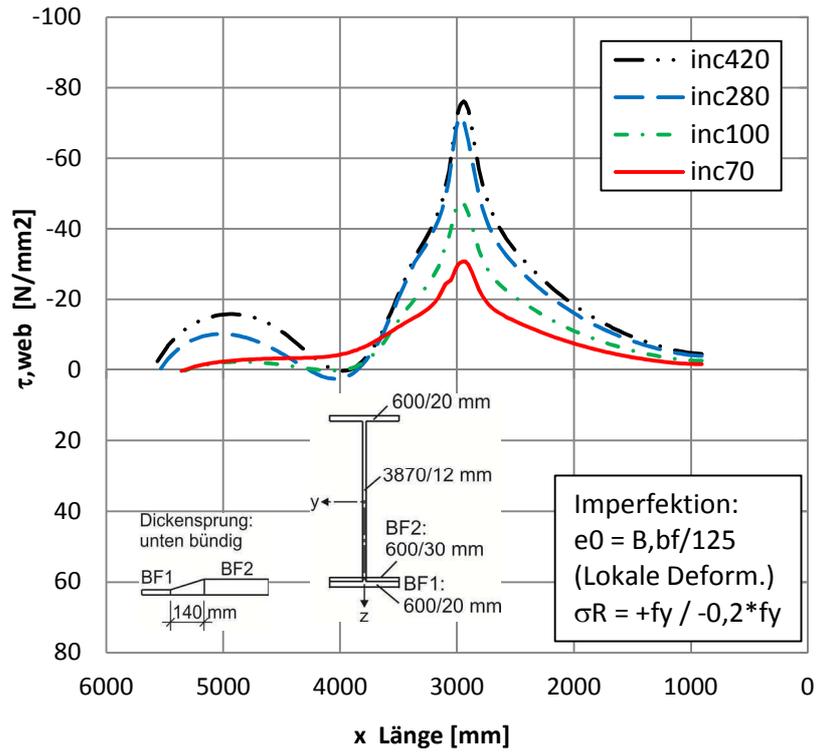


Abbildung 202: $h=3910\text{mm}$, UB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 3910 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$, e_0

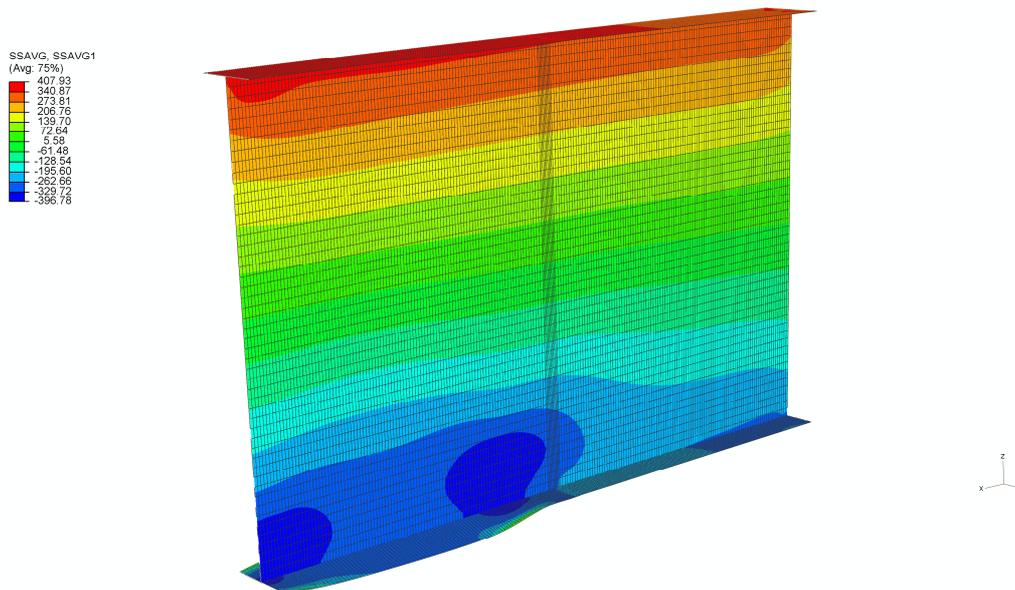


Abbildung 203: $h=3910\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/100$, INC 300

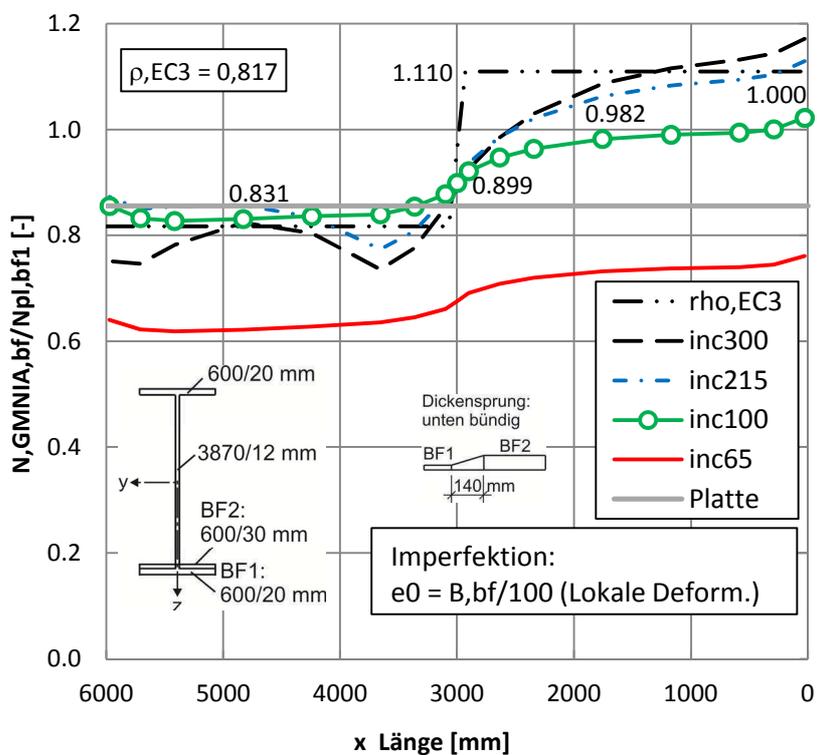


Abbildung 204: $h=3910\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion

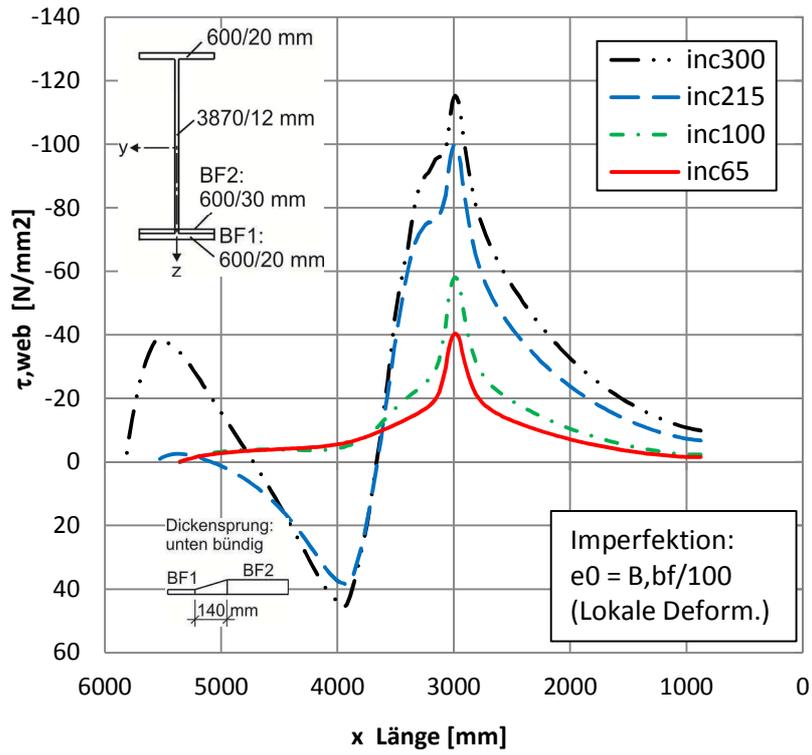


Abbildung 205: $h=3910\text{mm}$, UB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion

➤ $H = 3910 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$, $e_0 + \sigma_R$, Steife

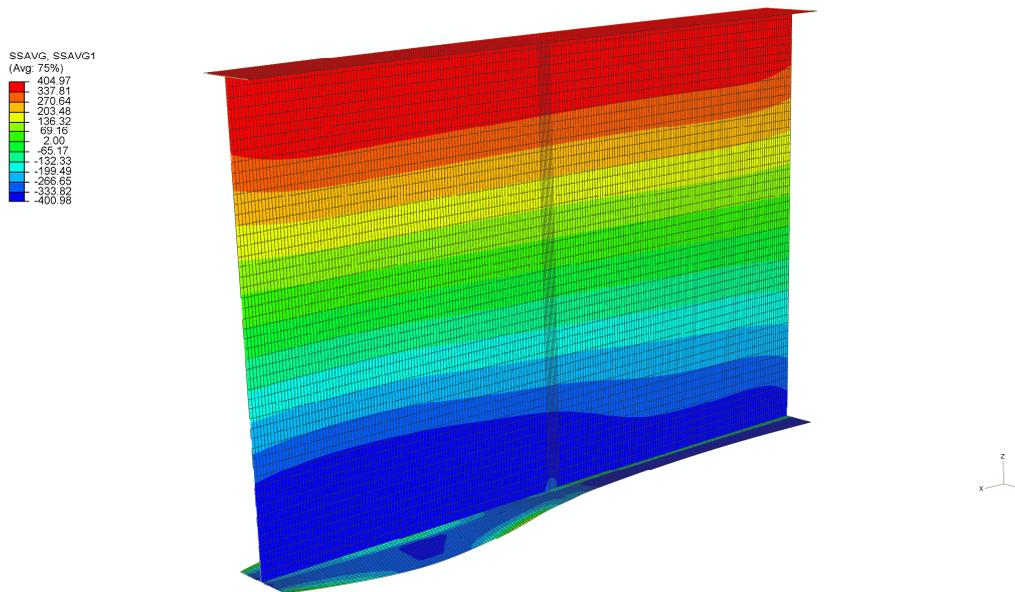


Abbildung 206: $h=3910\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , ST, INC 495

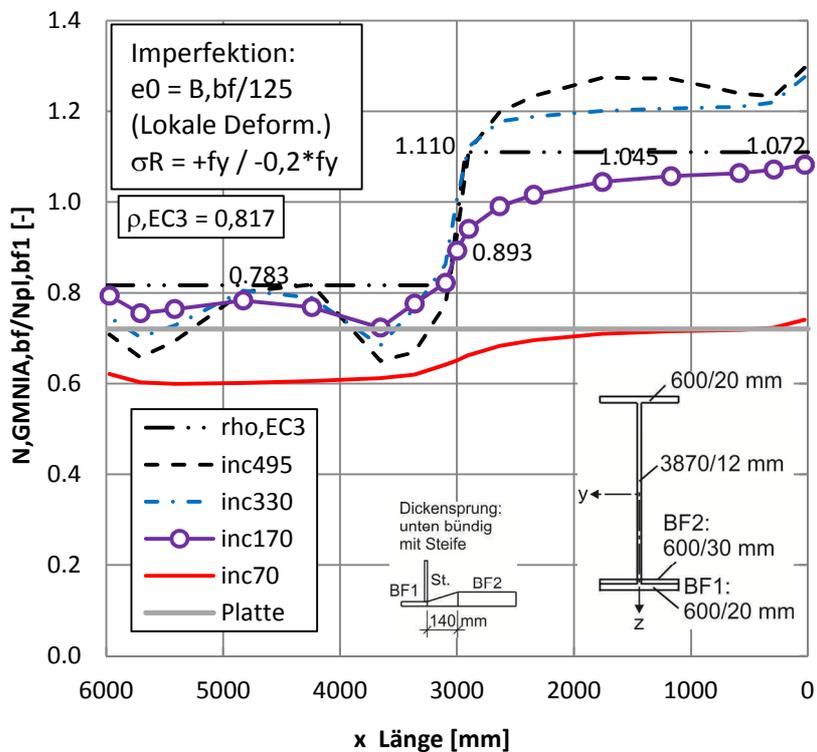


Abbildung 207: $h=3910\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, Untergurtrkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife

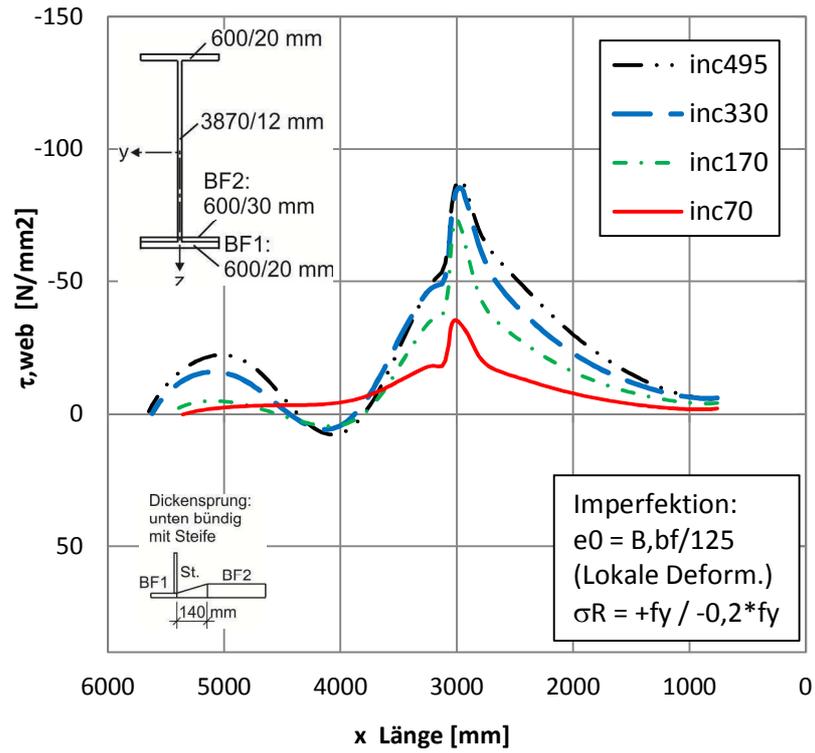


Abbildung 208: $h=3910\text{mm}$, UB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen, mit Steife

➤ $H = 3910 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$, e_0 , Steife

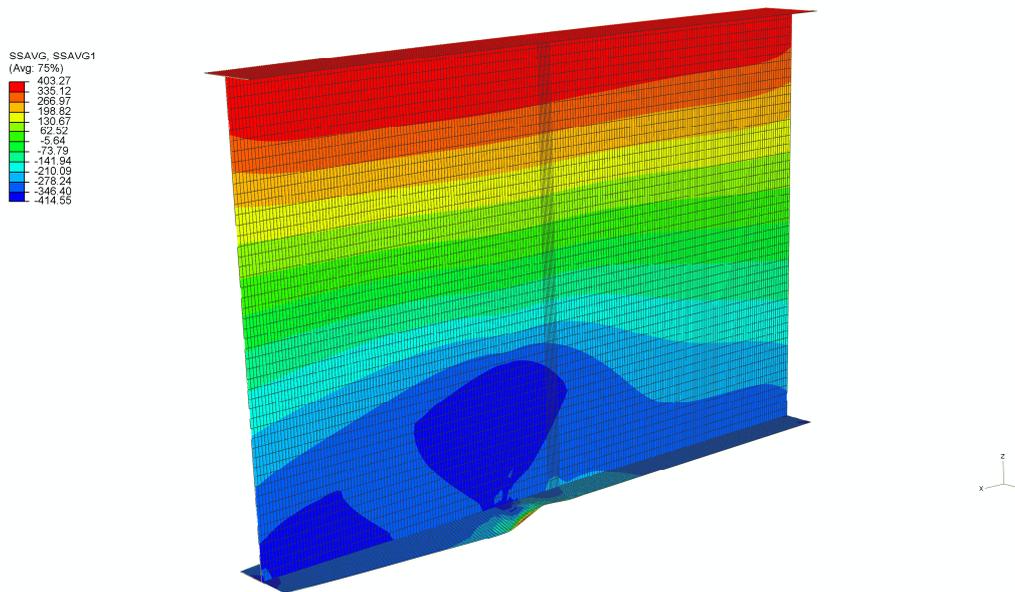


Abbildung 209: $h=3910\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/100$, ST, INC 300

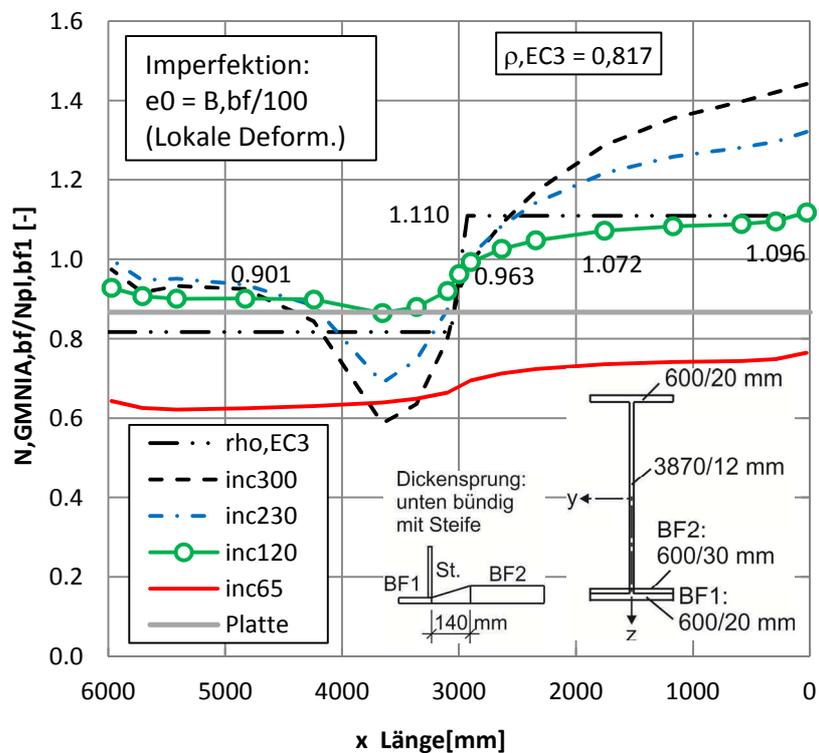


Abbildung 210: $h=3910\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion, mit Steife

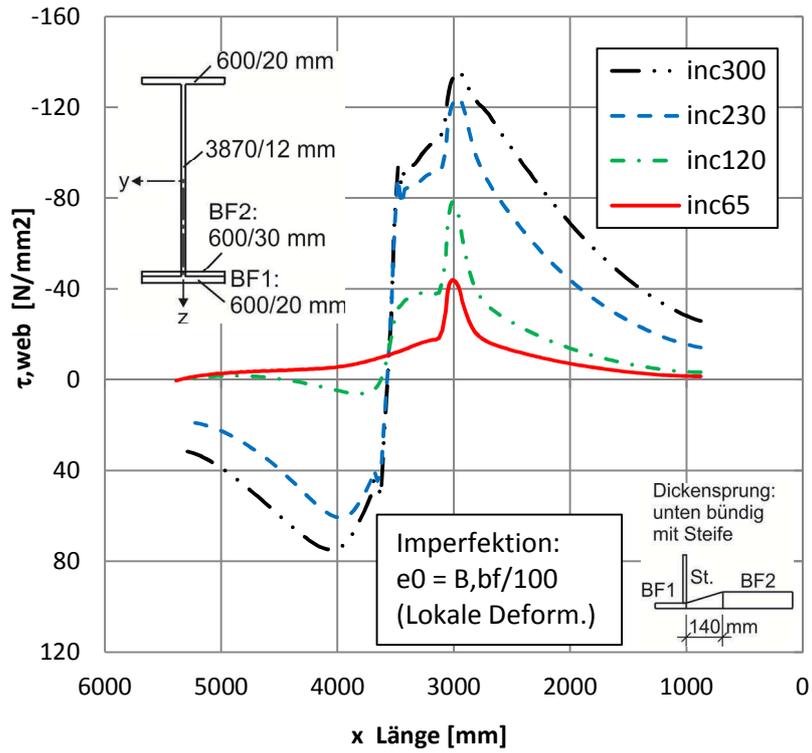


Abbildung 211: $h=3910\text{mm}$, UB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion, mit Steife

6.4.2. Träger mit Untergurtdickensprung unten bündig $t1/t2 = 3.0$
 - „Fall 10“

➤ $H = 3910 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$

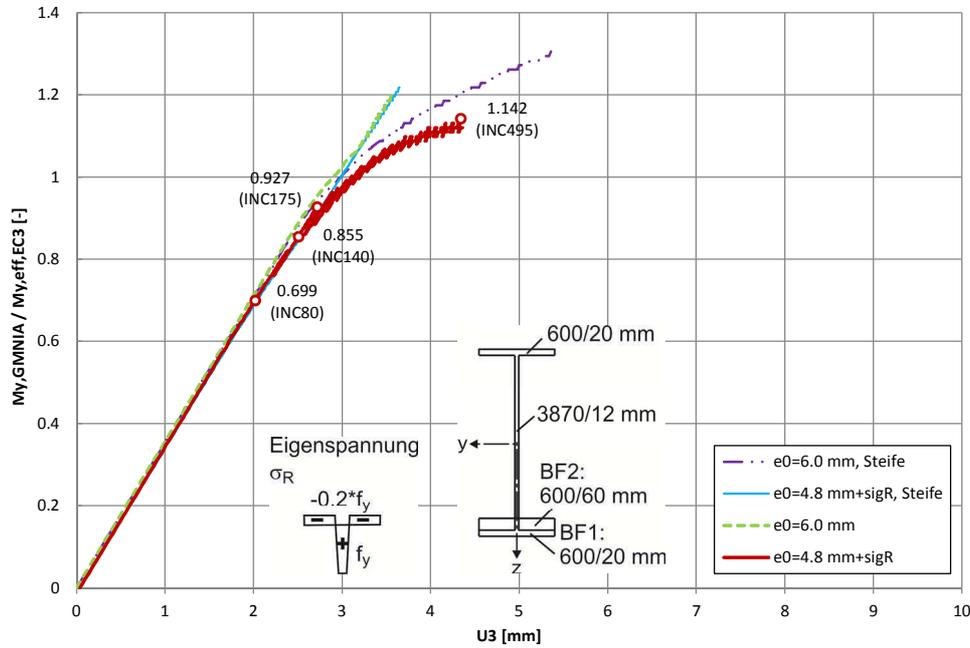


Abbildung 212: Lastverschiebungskurven, $h=3910$, UB, $t1/t2=3.0$, $\alpha=20$

| Case | My | My,GMNIA / | Nbf | Nbf,GMNIA / |
|--|----------|------------|----------|-------------|
| | [kNm] | My,eff,EC3 | | |
| $M_{pl,RK}$ | 34308.86 | 1.382 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 24825.51 | 1.000 | -3480.03 | 0.817 |
| H3910, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma_R$ | 28349.99 | 1.142 | -3221.27 | 0.756 |
| H3910, $\alpha 20$, $t1/t2=3.0$, e_0^{100} | 29699.99 | 1.196 | -3784.90 | 0.888 |
| H3910, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma_R$, ST | 30239.99 | 1.218 | -3450.12 | 0.810 |
| H3910, $\alpha 20$, $t1/t2=3.0$, e_0^{100} , ST | 32399.99 | 1.305 | -3605.34 | 0.846 |

Tabelle 31: Vergleiche Träger $H = 3910 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$

➤ $H = 3910 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$

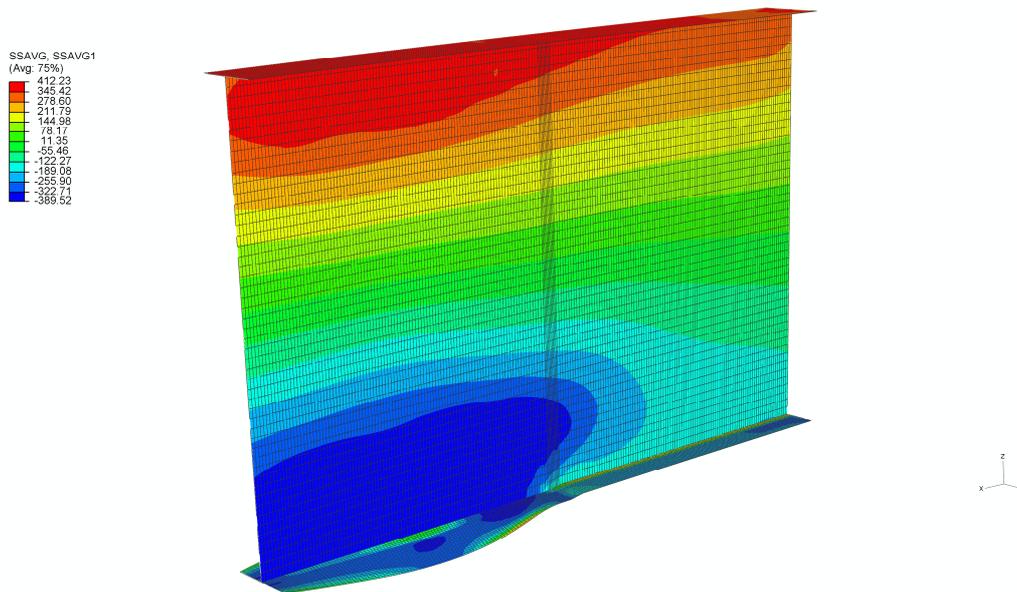


Abbildung 213: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , INC 495

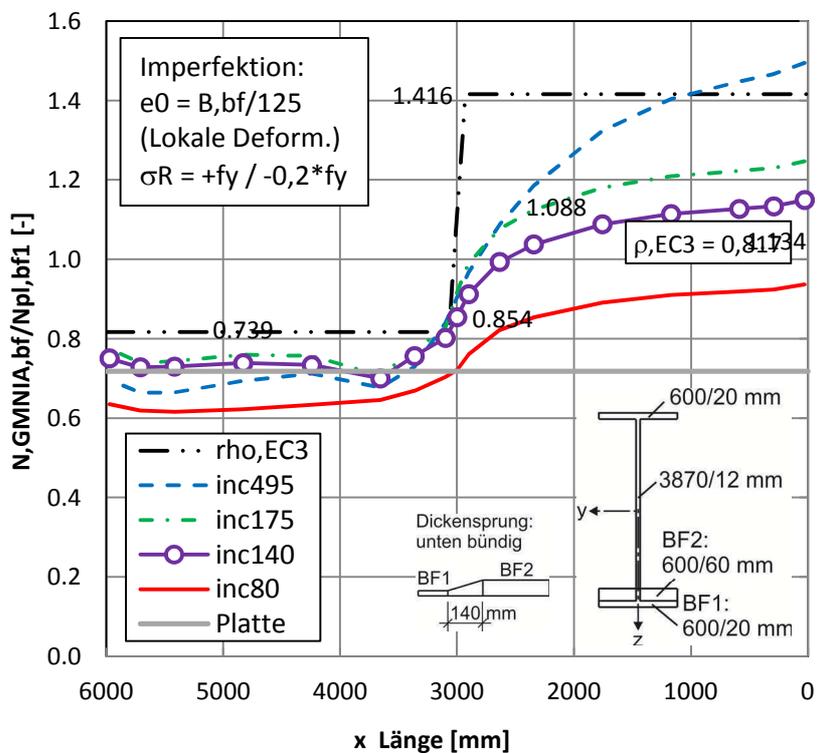


Abbildung 214: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen

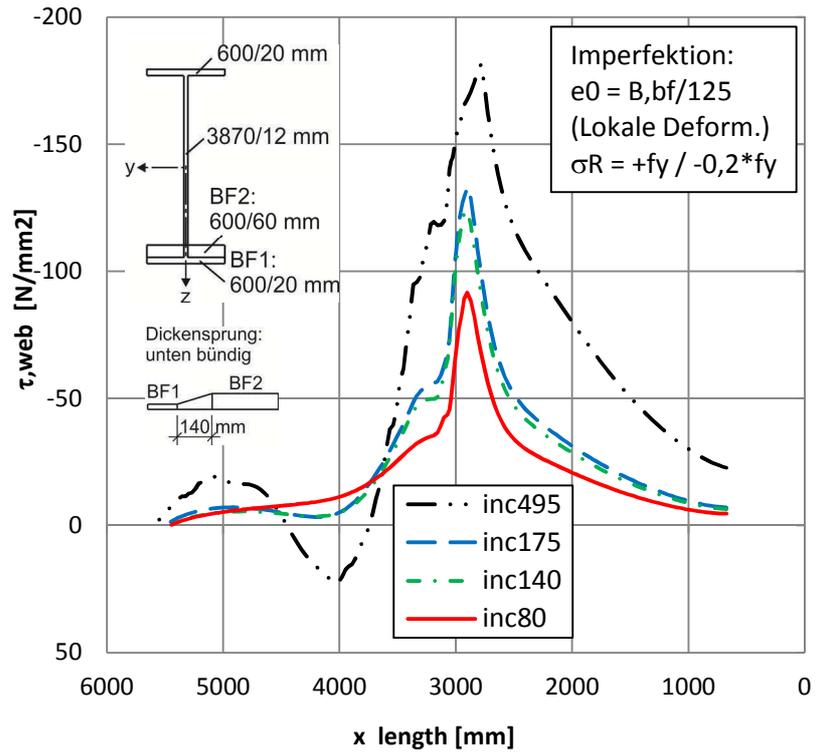


Abbildung 215: $h=3910\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 3910 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, e_0

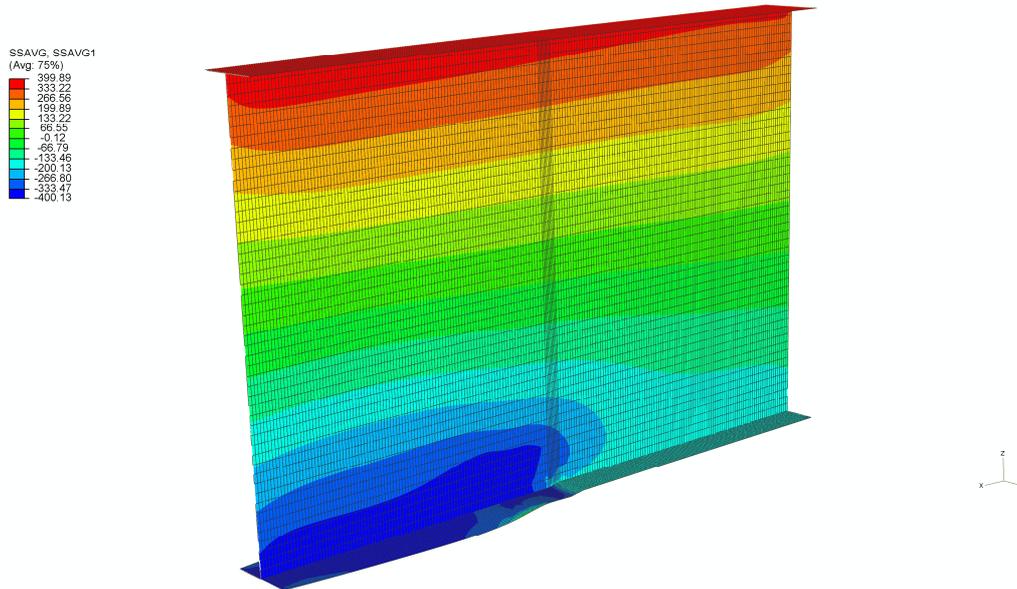


Abbildung 216: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/100$, INC 280

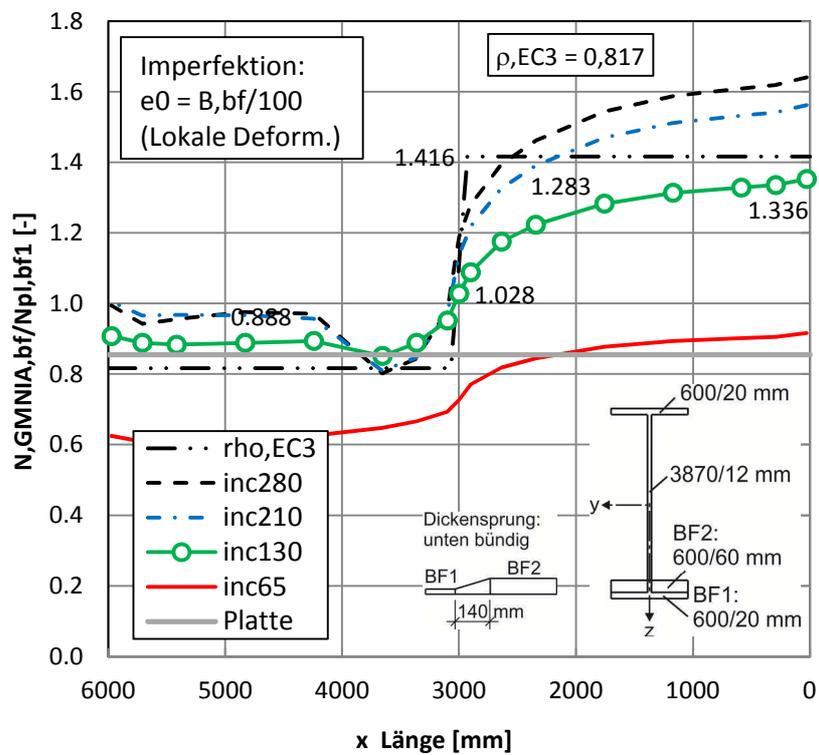


Abbildung 217: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion

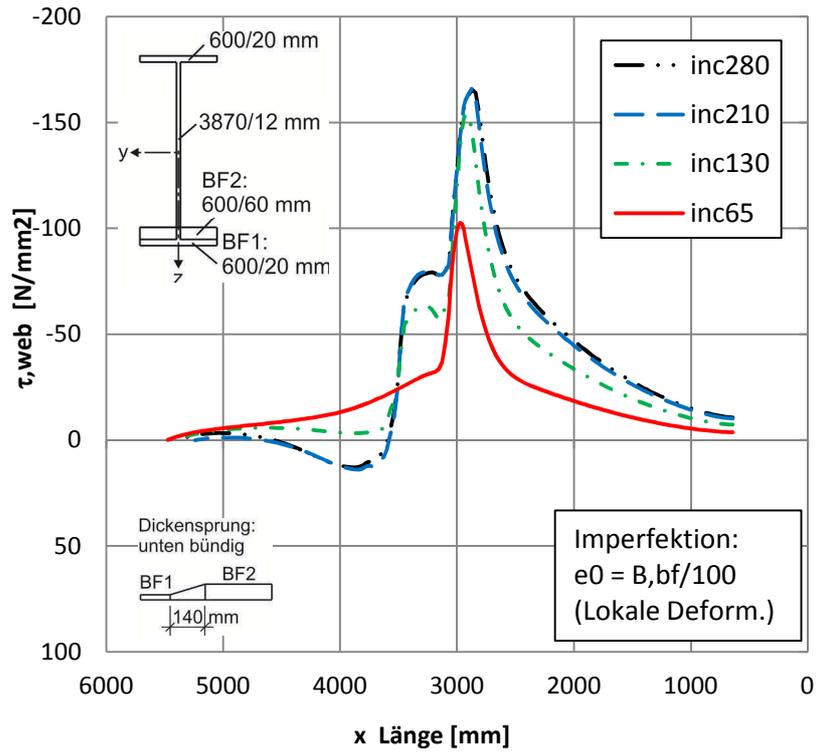


Abbildung 218: $h=3910mm$, UB, $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion

➤ $H = 3910 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$, Steife

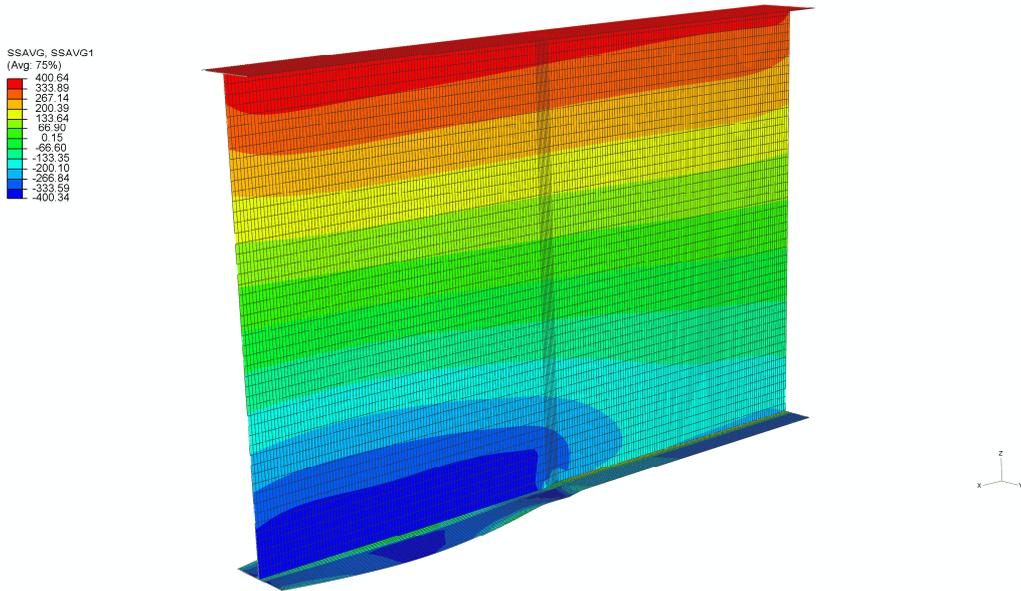


Abbildung 219: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , ST, INC 320

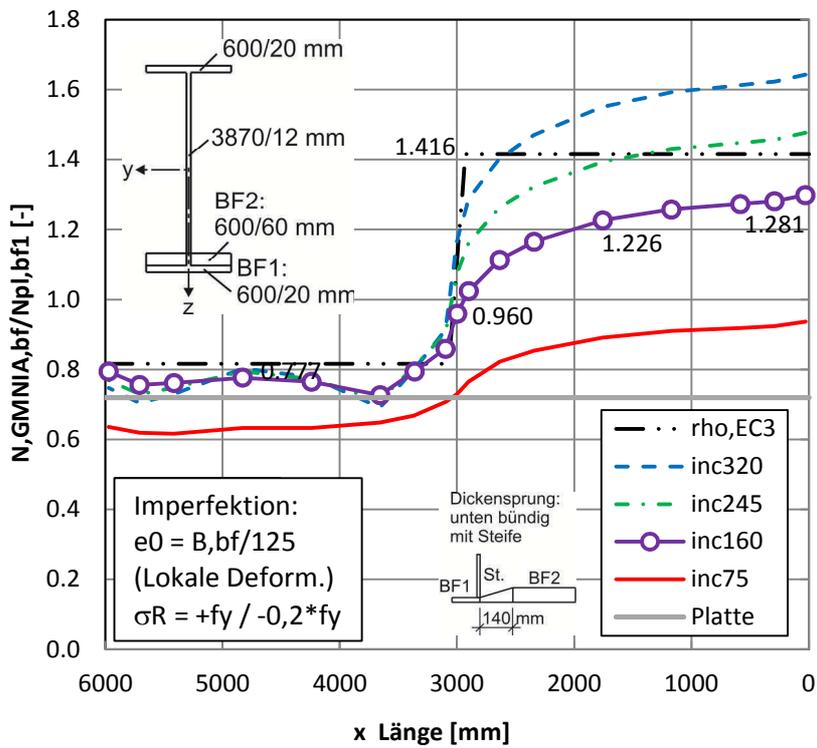


Abbildung 220: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife

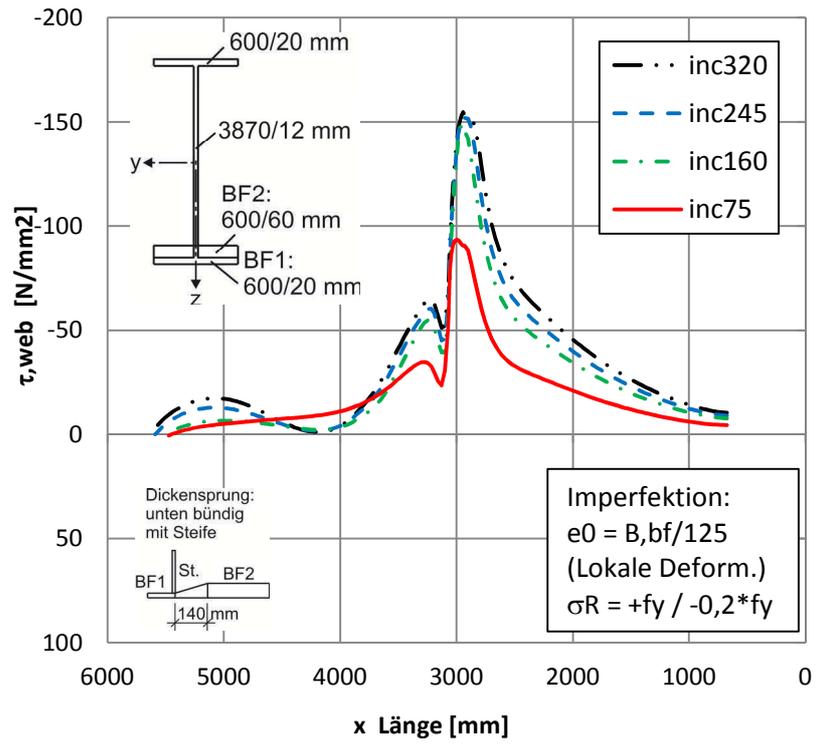


Abbildung 221: $h=3910\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen, mit Steife

➤ $H = 3910 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, e_0 , Steife

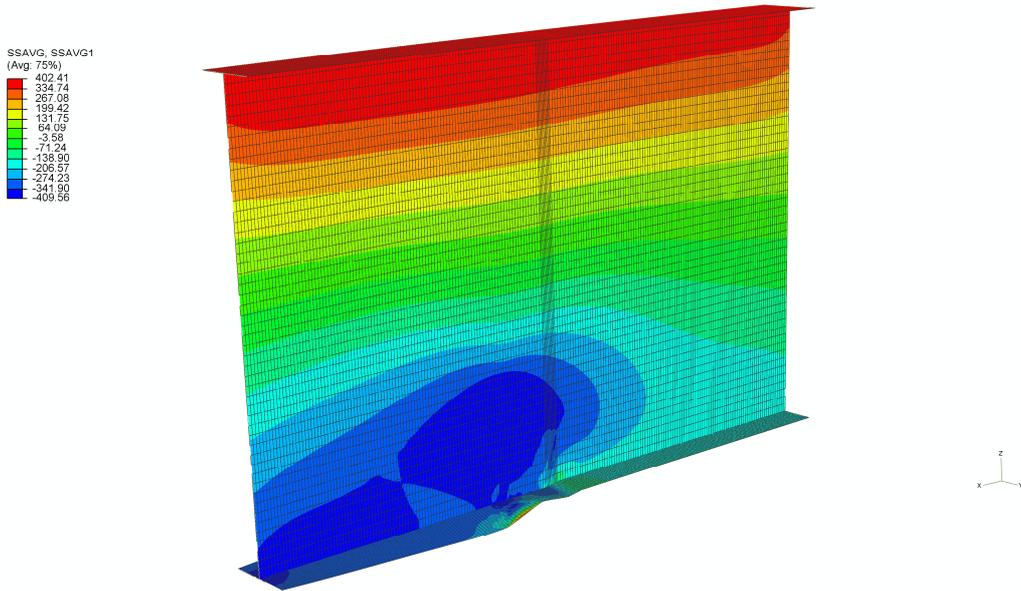


Abbildung 222: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/100$, ST, INC 300

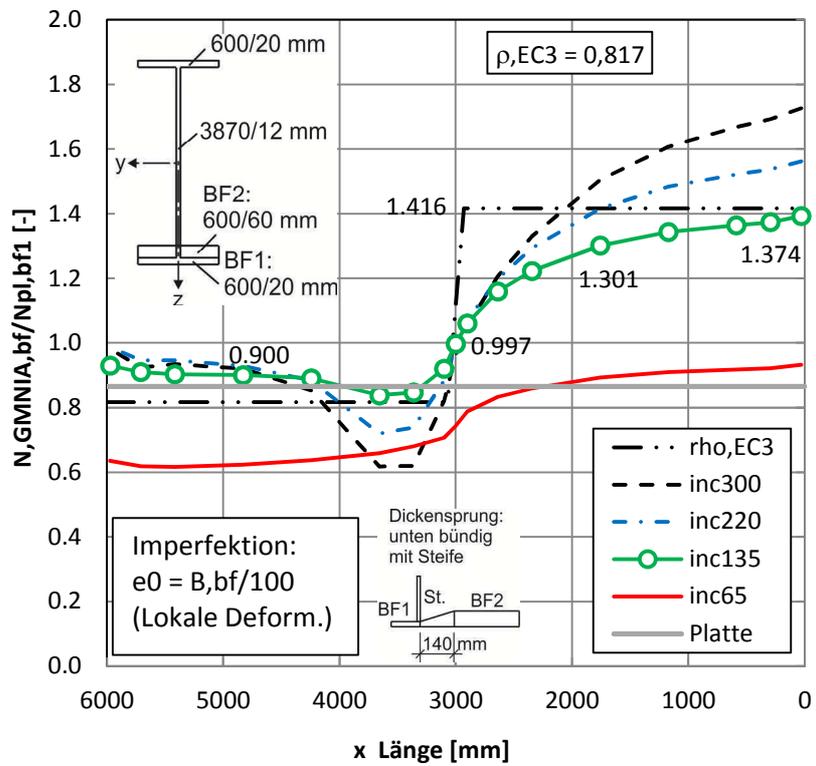


Abbildung 223: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion, mit Steife

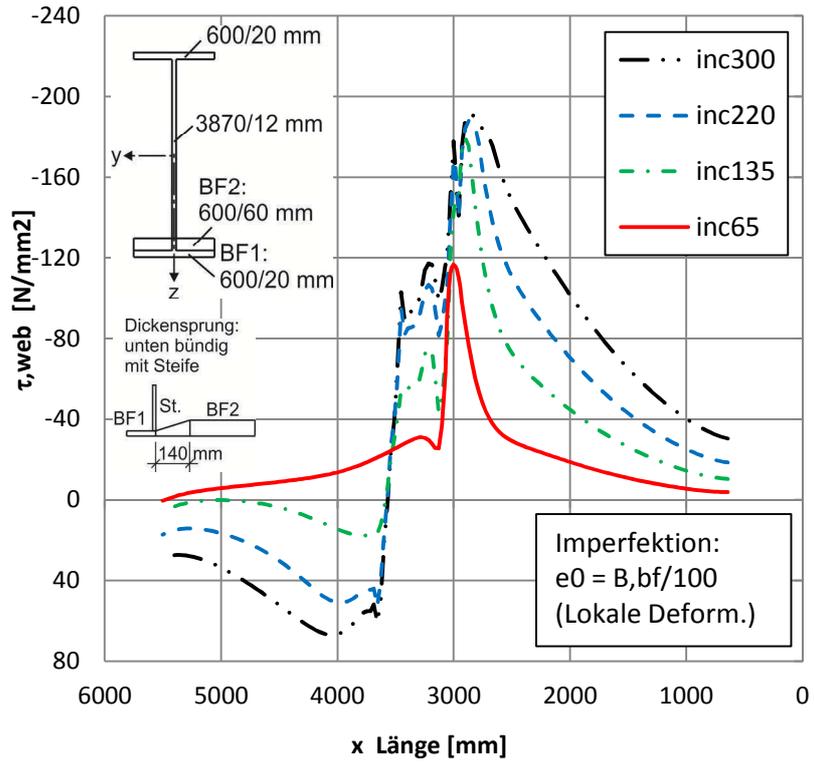


Abbildung 224: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Schubspannungen mit geom. Imperfektion, mit Steife

6.5. Untersuchung mit veränderlicher Normalspannung im Gurt

6.5.1. Träger mit Untergurtdickensprung unten bündig $t1/t2 = 1.5$

- „Fall 11“

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$

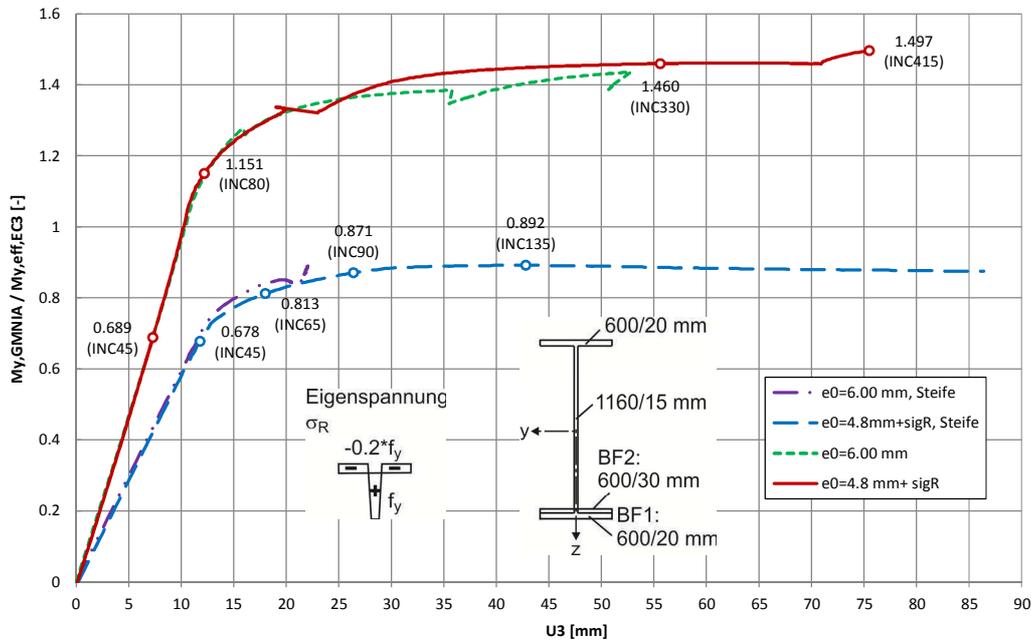


Abbildung 1: Lastverschiebungskurven, $h=1200$, UB, $t1/t2=1.5$, $\alpha=20$

| Case | My | My,GMNIA / | Nbf | Nbf,GMNIA / |
|--|---------|------------|----------|-------------|
| | [kNm] | My,eff,EC3 | | |
| | | [-] | | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha 20$, $t1/t2=1.5$, $e_0^{125} + \sigma_R$ | 7583.11 | 1.408 | -3100.56 | 0.728 |
| H1200, $\alpha 20$, $t1/t2=1.5$, e_0^{100} | 7418.26 | 1.377 | -3553.54 | 0.834 |
| H1200, $\alpha 20$, $t1/t2=1.5$, $e_0^{125} + \sigma_R$, ST | 4689.99 | 0.871 | -3342.39 | 0.785 |
| H1200, $\alpha 20$, $t1/t2=1.5$, e_0^{100} , ST | 4558.11 | 0.846 | -3027.79 | 0.711 |

Abbildung 2: Vergleiche Träger $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$, $e_0 + \sigma_R$

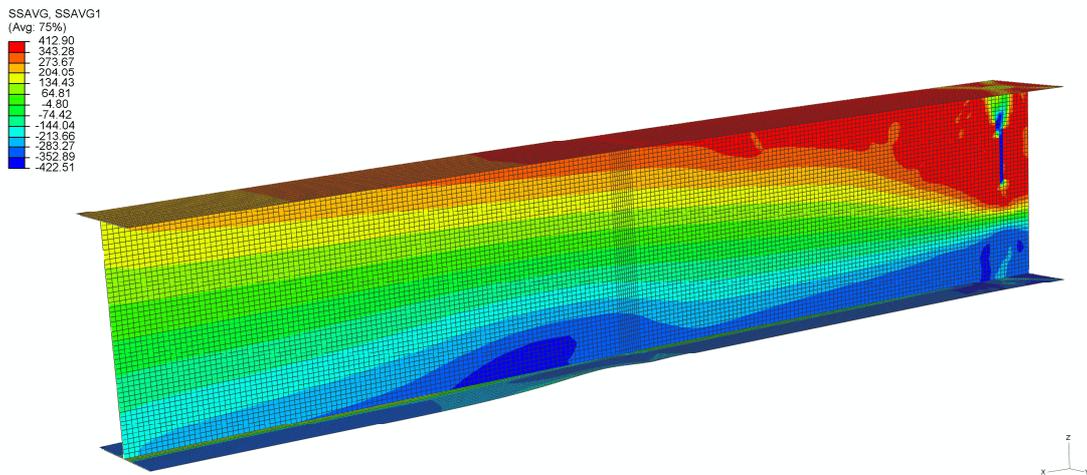


Abbildung 3: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , INC 195

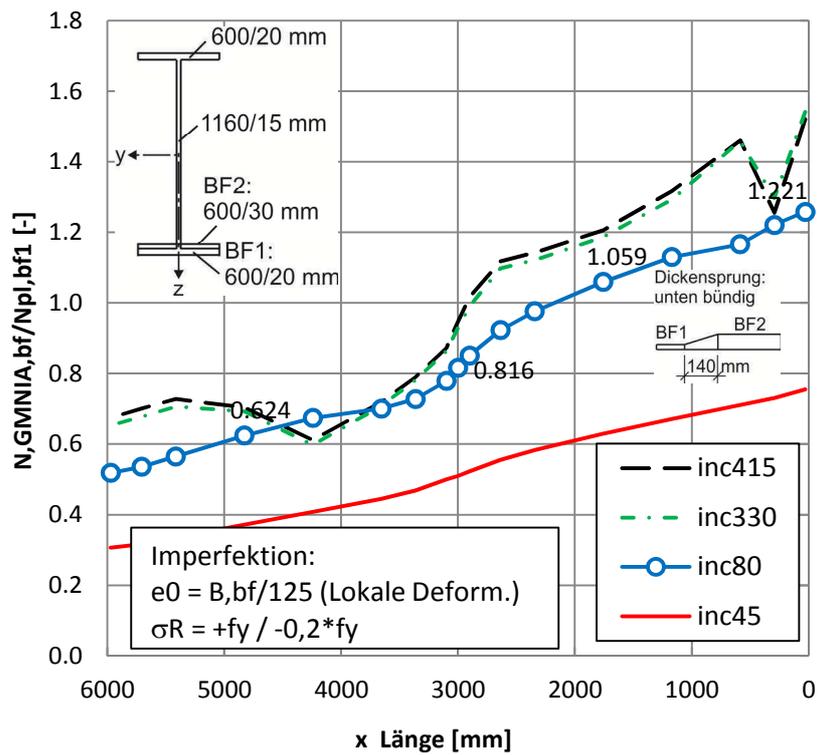


Abbildung 4: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen

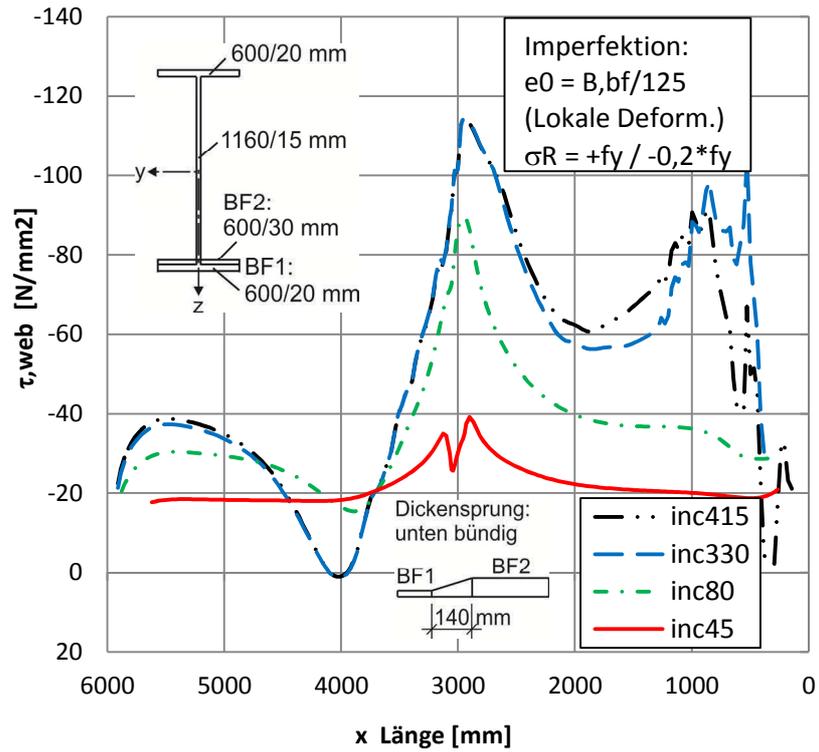


Abbildung 5: $h=1200\text{mm}$, UB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion und Eigenspannungen

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$, e_0

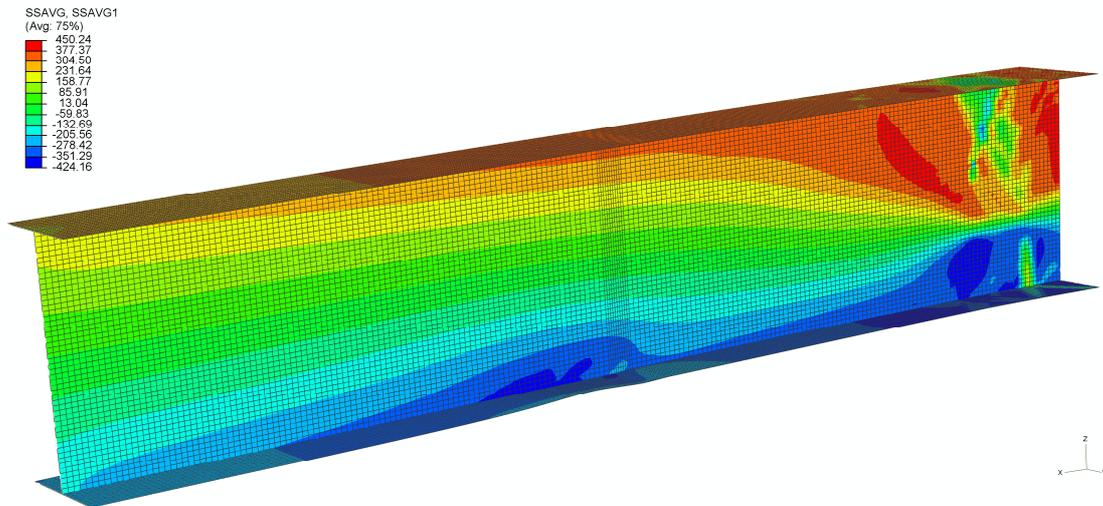


Abbildung 6: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/100$, INC 280

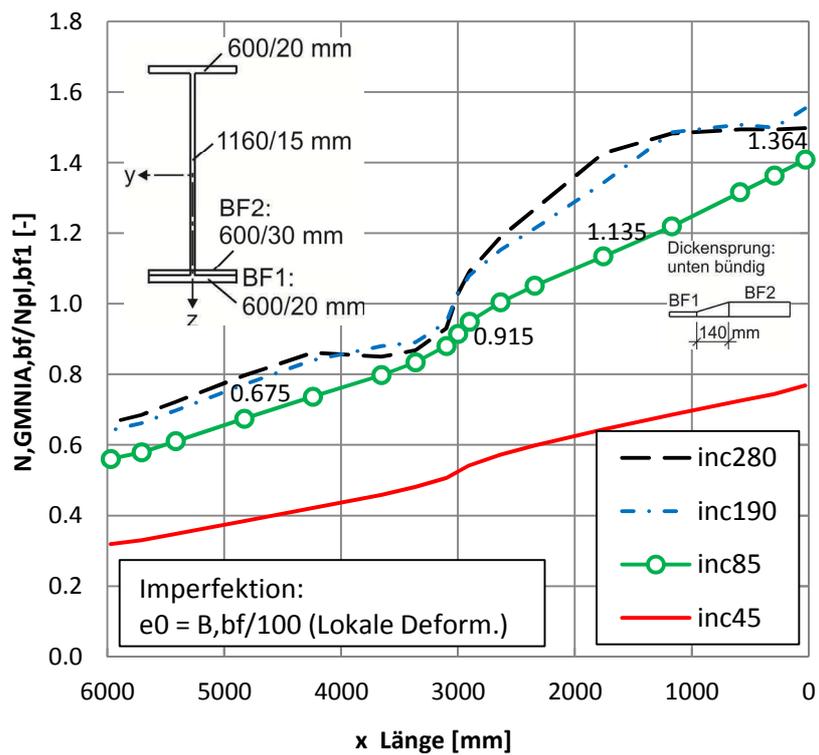


Abbildung 7: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion

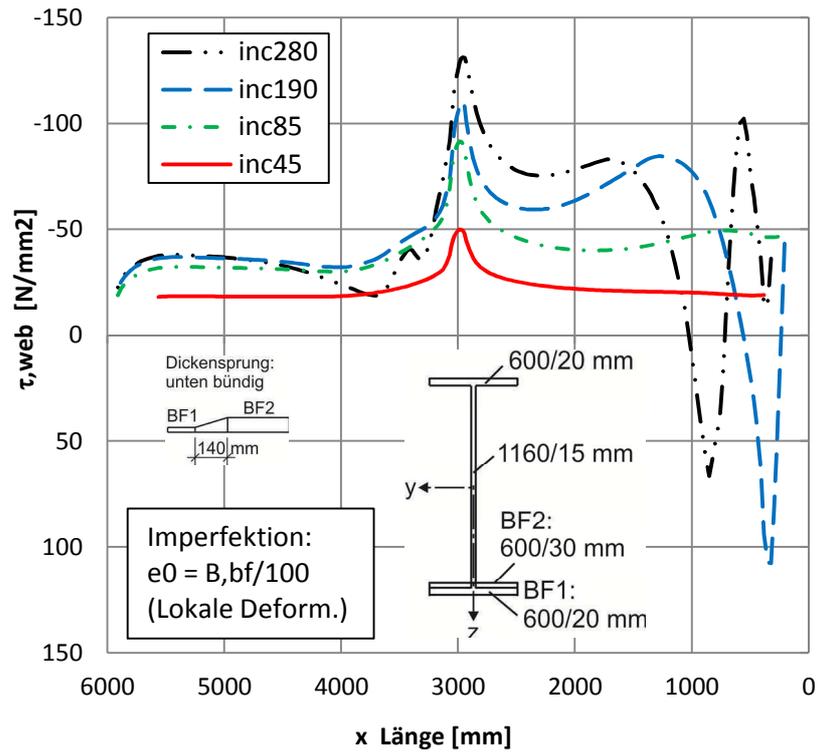


Abbildung 8: $h=1200$ mm, UB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$, $e_0 + \sigma_R$, Steife

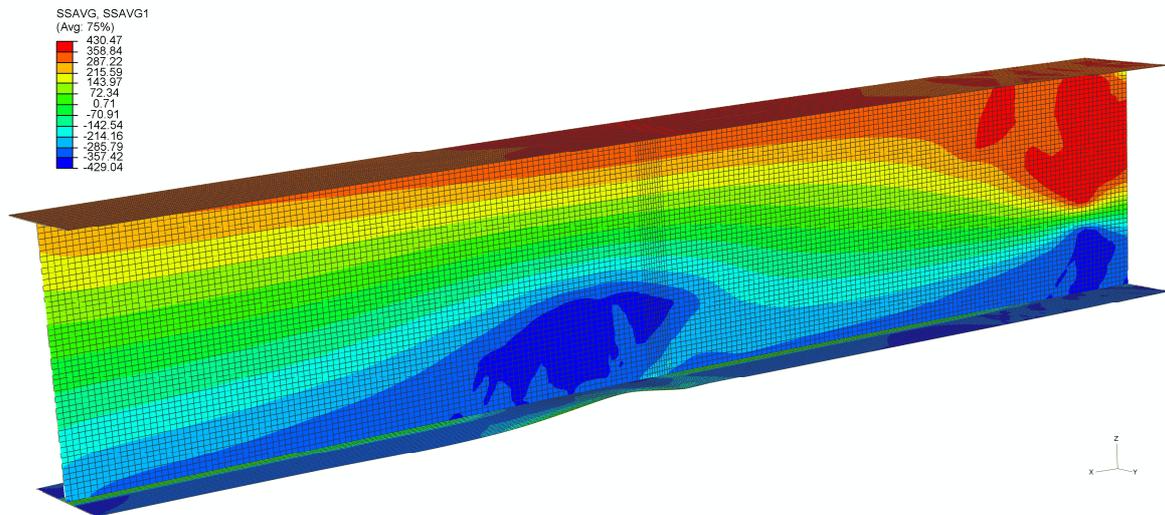


Abbildung 9: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , ST, INC 135

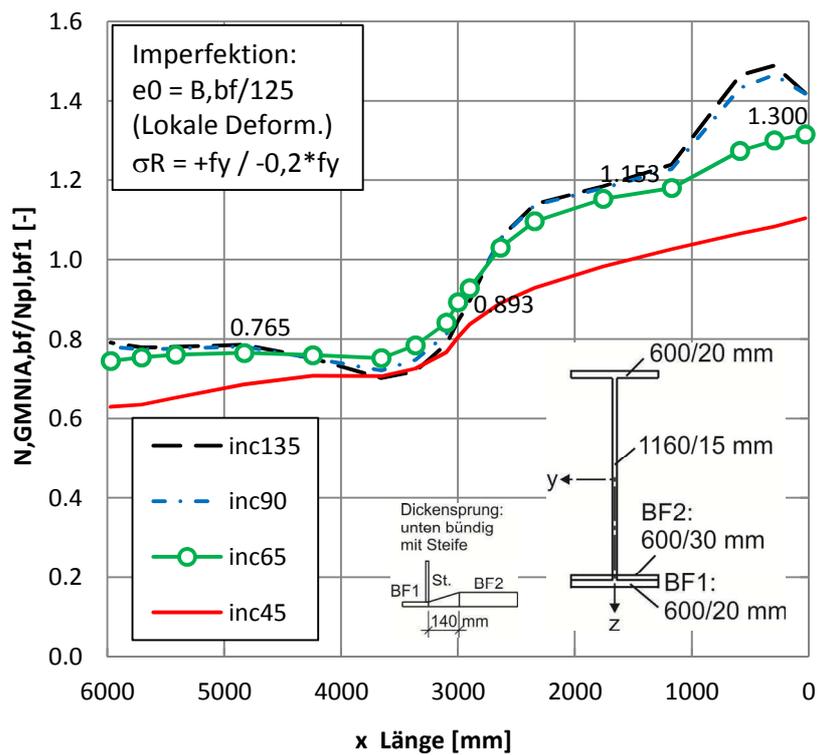


Abbildung 10: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife

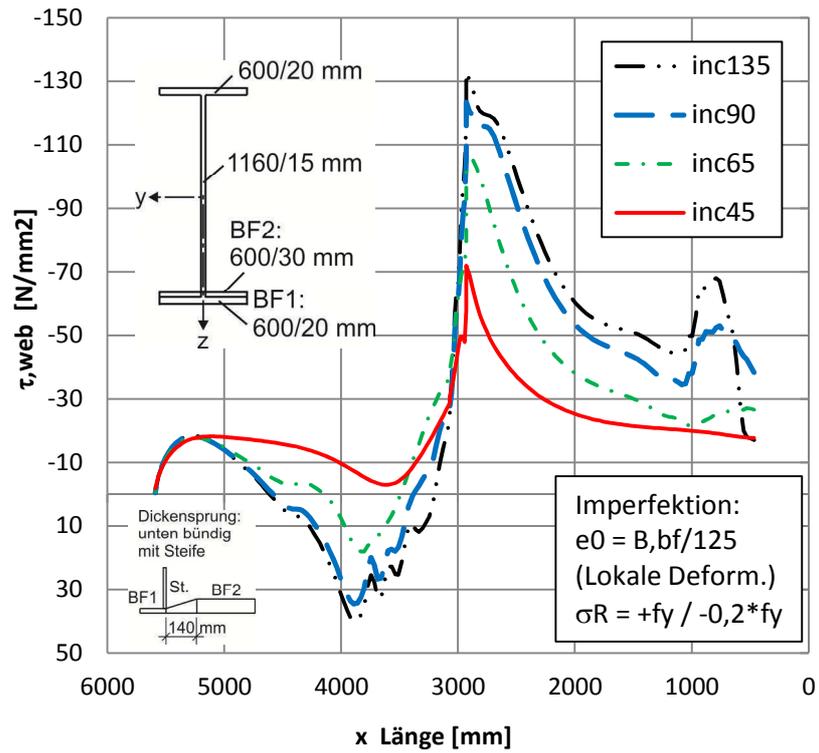


Abbildung 11: $h=1200$ mm, UB, $t_1/t_2=1.5$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 1.5$, $\alpha = 20$, e_0 , Steife

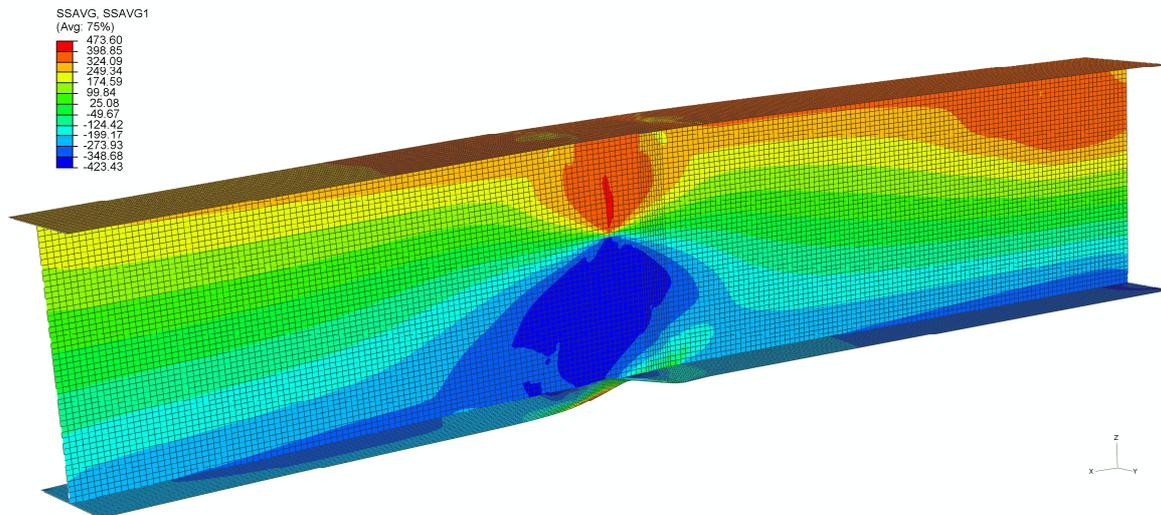


Abbildung 12: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/100$, ST, INC 255

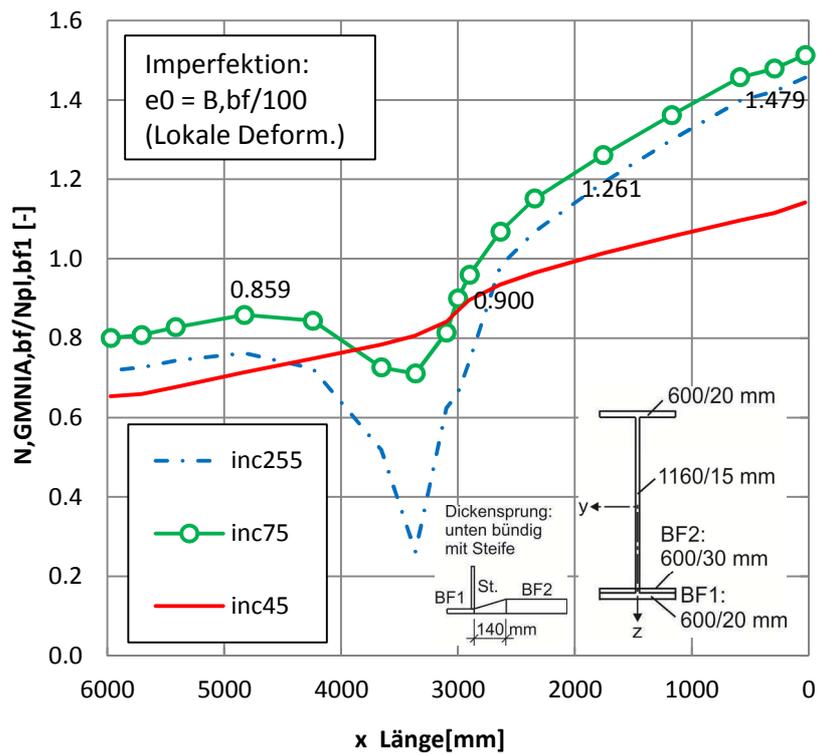


Abbildung 13: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, Untergurkräfte mit geom. Imperfektion, mit Steife

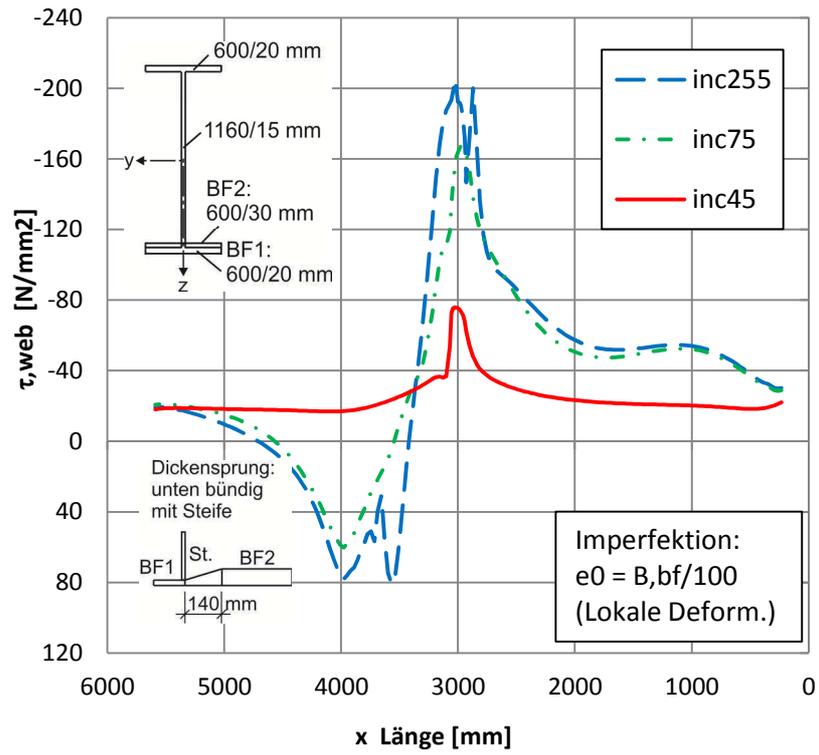


Abbildung 14: $h=1200\text{mm}$, UB, $t_1/t_2=1.5$, $\alpha=20$, Schubspannungen mit geom. Imperfektion, mit Steife

6.5.2. Träger mit Untergurtdickensprung unten bündig $t1/t2 = 3.0$
 - „Fall 12“

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$

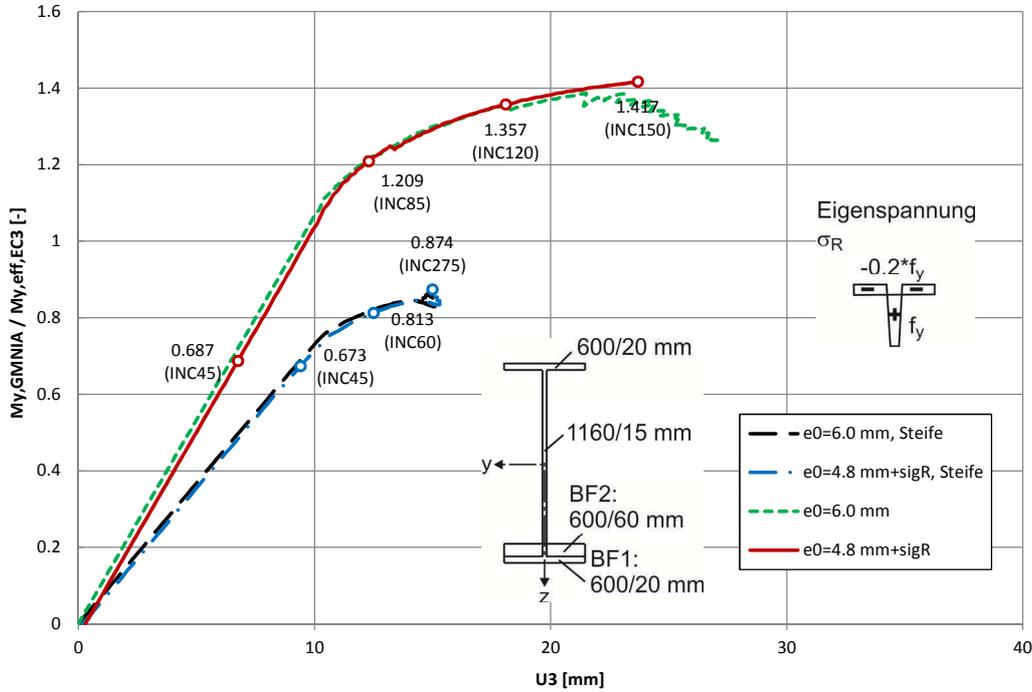


Abbildung 15: Lastverschiebungskurven, $h=1200$, UB, $t1/t2=3.0$, $\alpha=20$

| Case | My | My,GMNIA / My,eff,EC3 | Nbf | Nbf,GMNIA / Npl,eff,EC3 |
|--|---------|-----------------------|----------|-------------------------|
| | [kNm] | [-] | [kN] | [-] |
| $M_{pl,RK}$ | 7637.83 | 1.418 | -4260.00 | |
| $M_{eff,RK,EC3}$ | 5386.34 | 1.000 | -3480.03 | 0.817 |
| H1200, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma_R$ | 7632.56 | 1.417 | -3256.25 | 0.764 |
| H1200, $\alpha 20$, $t1/t2=3.0$, e_0^{100} | 7459.47 | 1.385 | -3636.09 | 0.854 |
| H1200, $\alpha 20$, $t1/t2=3.0$, $e_0^{125} + \sigma_R$, ST | 4706.47 | 0.874 | -3389.35 | 0.796 |
| H1200, $\alpha 20$, $t1/t2=3.0$, e_0^{100} , ST | 4657.02 | 0.865 | -2794.50 | 0.656 |

Abbildung 16: Vergleiche Träger $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$

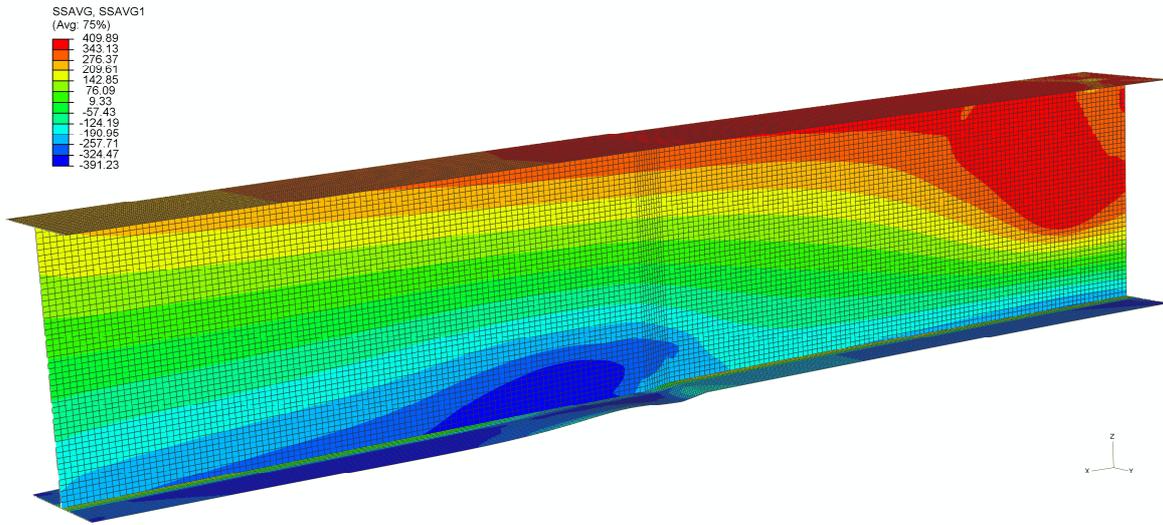


Abbildung 17: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , INC 155

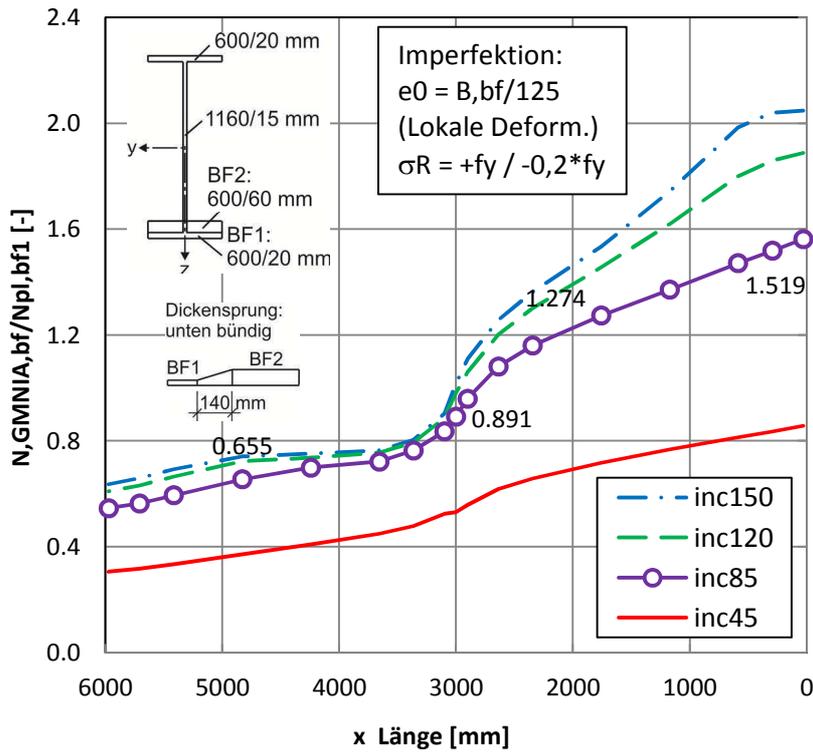


Abbildung 18: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurkräfte mit geom. Imperfektion und Eigenspannungen

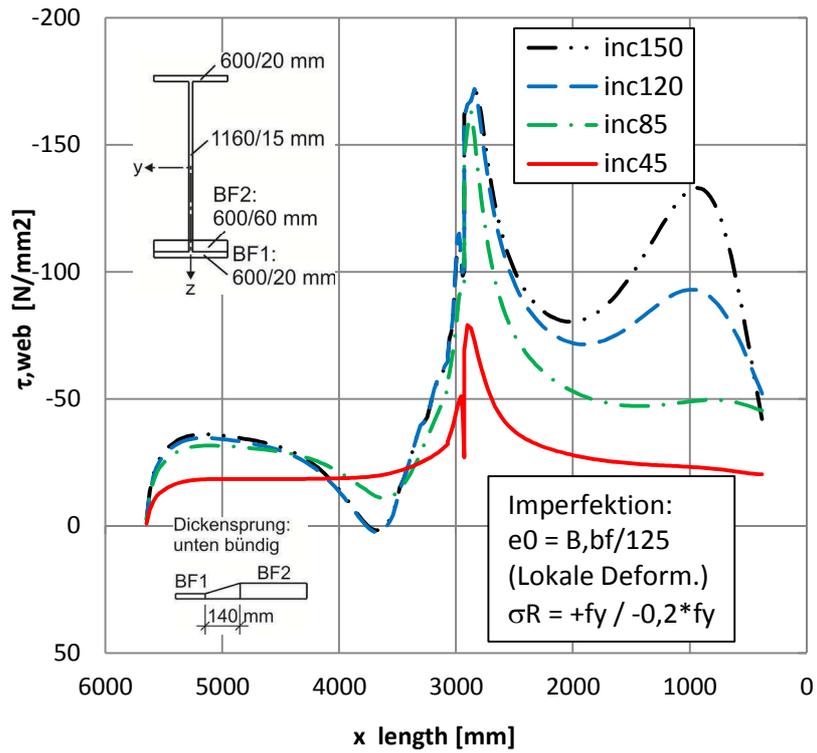


Abbildung 19: $h=1200$ mm, UB, $t_1/t_2=3.0$, $\alpha=20$, Untergurtrkräfte mit geom. Imperfektion und Eigenspannungen

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, e_0

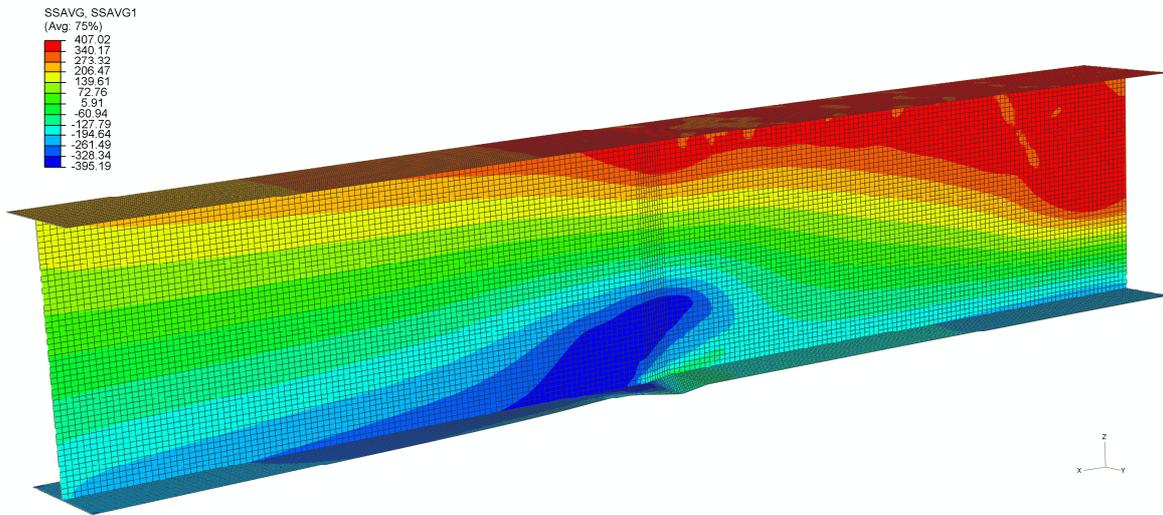


Abbildung 20: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/100$, INC 155

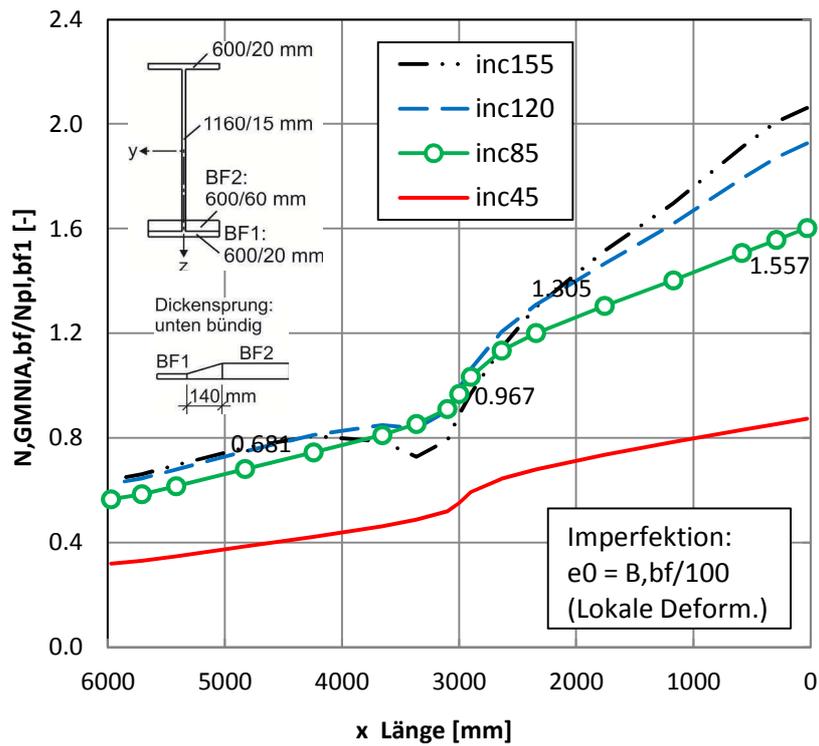


Abbildung 21: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurkräfte mit geom. Imperfektion

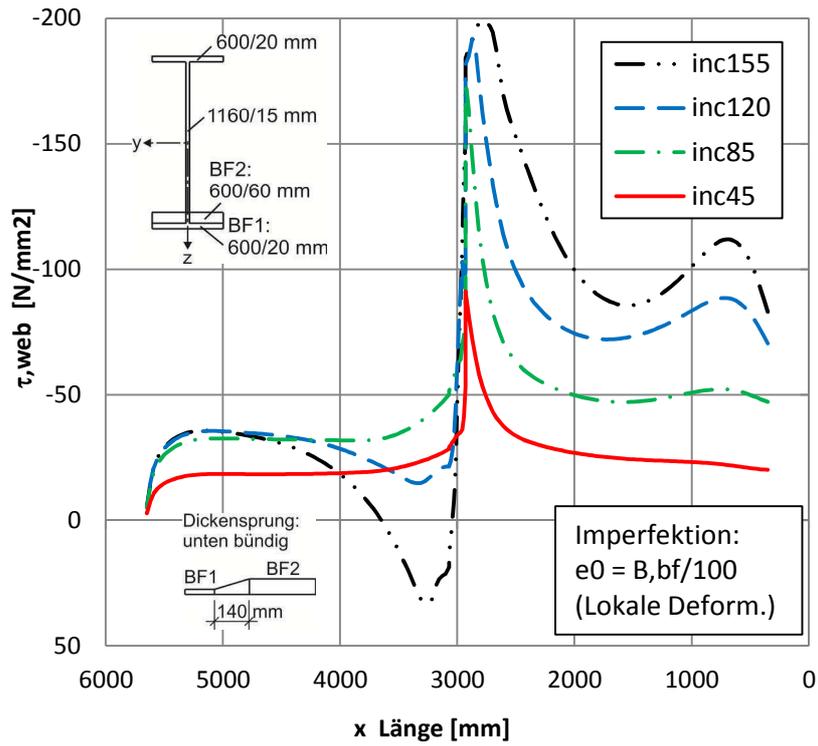


Abbildung 22: $h=1200$ mm, UB, $t_1/t_2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, $e_0 + \sigma_R$, Steife

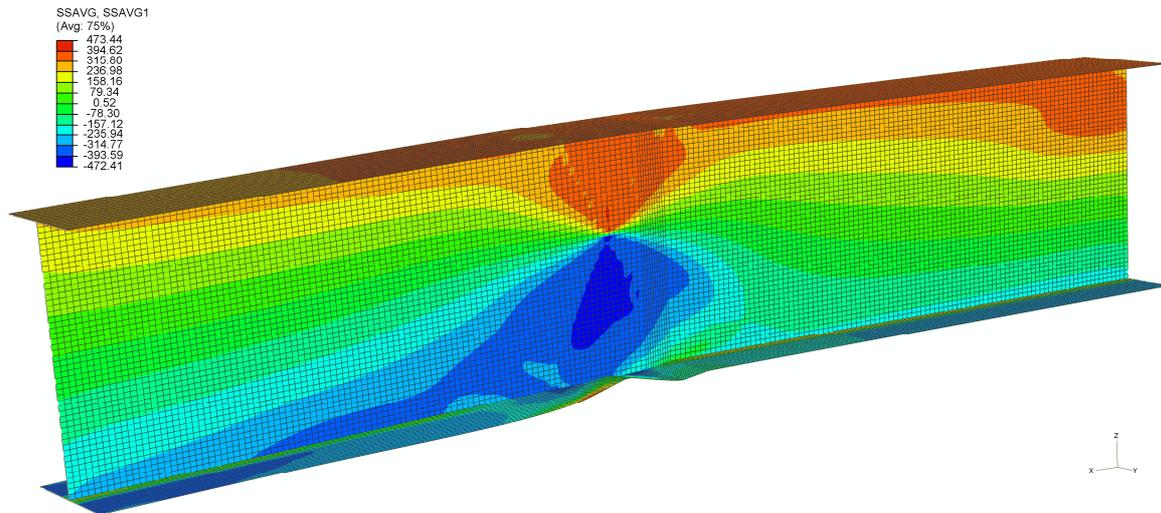


Abbildung 23: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , ST, INC 275

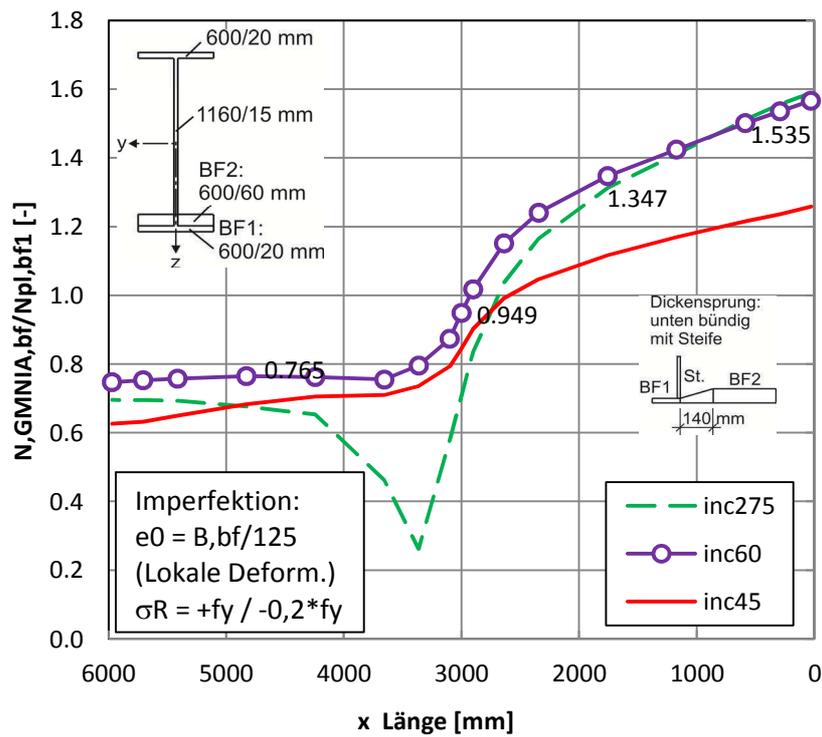


Abbildung 24: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurtrkräfte mit geom. Imperfektionen und Eigenspannungen, mit Steife

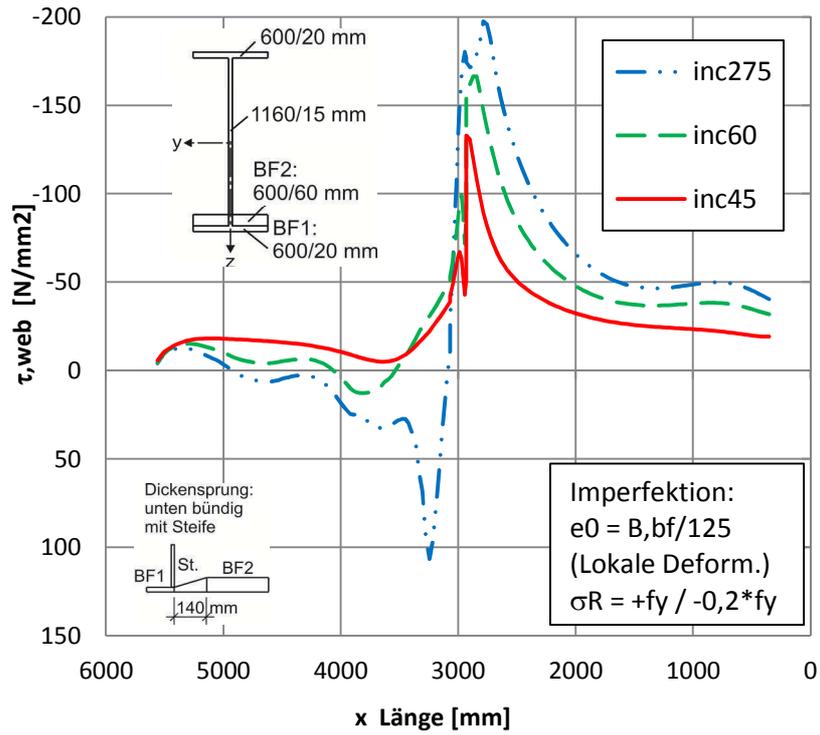


Abbildung 25: $h=1200\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=20$, Untergurkräfte mit geom. Imperfektion und Eigenspannungen, mit Steife

➤ $H = 1200 \text{ mm}$, UB, $t1/t2 = 3.0$, $\alpha = 20$, e_0 , Steife

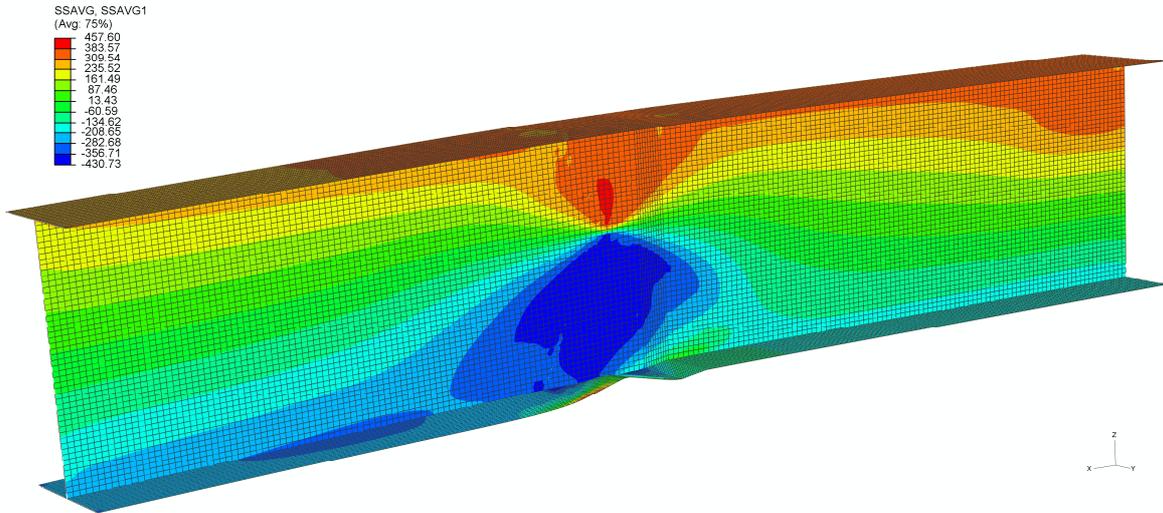


Abbildung 26: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/100$, ST, INC 275

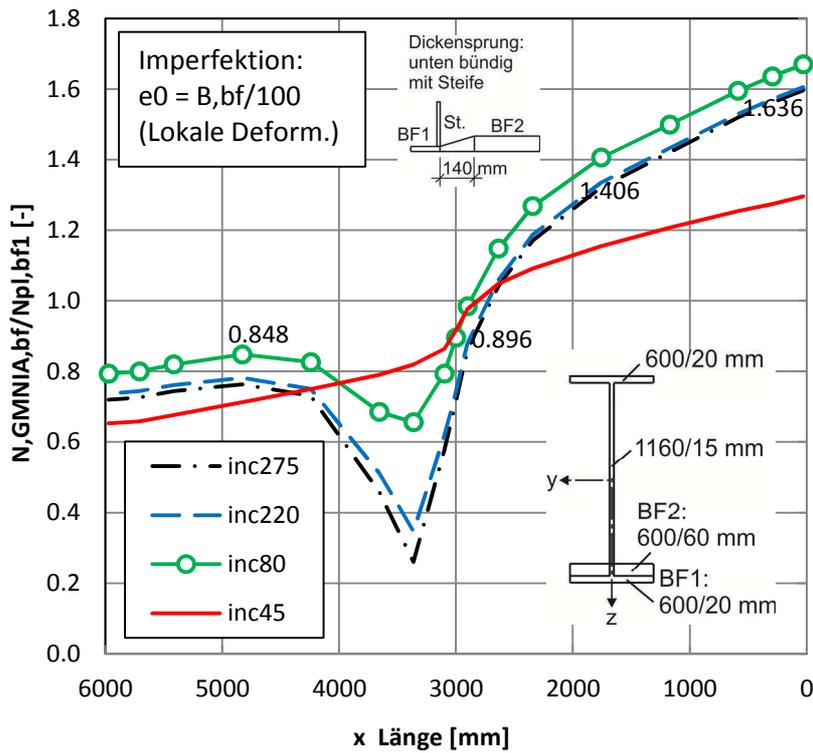


Abbildung 27: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, Untergurkräfte mit geom. Imperfektion, mit Steife

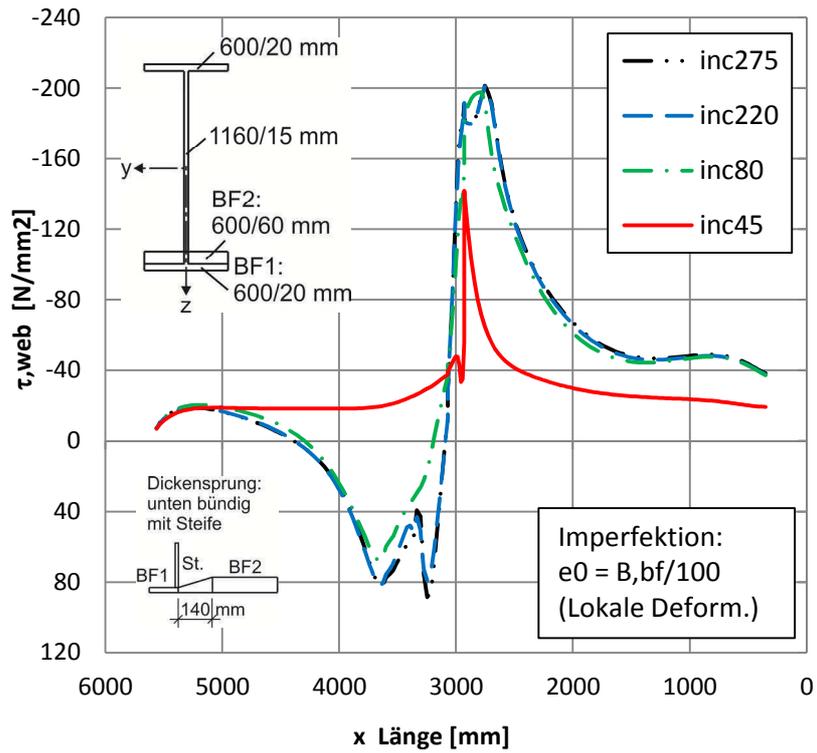


Abbildung 28: $h=1200\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=20$, Untergurtkräfte mit geom. Imperfektion, mit Steife

6.6. Nichtlineare vertikale Spannung im Steg

6.6.1. Träger H = 1200, Alpha = 20, $t_1/t_2 = 1.0$

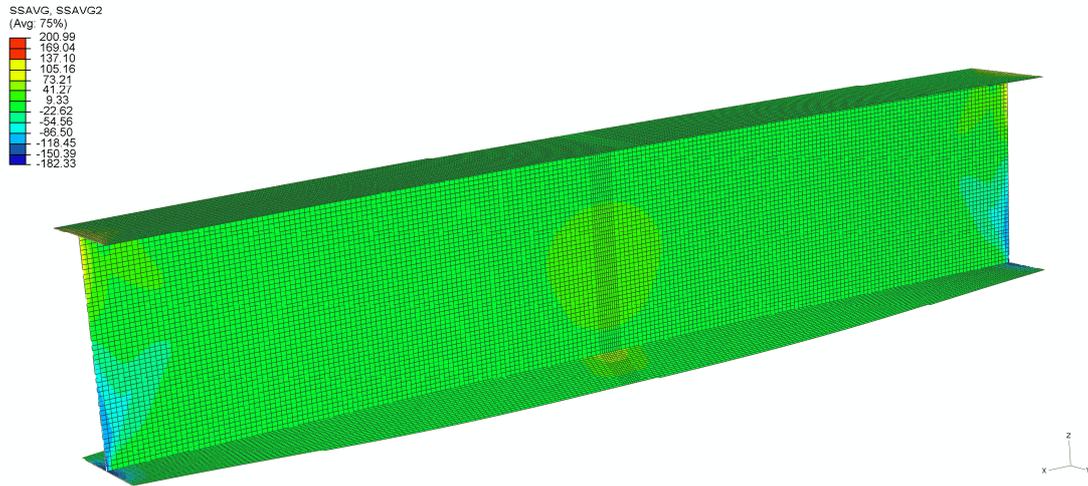


Abbildung 29: $h=1200\text{mm}$, $t_1/t_2=1.0$, $\alpha=20$, $B/125$, σ_R , INC 120

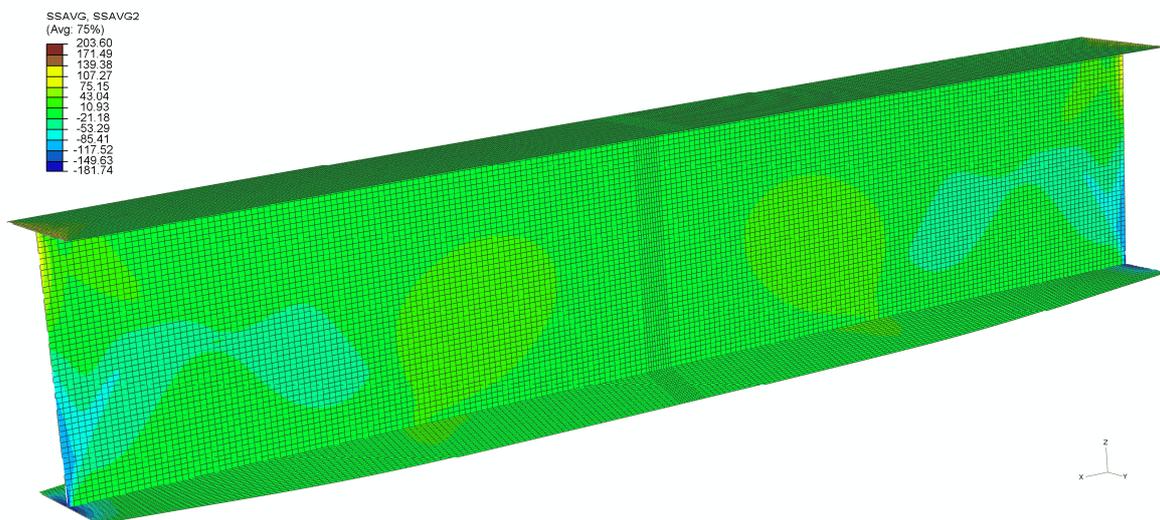


Abbildung 30: $h=1200\text{mm}$, $t_1/t_2=1.0$, $\alpha=20$, $B/100$, INC 90

6.6.2. Träger H = 1200, UB, Alpha = 20, t1/t2 = 1.5

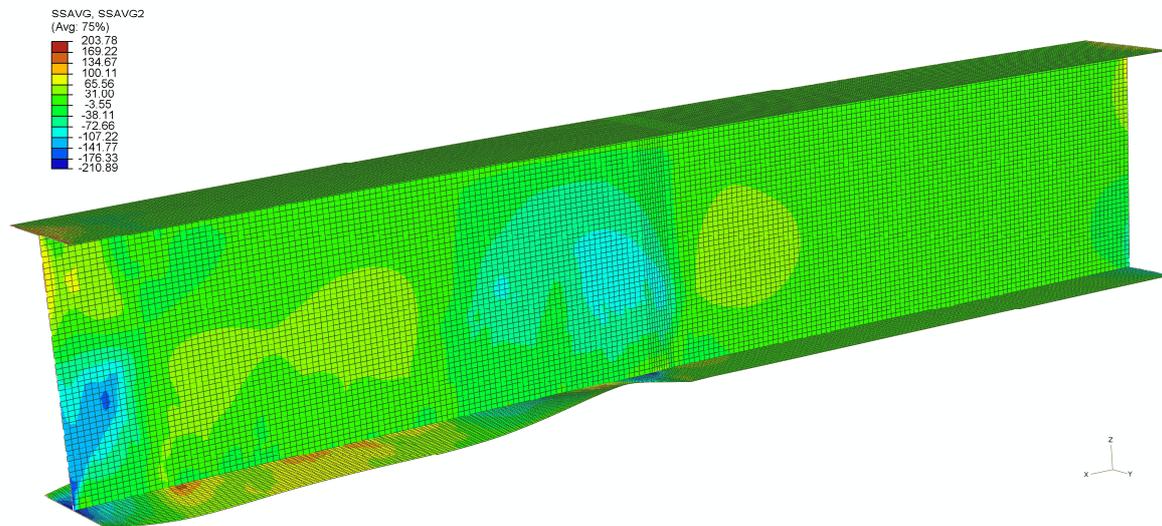


Abbildung 31: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , INC 170

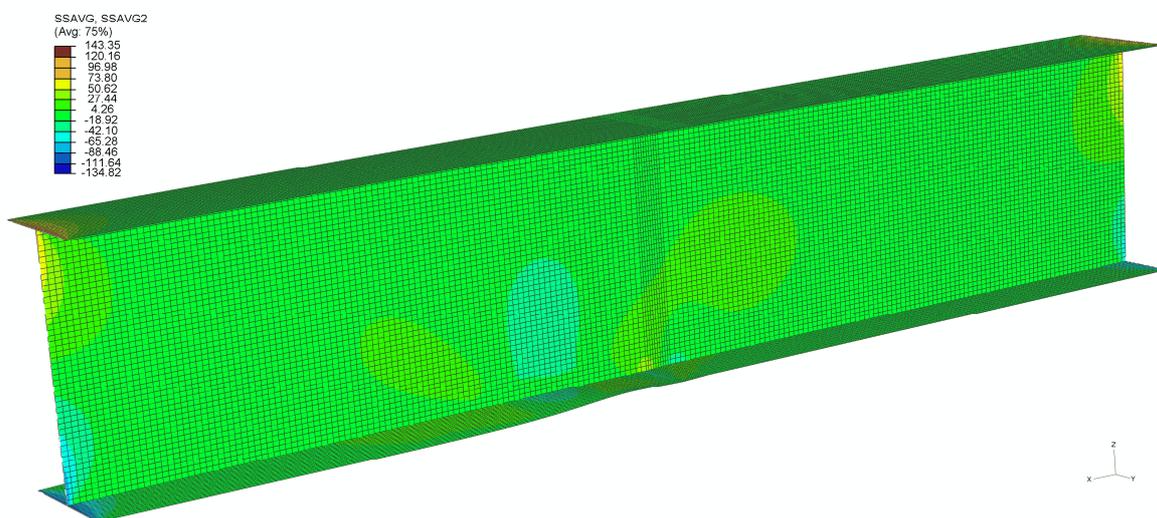


Abbildung 32: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/100$, INC 75

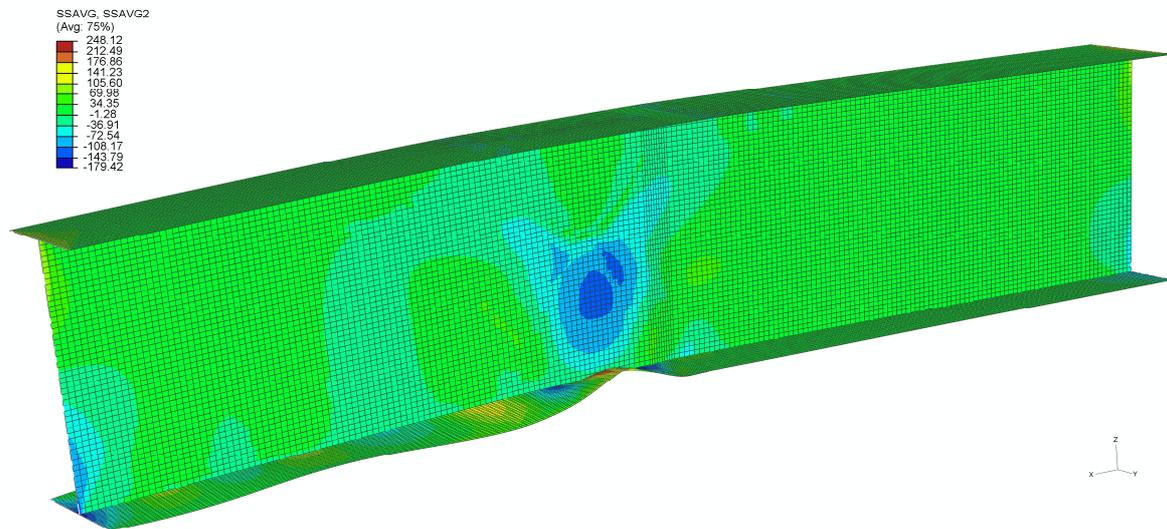


Abbildung 33: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , ST, INC 100

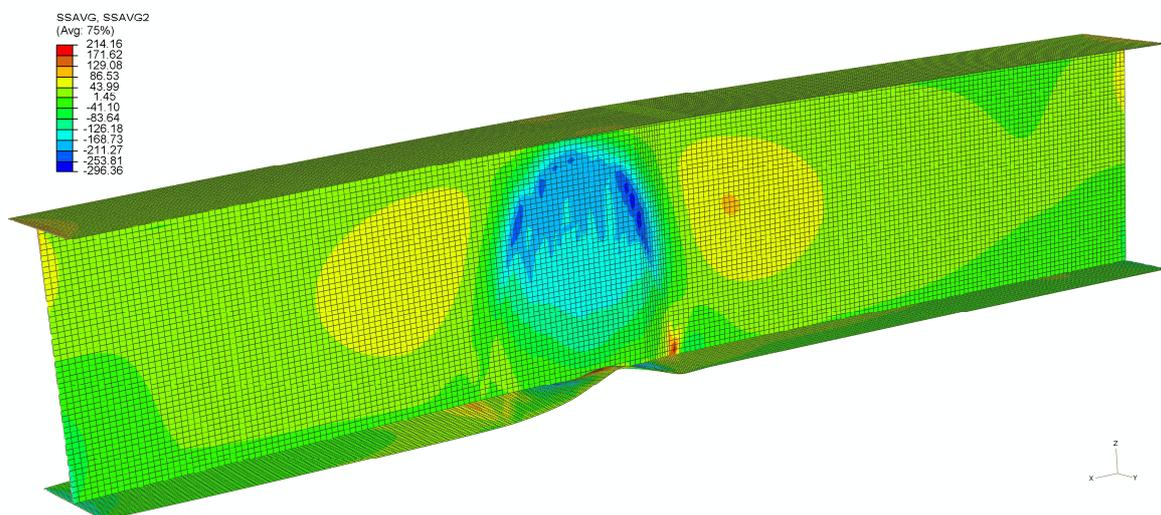


Abbildung 34: $h=1200\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/100$, ST, INC 75

6.6.3. Träger H = 1200, UB, Alpha = 20, t1/t2 = 3.0

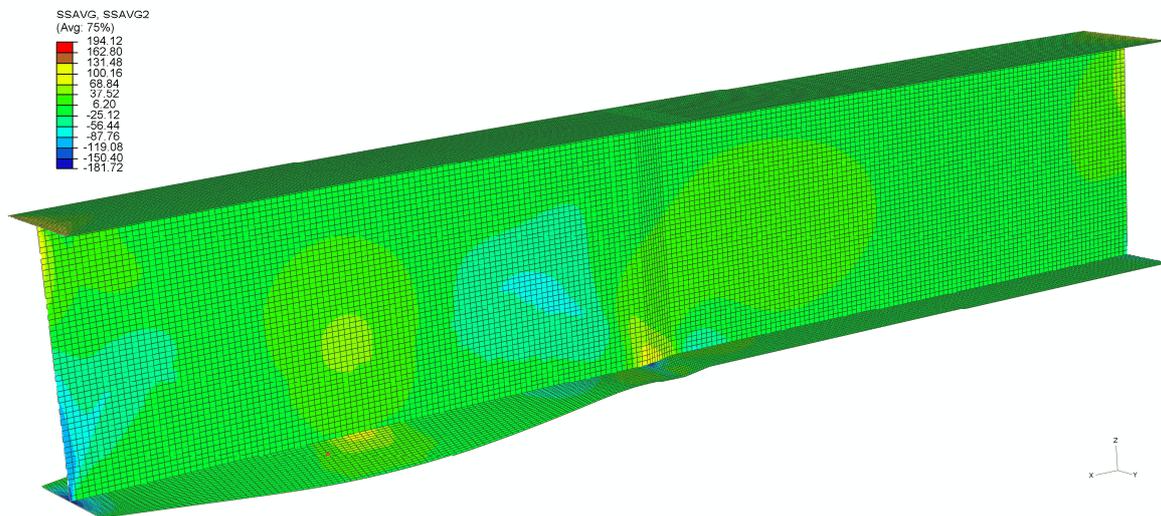


Abbildung 35: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , INC 100

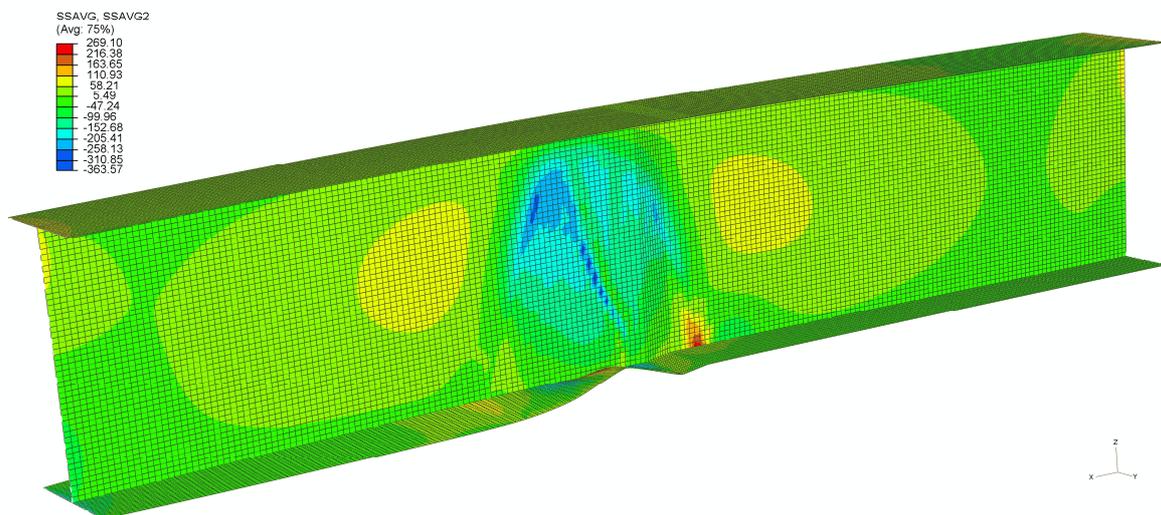


Abbildung 36: $h=1200\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/100$, INC 270

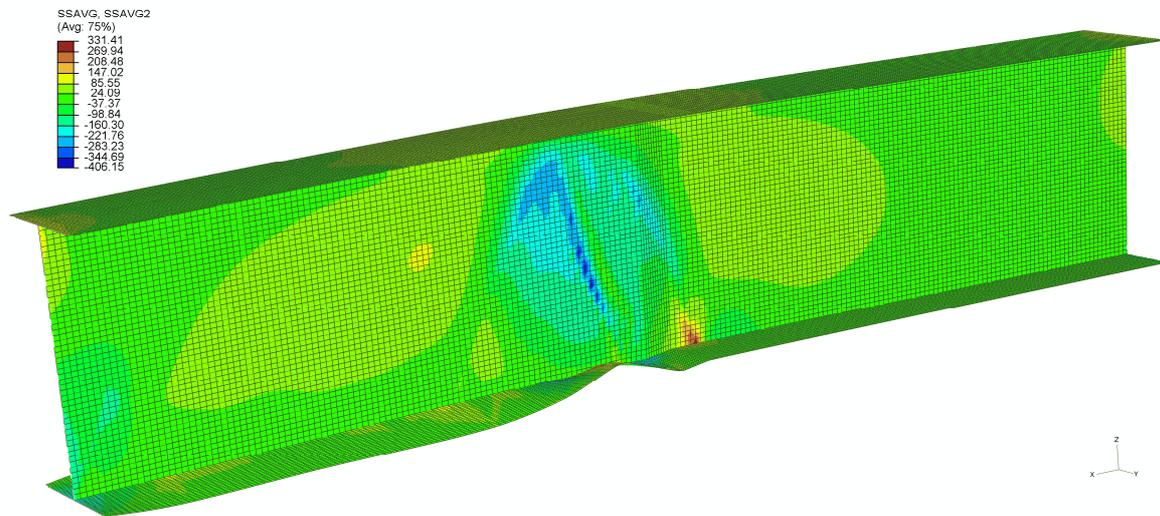


Abbildung 37: $h=1200\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=20$, $B/125$, σ_R , ST, INC 300

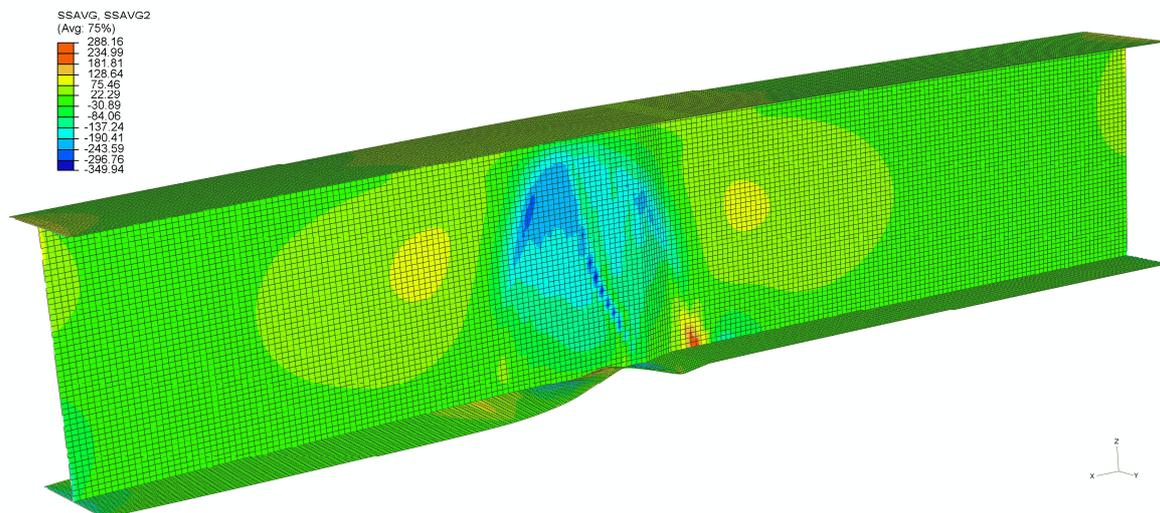


Abbildung 38: $h=1200\text{mm}$, UB, $t_1/t_2=3.0$, $\alpha=20$, $B/100$, ST, INC 270

6.6.4. Träger H = 3910, UB, Alpha = 20, t1/t2 = 1.5

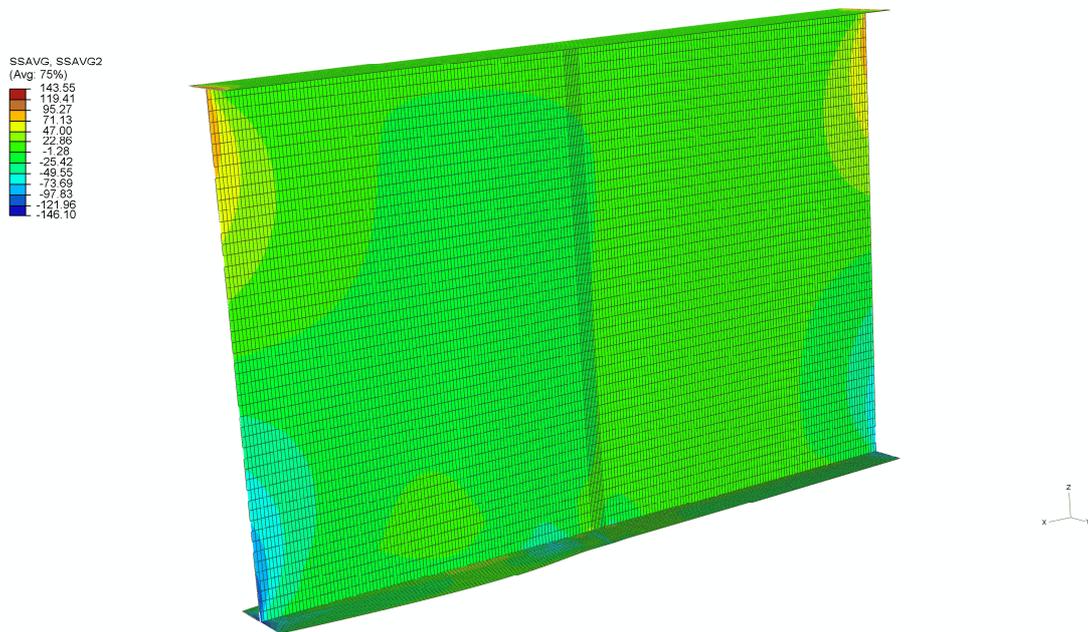


Abbildung 39: $h=3910\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R INC 420

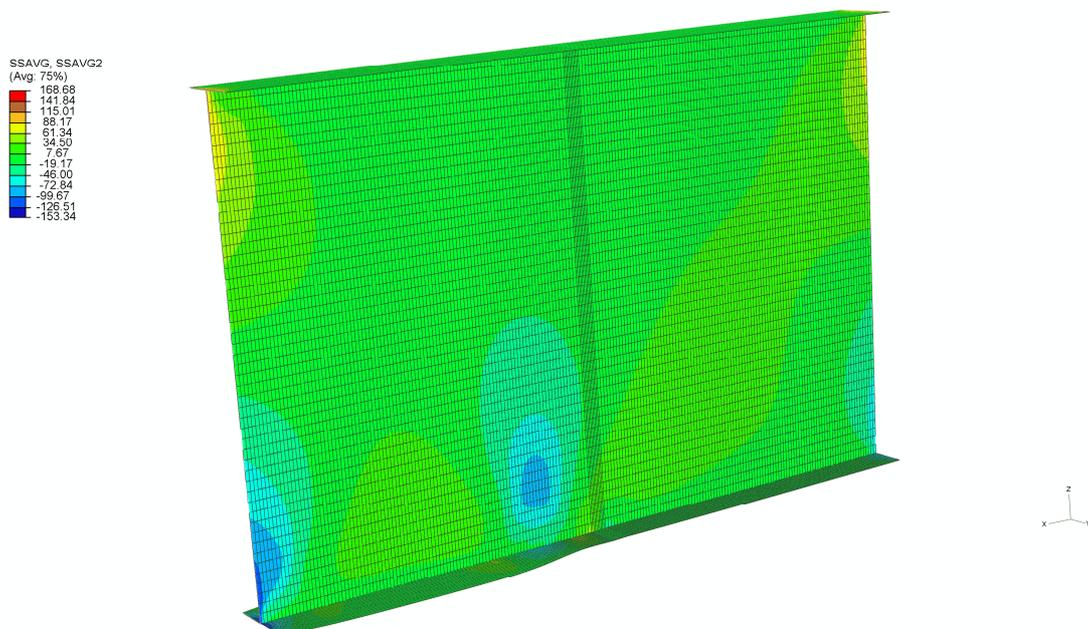


Abbildung 40: $h=3910\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/100$, INC 300

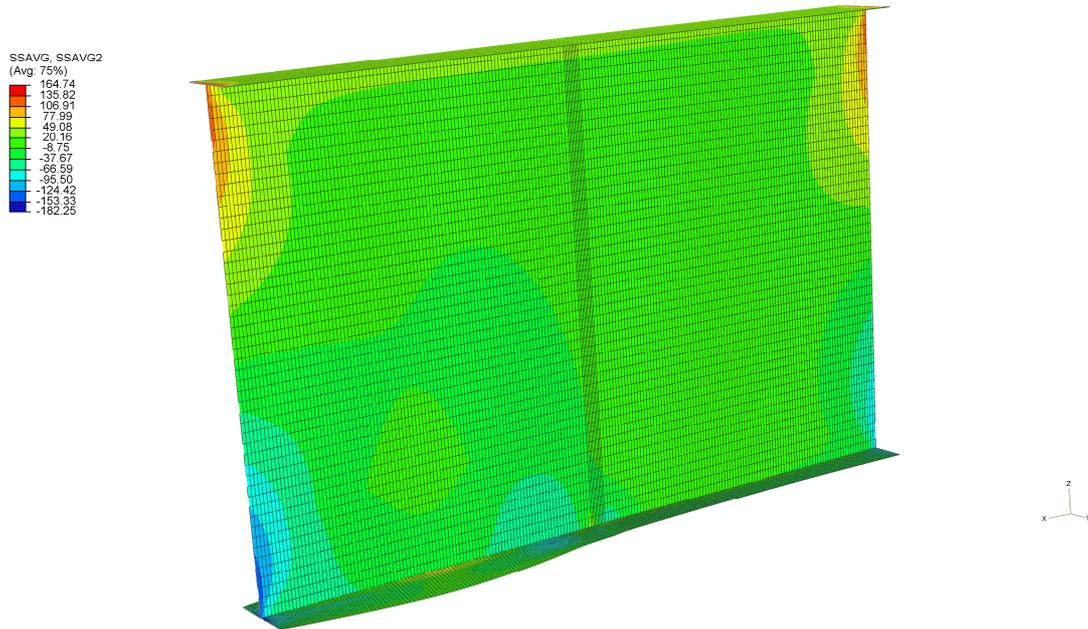


Abbildung 41: $h=3910\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/125$, σ_R , ST, INC 495

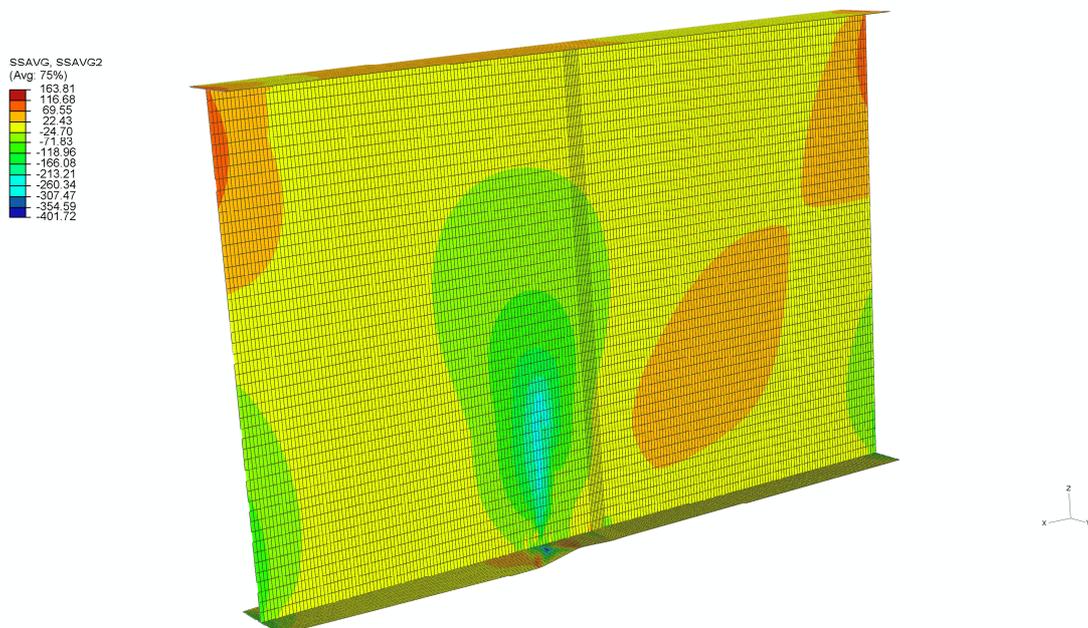


Abbildung 42: $h=3910\text{mm}$, UB, $t1/t2=1.5$, $\alpha=20$, $B/100$, ST, INC 300

6.6.5. Träger H = 3910, UB, Alpha = 20, t1/t2 = 3.0

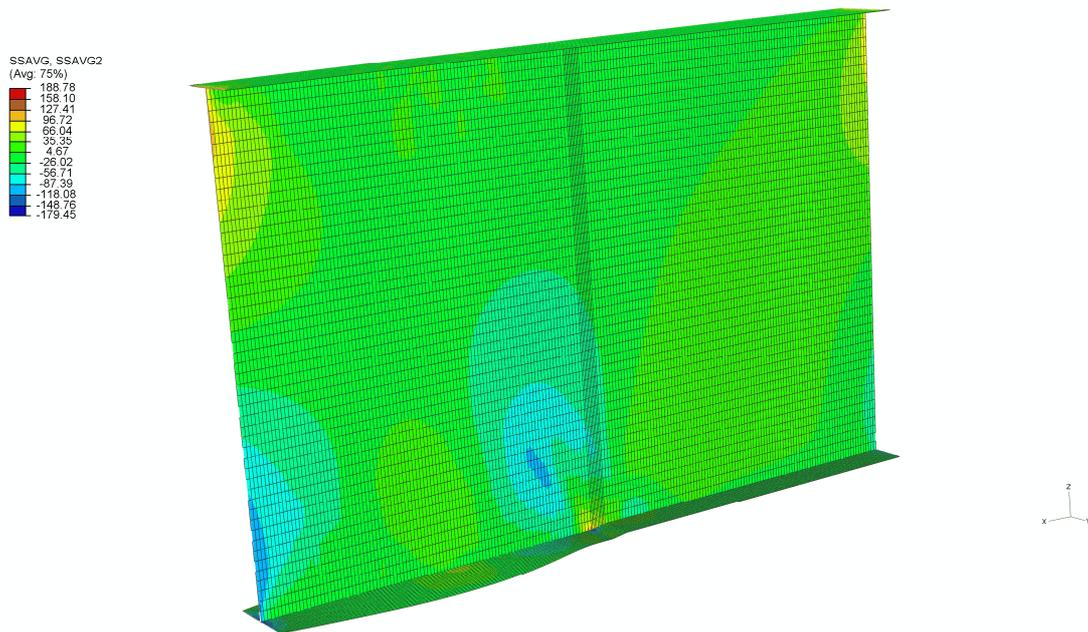


Abbildung 43: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , INC 495

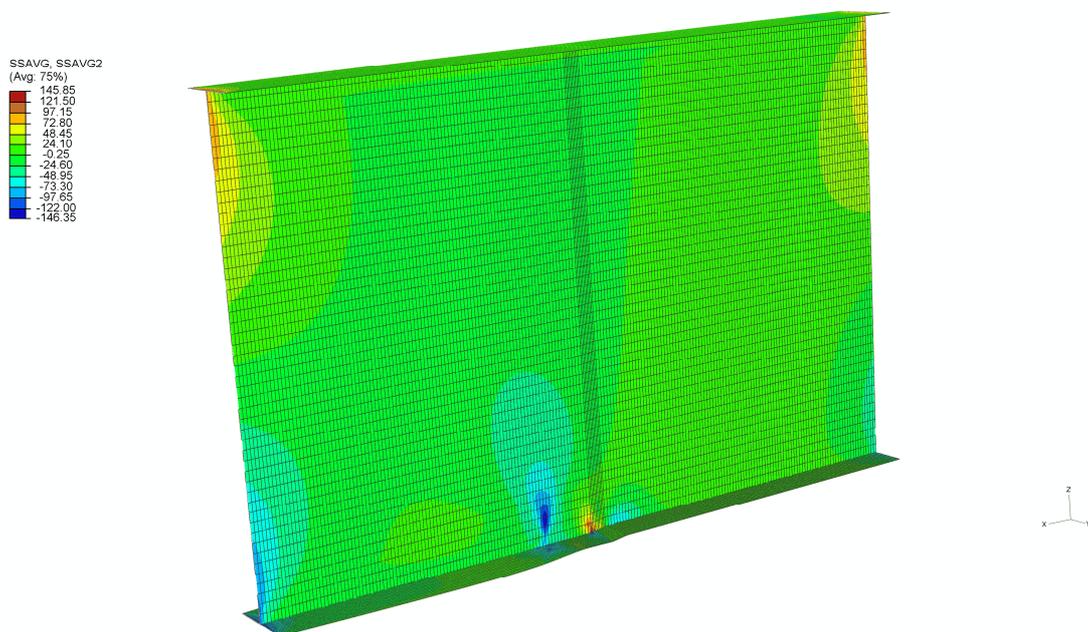


Abbildung 44: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/100$, INC 280

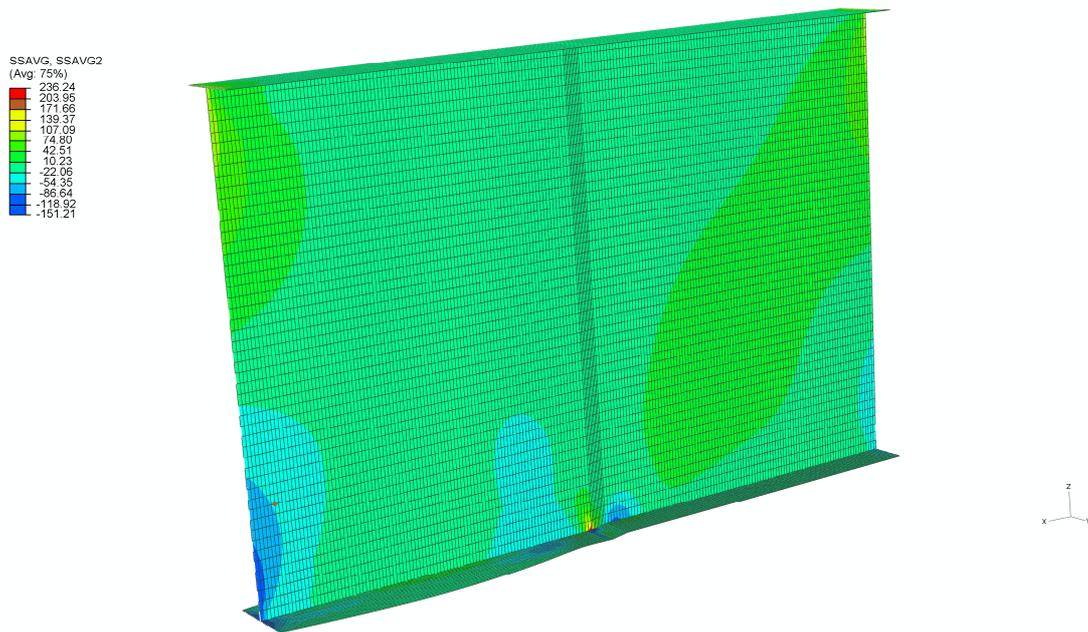


Abbildung 45: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/125$, σ_R , ST, INC 320

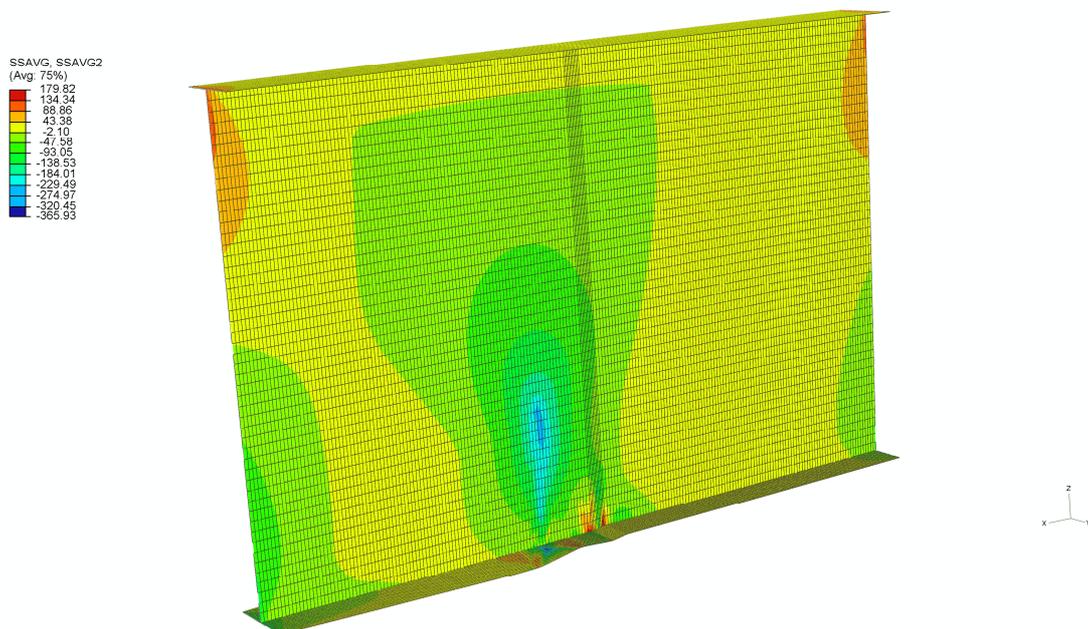


Abbildung 46: $h=3910\text{mm}$, UB, $t1/t2=3.0$, $\alpha=20$, $B/100$, ST, INC 300

7. Ergebniszusammenstellung

Tabelle 1: Zusammenstellung der nichtlinearen Ergebnisse

| | Case | UB, OB, Z | ik, im, 1.EF | My | My,GMNIA / My,eff,EC3 | Nbf | Nbf,GMNIA / Npl,eff,EC3 |
|--------|--|-----------|--------------|---------|--------------------------|----------|----------------------------|
| | | | | [kNm] | [-] | [kN] | [-] |
| | $M_{pl,RK,1200}$ | | | 7637,83 | 1,418 | -4260,00 | |
| | $M_{eff,RK,EC3,1200}$ | | | 5386,34 | 1,000 | -3480,03 | 0,817 |
| FALL 1 | H1200, $\alpha 20$, $t_1/t_2=1.0$, $e_0^{125}+\sigma R$ | | 1.EF | 4518,00 | 0,839 | -3005,23 | 0,705 |
| | H1200, $\alpha 20$, $t_1/t_2=1.0$, e_0^{100} | | 1.EF | 5733,00 | 1,064 | -3880,44 | 0,911 |
| | H1200, $\alpha 10$, $t_1/t_2=1.0$, $e_0^{125}+\sigma R$ | | 1.EF | 5103,00 | 0,947 | -3076,15 | 0,722 |
| | H1200, $\alpha 10$, $t_1/t_2=1.0$, e_0^{100} | | 1.EF | 5634,00 | 1,046 | -3776,28 | 0,886 |
| FALL 2 | H1200, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125}+\sigma R$ | UB | i_k | 6309,00 | 1,171 | -3265,55 | 0,767 |
| | H1200, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} | UB | i_k | 5958,00 | 1,106 | -3692,58 | 0,867 |
| | H1200, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125}+\sigma R$, ST | UB | i_k | 6498,01 | 1,206 | -3328,53 | 0,781 |
| | H1200, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} , ST | UB | i_k | 6444,01 | 1,196 | -3055,84 | 0,717 |
| | H1200, $\alpha 10$, $t_1/t_2=1.5$, $e_0^{125}+\sigma R$ | UB | i_k | 5994,00 | 1,113 | -3403,51 | 0,799 |
| | H1200, $\alpha 10$, $t_1/t_2=1.5$, e_0^{100} | UB | i_k | 5859,00 | 1,088 | -3800,96 | 0,892 |
| | H1200, $\alpha 10$, $t_1/t_2=1.5$, $e_0^{125}+\sigma R$, ST | UB | i_k | 7650,01 | 1,420 | -3520,32 | 0,826 |
| | H1200, $\alpha 10$, $t_1/t_2=1.5$, e_0^{100} , ST | UB | i_k | 7038,01 | 1,307 | -3801,76 | 0,892 |
| FALL 3 | H1200, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125}+\sigma R$ | OB | i_k | 5985,00 | 1,111 | -3311,85 | 0,777 |
| | H1200, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} | OB | i_k | 6327,00 | 1,175 | -3692,63 | 0,867 |
| | H1200, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125}+\sigma R$, ST | OB | i_k | 6786,01 | 1,260 | -3253,82 | 0,764 |
| | H1200, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} , ST | OB | i_k | 7029,01 | 1,305 | -3419,52 | 0,803 |
| FALL 4 | H1200, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125}+\sigma R$ | Z | i_k | 5841,00 | 1,084 | -3015,58 | 0,708 |
| | H1200, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} | Z | i_k | 6831,01 | 1,268 | -3687,58 | 0,866 |
| | H1200, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125}+\sigma R$, ST | Z | i_k | 6831,01 | 1,268 | -3204,28 | 0,752 |
| | H1200, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} , ST | Z | i_k | 7011,01 | 1,302 | -3063,34 | 0,719 |
| FALL 5 | H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$ | UB | i_k | 6174,00 | 1,146 | -3283,67 | 0,771 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} | UB | i_k | 6849,01 | 1,272 | -3758,18 | 0,882 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$, ST | UB | i_k | 6867,01 | 1,275 | -3259,51 | 0,765 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} , ST | UB | i_k | 6858,01 | 1,273 | -3755,44 | 0,882 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$ | UB | i_k | 6327,00 | 1,175 | -3627,62 | 0,852 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} | UB | i_k | 6066,00 | 1,126 | -3886,32 | 0,912 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$, ST | UB | i_k | 6885,01 | 1,278 | -3376,05 | 0,792 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} , ST | UB | i_k | 7560,01 | 1,404 | -3846,32 | 0,903 |
| FALL 6 | H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$ | OB | i_k | 6993,01 | 1,298 | -3314,61 | 0,778 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} | OB | i_k | 6030,00 | 1,119 | -3717,89 | 0,873 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$, ST | OB | i_k | 7011,01 | 1,302 | -3350,54 | 0,787 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} , ST | OB | i_k | 6993,01 | 1,298 | -3463,57 | 0,813 |
| FALL 7 | H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$ | Z | i_k | 7191,01 | 1,335 | -3260,56 | 0,765 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} | Z | i_k | 7029,01 | 1,305 | -3646,76 | 0,856 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$, ST | Z | i_k | 7164,01 | 1,330 | -3206,14 | 0,753 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} , ST | Z | i_k | 7119,01 | 1,322 | -3467,04 | 0,814 |

| | Case | UB, OB, Z | ik, im, 1.EF | My | My,GMNIA / | Nbf | Nbf,GMNIA / |
|---------|--|-------------------|--------------|----------|------------|----------|-------------|
| | | | | [kNm] | My,eff,EC3 | [kN] | Npl,eff,EC3 |
| | $M_{pl,RK,1200}$ | | | 7637,83 | 1,418 | -4260,00 | |
| | $M_{eff,RK,EC3,1200}$ | | | 5386,34 | 1,000 | -3480,03 | 0,817 |
| FALL 8 | H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$ | UB | i_m | 5940,00 | 1,103 | -3266,08 | 0,767 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} | UB | i_m | 6066,00 | 1,126 | -3633,94 | 0,853 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$, ST | UB | i_m | 6471,01 | 1,201 | -3222,50 | 0,756 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} , ST | UB | i_m | 7317,01 | 1,358 | -3688,98 | 0,866 |
| FALL 11 | H1200, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125}+\sigma R$ | UB, $\psi=0.2f_y$ | i_k | 7583,11 | 1,408 | -3100,56 | 0,728 |
| | H1200, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} | UB, $\psi=0.2f_y$ | i_k | 7418,26 | 1,377 | -3553,54 | 0,834 |
| | H1200, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125}+\sigma R$, ST | UB, $\psi=0.2f_y$ | i_k | 4689,99 | 0,871 | -3342,39 | 0,785 |
| | H1200, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} , ST | UB, $\psi=0.2f_y$ | i_k | 4558,11 | 0,846 | -3027,79 | 0,711 |
| FALL 12 | H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$ | UB, $\psi=0.2f_y$ | i_k | 7632,56 | 1,417 | -3256,25 | 0,764 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} | UB, $\psi=0.2f_y$ | i_k | 7459,47 | 1,385 | -3636,09 | 0,854 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$, ST | UB, $\psi=0.2f_y$ | i_k | 4706,47 | 0,874 | -3389,35 | 0,796 |
| | H1200, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} , ST | UB, $\psi=0.2f_y$ | i_k | 4657,02 | 0,865 | -2794,50 | 0,656 |
| | $M_{pl,RK,3910}$ | | | 34308,86 | 1,382 | -4260,00 | |
| | $M_{eff,RK,EC3,3910}$ | | | 24825,51 | 1,000 | -3480,03 | 0,817 |
| FALL 9 | H3910, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125}+\sigma R$ | UB | i_k | 29159,99 | 1,175 | -3270,72 | 0,768 |
| | H3910, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} | UB | i_k | 26406,00 | 1,064 | -3637,60 | 0,854 |
| | H3910, $\alpha 20$, $t_1/t_2=1.5$, $e_0^{125}+\sigma R$, ST | UB | i_k | 31859,99 | 1,283 | -3307,63 | 0,776 |
| | H3910, $\alpha 20$, $t_1/t_2=1.5$, e_0^{100} , ST | UB | i_k | 30239,99 | 1,218 | -3747,01 | 0,880 |
| FALL 10 | H3910, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$ | UB | i_k | 28349,99 | 1,142 | -3221,27 | 0,756 |
| | H3910, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} | UB | i_k | 29699,99 | 1,196 | -3784,90 | 0,888 |
| | H3910, $\alpha 20$, $t_1/t_2=3.0$, $e_0^{125}+\sigma R$, ST | UB | i_k | 30239,99 | 1,218 | -3450,12 | 0,810 |
| | H3910, $\alpha 20$, $t_1/t_2=3.0$, e_0^{100} , ST | UB | i_k | 32399,99 | 1,305 | -3605,34 | 0,846 |

8. Zusammenfassung und Schlussfolgerung

In dieser Arbeit wurden ideales Plattenbeulen und nichtlineares Beultragverhalten von dreiseitig gelenkig gelagerten Rechteckplatten sowie als Hauptteil dieser Arbeit an baupraktisch üblichen I-Profil Trägern mit Gurtdickensprüngen am gedrückten Gurt in vielen Variationen in Form einer umfangreichen Parameterstudie durchgeführt.

Als Ergebnis dieser Arbeit kann die Bereitstellung nahezu aller erforderlichen Daten für die Ausarbeitung von neuen Bemessungsregeln welche das Stabilitätstragverhalten im Bereich von Gurtdickensprüngen genauer regeln sollen.

Die Wirkung von aussteifenden Elementen in Form von flanschinnenseitig eingeschweißten Quersteifen an der Unstetigkeitsstelle wurde in dieser Parameterstudie ebenso erfasst.

Graz, Juni 2010

Michael Tillian

QUELLENVERZEICHNIS

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- [3] *ÖNORM EN1993-1-1: Eurocode 3: Bemessung und Konstruktion von Stahlbauten, Teil-1-1: Allgemeine Bemessungsregeln und Regeln für den Hochbau, 2007*
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Anhang A

a. Querschnittswerte Träger H = 1200 mm

Spannungsermittlung geschweißter I - Träger

Träger Abmessungen:

| | |
|--------------|----------|
| b UG= | 60.0 cm |
| t UG= | 2.0 cm |
| b OG= | 60.0 cm |
| t OG= | 2.0 cm |
| h Web= | 116.0 cm |
| t Web= | 1.5 cm |
| Einbind. UG= | 1.0 cm |
| Einbind. OG= | 1.0 cm |

Belastung:

M= -6000 kNm

Stahl: S355 355 N/mm²

Querschnittswerte:

| | Bez | b [cm] | h [cm] | A [cm ²] | e [cm] | A*e [cm ³] | A*e ² [cm ⁴] | J _{y,0} [cm ⁴] | J _z [cm ⁴] |
|---------------|-------------|-----------|-----------|-------------------------|-----------|---------------------------|--|--|--------------------------------------|
| 1 | Einbind. UG | 1.5 | 1.0 | 1.50 | 1.5 | 2.25 | 3.38 | 0.13 | 0.28 |
| 2 | Einbind. OG | 1.5 | 1.0 | 1.50 | 118.5 | 177.75 | 21063.38 | 0.13 | 0.28 |
| 3 | OG | 60.00 | 2.00 | 120.00 | 119.00 | 14280.00 | 1699320.00 | 40.00 | 36000.00 |
| 4 | Steg | 1.50 | 116.00 | 174.00 | 60.00 | 10440.00 | 626400.00 | 195112.00 | 32.63 |
| 5 | UG | 60.00 | 2.00 | 120.00 | 1.00 | 120.00 | 120.00 | 40.00 | 36000.00 |
| Zwischensumme | | | 120.00 | 417.00 | | 25020.00 | 2346906.75 | 195192.25 | 72033.19 |

z_s= 60.0 cm

y_s= 0.0 cm

J_{y,ges}= 1040899.0 cm⁴

J_{z,ges}= 72033.2 cm⁴

W_{y,OG}= -17348.3 cm³

W_{y,UG}= 17348.3 cm³

σ_o= 345.9 N/mm²

σ_u= -345.9 N/mm²

σ_{o,m}= 340.1 N/mm²

σ_{u,m}= -340.1 N/mm²

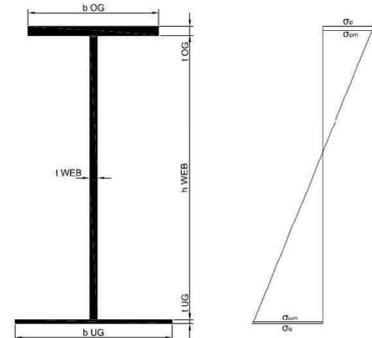


Abbildung 271: Spannungsermittlung geschweißter I-Profil Träger H = 1200 mm

Berechnung der crit Beulspannungen σ_{crit} :

$\sigma_{crit} = k_{\sigma} \cdot \sigma_e$

sig_Euler = 189800.085 N/mm²

fyk = 355 N/mm²

$\sigma_e = 189800 \cdot (t/b)^2$

E [N/mm²] =

210000 nue [-]=

0.3

| # | t [mm] | b [mm] | k_{σ} [-] | σ_e [N/mm ²] | σ_{crit} [N/mm ²] | $\lambda_p = \sqrt{\frac{f_{yk}}{\sigma_{crit}}}$ | rho 3-seitige Platte |
|--------------------|--------|--------|------------------|---------------------------------|--------------------------------------|---|----------------------|
| Flange UG gelenkig | 20.00 | 300.00 | 0.43 | 843.56 | 358.51 | 0.99509093 | 0.8151 |

a/b = 20:

| | | | | | | | |
|--------------------|-------|--------|--------|--------|--------|------------|--------|
| Flange UG gelenkig | 20.00 | 300.00 | 0.4275 | 843.56 | 360.62 | 0.99217705 | 0.8169 |
|--------------------|-------|--------|--------|--------|--------|------------|--------|

a/b = 20:

| | | | | | | | |
|--------------------|-------|--------|--------|---------|--------|------------|--------|
| Flange UG gelenkig | 30.00 | 300.00 | 0.4275 | 1898.00 | 811.40 | 0.66145136 | 1.0000 |
|--------------------|-------|--------|--------|---------|--------|------------|--------|

a/b = 20:

| | | | | | | | |
|--------------------|-------|--------|--------|---------|---------|------------|--------|
| Flange UG gelenkig | 60.00 | 300.00 | 0.4275 | 7592.00 | 3245.58 | 0.33072568 | 1.0000 |
|--------------------|-------|--------|--------|---------|---------|------------|--------|

Abbildung 272: Berechnung der Beulspannung σ_{crit}

Spannungsermittlung geschweißter I - Träger

Träger Abmessungen:

| | |
|--------------|----------|
| b UG= | 60.0 cm |
| t UG= | 2.0 cm |
| b OG= | 60.0 cm |
| t OG= | 2.0 cm |
| h Web= | 116.0 cm |
| t Web= | 1.5 cm |
| Einbind. UG= | 1.0 cm |
| Einbind. OG= | 1.0 cm |

Belastung:

M= -6000 kNm

Stahl: S355 355 N/mm²

rho_UG,EC3= 0.81690833

Querschnittswerte:

| | Bez | b [cm] | h [cm] | A [cm ²] | e [cm] | A*e [cm ³] | A*e ² [cm ⁴] | J _{y,0} [cm ⁴] | J _z [cm ⁴] |
|---------------|-------------|---------|--------|----------------------|--------|------------------------|-------------------------------------|-------------------------------------|-----------------------------------|
| 1 | Einbind. UG | 1.5 | 1.0 | 1.50 | 1.5 | 2.25 | 3.38 | 0.13 | 0.28 |
| 2 | Einbind. OG | 1.5 | 1.0 | 1.50 | 118.5 | 177.75 | 21063.38 | 0.13 | 0.28 |
| 3 | OG | 60.00 | 2.00 | 120.00 | 119.00 | 14280.00 | 1699320.00 | 40.00 | 36000.00 |
| 4 | Steg | 1.50 | 116.00 | 174.00 | 60.00 | 10440.00 | 626400.00 | 195112.00 | 32.63 |
| 5 | UG | 49.0145 | 2.00 | 98.03 | 1.00 | 98.03 | 98.03 | 32.68 | 19625.58 |
| Zwischensumme | | | 120.00 | 395.03 | | 24998.03 | 2346884.78 | 195184.93 | 55658.77 |

z_s = 63.3 cm

z_o = -56.718 cm

y_s = 0.0 cm

z_u = 63.282 cm

J_{y,ges} = 960156.8 cm⁴

J_{z,ges} = 55658.8 cm⁴

W_{y,OG} = -16928.5 cm³

W_{y,UG} = 15172.8 cm³

W_{y,OGm} = -16635.2 cm³

W_{y,UGm} = 15416.4 cm³

σ_o = 354.4 N/mm²

σ_u = -395.4 N/mm²

$\sigma_{o,m}$ = 360.7 N/mm²

$\sigma_{u,m}$ = -389.2 N/mm²

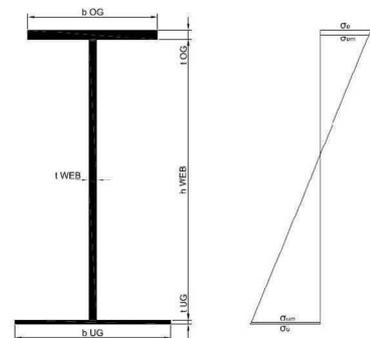


Abbildung 273: Effektive Spannungsermittlung geschweißter I-Profil Träger H = 1200 mm

b. Querschnittswerte Träger H = 3910 mm

Spannungsermittlung geschweißter I - Träger

Träger Abmessungen:

| | | |
|--------------|-------|----|
| b UG= | 60.0 | cm |
| t UG= | 2.0 | cm |
| b OG= | 60.0 | cm |
| t OG= | 2.0 | cm |
| h Web= | 387.0 | cm |
| t Web= | 1.2 | cm |
| Einbind. UG= | 1.0 | cm |
| Einbind. OG= | 1.0 | cm |

Belastung:

M= -6000 kNm

Stahl: S355 355 N/mm²

Querschnittswerte:

| | Bez | b [cm] | h [cm] | A [cm ²] | e [cm] | A*e [cm ³] | A*e ² [cm ⁴] | J _{y,0} [cm ⁴] | J _z [cm ⁴] |
|---------------|-------------|-----------|-----------|-------------------------|-----------|---------------------------|--|--|--------------------------------------|
| 1 | Einbind. UG | 1.2 | 1.0 | 1.20 | 1.5 | 1.80 | 2.70 | 0.10 | 0.14 |
| 2 | Einbind. OG | 1.2 | 1.0 | 1.20 | 389.5 | 467.40 | 182052.30 | 0.10 | 0.14 |
| 3 | OG | 60.00 | 2.00 | 120.00 | 390.00 | 46800.00 | 18252000.00 | 40.00 | 36000.00 |
| 4 | Steg | 1.20 | 387.00 | 464.40 | 195.50 | 90790.20 | 17749484.10 | 5796060.30 | 55.73 |
| 5 | UG | 60.00 | 2.00 | 120.00 | 1.00 | 120.00 | 120.00 | 40.00 | 36000.00 |
| Zwischensumme | | | 391.00 | 706.80 | | 138179.40 | 36183659.10 | 5796140.50 | 72056.02 |

z_s= 195.5 cm

y_s= 0.0 cm

J_{y,ges}= 14965726.9 cm⁴

J_{z,ges}= 72056.0 cm⁴

W_{y,OG}= -76551.0 cm³

W_{y,UG}= 76551.0 cm³

σ_o= 78.4 N/mm²

σ_u= -78.4 N/mm²

σ_{o,m}= 78.0 N/mm²

σ_{u,m}= -78.0 N/mm²

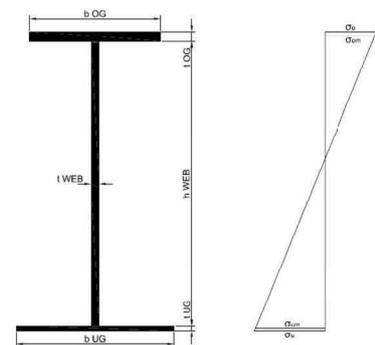


Abbildung 274: Spannungsermittlung geschweißter I-Profil Träger H = 3910 mm

Berechnung der crit Beulspannungen σ_{crit} :

$\sigma_{crit} = k_{\sigma} \cdot \sigma_e$

sig_Euler = 189800.085 N/mm²

fyk = 355 N/mm²

$\sigma_e = 189800 \cdot (t/b)^2$

E [N/mm²] =

210000 nue [-] = 0.3

| # | t [mm] | b [mm] | k_{σ} [-] | σ_e [N/mm ²] | σ_{crit} [N/mm ²] | $\lambda_p = \sqrt{\frac{f_{yk}}{\sigma_{crit}}}$ | rho 3-seitige Platte |
|--------------------|--------|--------|------------------|---------------------------------|--------------------------------------|---|----------------------|
| Flange UG gelenkig | 20.00 | 300.00 | 0.43 | 843.56 | 358.51 | 0.99509093 | 0.8151 |

a/b = 20:

| | | | | | | | |
|--------------------|-------|--------|--------|--------|--------|------------|--------|
| Flange UG gelenkig | 20.00 | 300.00 | 0.4275 | 843.56 | 360.62 | 0.99217705 | 0.8169 |
|--------------------|-------|--------|--------|--------|--------|------------|--------|

a/b = 20:

| | | | | | | | |
|--------------------|-------|--------|--------|---------|--------|------------|--------|
| Flange UG gelenkig | 30.00 | 300.00 | 0.4275 | 1898.00 | 811.40 | 0.66145136 | 1.0000 |
|--------------------|-------|--------|--------|---------|--------|------------|--------|

a/b = 20:

| | | | | | | | |
|--------------------|-------|--------|--------|---------|---------|------------|--------|
| Flange UG gelenkig | 60.00 | 300.00 | 0.4275 | 7592.00 | 3245.58 | 0.33072568 | 1.0000 |
|--------------------|-------|--------|--------|---------|---------|------------|--------|

Abbildung 275: Berechnung der Beulspannung σ_{crit}

Spannungsermittlung geschweißter I - Träger

Träger Abmessungen:

| | |
|--------------|----------|
| b UG= | 60.0 cm |
| t UG= | 2.0 cm |
| b OG= | 60.0 cm |
| t OG= | 2.0 cm |
| h Web= | 387.0 cm |
| t Web= | 1.2 cm |
| Einbind. UG= | 1.0 cm |
| Einbind. OG= | 1.0 cm |

Belastung:

M = -6000 kNm

Stahl: S355 355 N/mm²

rho_UG_EC3 = 0.81690833

f = 1

Querschnittswerte:

| | Bez | b [cm] | h [cm] | A [cm ²] | e [cm] | A*e [cm ³] | A*e ² [cm ⁴] | J _{y,0} [cm ⁴] | J _z [cm ⁴] |
|---------------|-------------|---------|--------|----------------------|--------|------------------------|-------------------------------------|-------------------------------------|-----------------------------------|
| 1 | Einbind. UG | 1.2 | 1.0 | 1.20 | 1.5 | 1.80 | 2.70 | 0.10 | 0.14 |
| 2 | Einbind. OG | 1.2 | 1.0 | 1.20 | 389.5 | 467.40 | 182052.30 | 0.10 | 0.14 |
| 3 | OG | 60.00 | 2.00 | 120.00 | 390.00 | 46800.00 | 18252000.00 | 40.00 | 36000.00 |
| 4 | Steg | 1.20 | 387.00 | 464.40 | 195.50 | 90790.20 | 17749484.10 | 5796060.30 | 55.73 |
| 5 | UG | 49.0145 | 2.00 | 98.03 | 1.00 | 98.03 | 98.03 | 32.68 | 19625.58 |
| Zwischensumme | | | 391.00 | 684.83 | | 138157.43 | 36183637.13 | 5796133.18 | 55681.59 |

z_s = 201.7 cm z_o = -189.260 cm

y_s = 0.0 cm z_u = 201.740 cm

J_{y,ges} = 14107885.2 cm⁴

J_{z,ges} = 55681.6 cm⁴

W_{y,OG} = -74542.4 cm³

W_{y,OGm} = -74150.6 cm³

W_{y,UG} = 69931.0 cm³

W_{y,UGm} = 70279.4 cm³

σ_o = 80.5 N/mm²

σ_u = -85.8 N/mm²

σ_{o,m} = 80.9 N/mm²

σ_{u,m} = -85.4 N/mm²

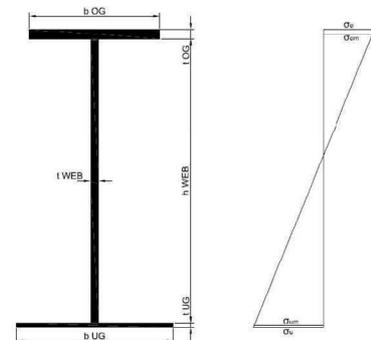


Abbildung 276: Effektive Spannungsermittlung geschweißter I-Profil Träger H = 3910 mm

c. Berechnung der nichtlinearen Normalkraft im Untergurt

| Gurtkräfte und Gurtkraftverläufe für t1=2-20 mm | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|--------------|-------------|----------------|----------|----------|----------|----------|--------------|----------|----------|----------|--------------|--------------|----------------------|---------------|----------------------|----------------------|------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|---------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|-------------|-------------|-------------|-----------------------------|-------------|----------|---------|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|---------|---------|----------|----------|----------|----------|----------|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|---|----|----------|----------|----------|----------|----------|----------|----------|----------|----------|---------|----------|----------|---------|----------|----------|----------|----------|---|----|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|---|----|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|---------|----------|----------|----------|---|-----|----------|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|---|-----|----------|----------|----------|----------|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|---|-----|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----|-----|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|---------|----------|----------|----------|----------|----------|----|-----|----------|----------|---------|----------|----------|----------|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----|-----|----------|----------|----------|----------|----------|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----|-----|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----|-----|----------|---------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----|-----|----------|----------|----------|----------|----------|----------|----------|----------|---------|----------|---------|----------|---------|---------|---------|----------|----------|----|-----|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----|-----|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----|-----|---------|---------|---------|---------|---------|---------|---------|--------|--------|--------|--------|---------|---------|---------|---------|---------|---------|----|-----|---------|---------|---------|---------|---------|---------|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----|-----|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----|-----|---------|-----|---------|---------|---------|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|-----|---------|----|-----|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|------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| Träger H=1200 mm | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Material S355 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| L = 6000 mm (α=20) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <table border="1"> <tr> <th>number,El</th> <th>40</th> <th>[-]</th> <th>Neff,bf =</th> <th>-3480.0</th> <th>(kN)</th> </tr> <tr> <td>b, bf =</td> <td>500.0</td> <td>(mm)</td> <td>L1 =</td> <td>2930</td> <td>(mm)</td> </tr> <tr> <td>b, bf, cent.</td> <td>389.150</td> <td>(N/mm²)</td> <td>b, bf, trans.</td> <td>140</td> <td>(mm)</td> </tr> <tr> <td>b, bf, max.</td> <td>395.446</td> <td>(N/mm²)</td> <td>b, bf, trans.</td> <td>2930</td> <td>(mm)</td> </tr> <tr> <td>Imp = B0/G/125 + sigr.0.2</td> <td>1.5</td> <td>(N/mm²)</td> <td>Npl,bf =</td> <td>-4260.0</td> <td>(kN)</td> </tr> <tr> <td>I [-]</td> <td>1.5</td> <td>(N/mm²)</td> <td>L =</td> <td>6000</td> <td>(mm)</td> </tr> </table> | | | | | | | | | | | | | | | number,El | 40 | [-] | Neff,bf = | -3480.0 | (kN) | b, bf = | 500.0 | (mm) | L1 = | 2930 | (mm) | b, bf, cent. | 389.150 | (N/mm ²) | b, bf, trans. | 140 | (mm) | b, bf, max. | 395.446 | (N/mm ²) | b, bf, trans. | 2930 | (mm) | Imp = B0/G/125 + sigr.0.2 | 1.5 | (N/mm ²) | Npl,bf = | -4260.0 | (kN) | I [-] | 1.5 | (N/mm ²) | L = | 6000 | (mm) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| number,El | 40 | [-] | Neff,bf = | -3480.0 | (kN) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| b, bf = | 500.0 | (mm) | L1 = | 2930 | (mm) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| b, bf, cent. | 389.150 | (N/mm ²) | b, bf, trans. | 140 | (mm) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| b, bf, max. | 395.446 | (N/mm ²) | b, bf, trans. | 2930 | (mm) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Imp = B0/G/125 + sigr.0.2 | 1.5 | (N/mm ²) | Npl,bf = | -4260.0 | (kN) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| I [-] | 1.5 | (N/mm ²) | L = | 6000 | (mm) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <table border="1"> <tr> <th>x [mm]</th> <th>rho, EC3 [-]</th> <th>GMNIA</th> <th>f_t</th> <th>1.2</th> </tr> <tr> <td>0</td> <td>0.81691</td> <td>0.583</td> <td>0.6996 plate</td> <td></td> </tr> <tr> <td>6000</td> <td>0.81691</td> <td>0.583</td> <td>0.6996 plate</td> <td></td> </tr> </table> | | | | | | | | | | | | | | | x [mm] | rho, EC3 [-] | GMNIA | f _t | 1.2 | 0 | 0.81691 | 0.583 | 0.6996 plate | | 6000 | 0.81691 | 0.583 | 0.6996 plate | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| x [mm] | rho, EC3 [-] | GMNIA | f _t | 1.2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| 6000 | 0.81691 | 0.583 | 0.6996 plate | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <table border="1"> <tr> <th>SSAVG11</th> </tr> <tr> <td>[N/mm²]</td> </tr> <tr> <td>INC = 0</td> </tr> <tr> <td>Node</td> <td>[mm]</td> <td>pos 000</td> <td>pos 010</td> <td>pos 020</td> <td>pos 040</td> <td>pos 060</td> <td>pos 080</td> <td>pos 090</td> <td>pos 100</td> <td>pos 150</td> <td>pos 200</td> <td>pos 210</td> <td>pos 220</td> <td>pos 240</td> <td>pos 260</td> <td>pos 280</td> <td>pos 290</td> <td>pos 300</td> </tr> </table> | | | | | | | | | | | | | | | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | [N/mm ²] | INC = 0 | INC = 0 | INC = 0 | INC = 0 | INC = 0 | INC = 0 | INC = 0 | INC = 0 | INC = 0 | INC = 0 | INC = 0 | INC = 0 | INC = 0 | INC = 0 | INC = 0 | INC = 0 | Node | [mm] | pos 000 | pos 010 | pos 020 | pos 040 | pos 060 | pos 080 | pos 090 | pos 100 | pos 150 | pos 200 | pos 210 | pos 220 | pos 240 | pos 260 | pos 280 | pos 290 | pos 300 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | SSAVG11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| <table border="1"> <tr> <td>0</td> <td>0</td> <td>-80.8268</td> <td>-79.8867</td> <td>-80.3905</td> <td>-80.5996</td> <td>-80.7263</td> <td>-80.8058</td> <td>-80.8275</td> <td>-80.8366</td> <td>-80.8375</td> <td>-80.8367</td> <td>-80.8276</td> <td>-80.8053</td> <td>-80.7255</td> <td>-80.601</td> <td>-80.3901</td> <td>-79.886</td> <td>-80.8261</td> </tr> <tr> <td>1</td> <td>15</td> <td>-82.2236</td> <td>-80.0134</td> <td>-80.4313</td> <td>-80.6229</td> <td>-80.7361</td> <td>-80.8067</td> <td>-80.8259</td> <td>-80.8346</td> </tr> <tr> <td>2</td> <td>30</td> <td>-81.4947</td> <td>-80.1371</td> <td>-80.4715</td> <td>-80.6445</td> <td>-80.7454</td> <td>-80.8074</td> <td>-80.8242</td> <td>-80.8312</td> <td>-80.8318</td> <td>-80.8312</td> <td>-80.8242</td> <td>-80.8071</td> <td>-80.7449</td> <td>-80.6446</td> <td>-80.4713</td> <td>-80.1366</td> <td>-81.4942</td> </tr> <tr> <td>3</td> <td>45</td> <td>-81.0959</td> <td>-80.2561</td> <td>-80.5109</td> <td>-80.6658</td> <td>-80.7542</td> <td>-80.808</td> <td>-80.8225</td> <td>-80.8285</td> <td>-80.8291</td> <td>-80.8286</td> <td>-80.8225</td> <td>-80.8077</td> <td>-80.7538</td> <td>-80.6666</td> <td>-80.5107</td> <td>-80.2557</td> <td>-81.0955</td> </tr> <tr> <td>4</td> <td>60</td> <td>-80.8471</td> <td>-80.3687</td> <td>-80.5493</td> <td>-80.6853</td> <td>-80.7623</td> <td>-80.8085</td> <td>-80.8208</td> <td>-80.8259</td> <td>-80.8264</td> <td>-80.826</td> <td>-80.8208</td> <td>-80.8082</td> <td>-80.762</td> <td>-80.6859</td> <td>-80.5491</td> <td>-80.3683</td> <td>-80.8468</td> </tr> <tr> <td>5</td> <td>75</td> <td>-80.6937</td> <td>-80.4735</td> <td>-80.5863</td> <td>-80.7036</td> <td>-80.7699</td> <td>-80.8088</td> <td>-80.8191</td> <td>-80.8233</td> <td>-80.8237</td> <td>-80.8233</td> <td>-80.8191</td> <td>-80.8086</td> <td>-80.7696</td> <td>-80.7041</td> <td>-80.5862</td> <td>-80.4733</td> <td>-80.6935</td> </tr> <tr> <td>6</td> <td>90</td> <td>-80.5999</td> <td>-80.5698</td> <td>-80.6218</td> <td>-80.7207</td> <td>-80.7768</td> <td>-80.8089</td> <td>-80.8173</td> <td>-80.8208</td> <td>-80.8211</td> <td>-80.8208</td> <td>-80.8173</td> <td>-80.8088</td> <td>-80.7767</td> <td>-80.721</td> <td>-80.6217</td> <td>-80.5696</td> <td>-80.5997</td> </tr> <tr> <td>7</td> <td>105</td> <td>-80.5487</td> <td>-80.657</td> <td>-80.6554</td> <td>-80.7365</td> <td>-80.7832</td> <td>-80.8089</td> <td>-80.8156</td> <td>-80.8182</td> <td>-80.8185</td> <td>-80.8182</td> <td>-80.8155</td> <td>-80.8088</td> <td>-80.7831</td> <td>-80.7367</td> <td>-80.6554</td> <td>-80.6569</td> <td>-80.5485</td> </tr> <tr> <td>8</td> <td>120</td> <td>-80.5188</td> <td>-80.7347</td> <td>-80.6871</td> <td>-80.7511</td> <td>-80.789</td> <td>-80.8088</td> <td>-80.8137</td> <td>-80.8157</td> <td>-80.8159</td> <td>-80.8157</td> <td>-80.8137</td> <td>-80.8087</td> <td>-80.7891</td> <td>-80.7517</td> <td>-80.6871</td> <td>-80.7346</td> <td>-80.5188</td> </tr> <tr> <td>9</td> <td>135</td> <td>-80.5119</td> <td>-80.8029</td> <td>-80.7165</td> <td>-80.7644</td> <td>-80.7941</td> <td>-80.8084</td> <td>-80.8119</td> <td>-80.8132</td> <td>-80.8133</td> <td>-80.8132</td> <td>-80.8118</td> <td>-80.8084</td> <td>-80.7942</td> <td>-80.7644</td> <td>-80.7166</td> <td>-80.8029</td> <td>-80.5119</td> </tr> <tr> <td>10</td> <td>150</td> <td>-80.5204</td> <td>-80.8617</td> <td>-80.7436</td> <td>-80.7765</td> <td>-80.7987</td> <td>-80.8099</td> <td>-80.8107</td> <td>-80.8107</td> <td>-80.8107</td> <td>-80.8107</td> <td>-80.8099</td> <td>-80.808</td> <td>-80.7988</td> <td>-80.7644</td> <td>-80.7436</td> <td>-80.8618</td> <td>-80.5204</td> </tr> <tr> <td>11</td> <td>165</td> <td>-80.5416</td> <td>-80.9113</td> <td>-80.768</td> <td>-80.7873</td> <td>-80.8027</td> <td>-80.8073</td> <td>-80.808</td> <td>-80.8082</td> <td>-80.8082</td> <td>-80.8082</td> <td>-80.8079</td> <td>-80.8073</td> <td>-80.8028</td> <td>-80.7871</td> <td>-80.7681</td> <td>-80.9114</td> <td>-80.5417</td> </tr> <tr> <td>12</td> <td>180</td> 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<td>132.16</td> <td>131.976</td> <td>132.144</td> </tr> <tr> <td>25</td> <td>375</td> <td>-27.5053</td> <td>-27.7666</td> <td>-27.5786</td> <td>-27.551</td> <td>-27.539</td> <td>-27.525</td> <td>-27.523</td> <td>-27.5194</td> <td>-27.5192</td> <td>-27.5194</td> <td>-27.5192</td> <td>-27.5194</td> <td>-27.5192</td> <td>-27.5194</td> <td>-27.5192</td> <td>-27.5787</td> <td>-27.5053</td> </tr> <tr> <td>26</td> <td>390</td> <td>-80.677</td> <td>-81.0008</td> <td>-80.8139</td> <td>-80.7917</td> <td>-80.7827</td> <td>-80.7714</td> <td>-80.7677</td> <td>-80.7661</td> <td>-80.766</td> <td>-80.7661</td> <td>-80.766</td> <td>-80.7661</td> <td>-80.7661</td> <td>-80.7661</td> <td>-80.7661</td> <td>-81.0008</td> <td>-80.677</td> </tr> <tr> <td>27</td> <td>405</td> <td>-80.617</td> <td>-80.9766</td> <td>-80.7962</td> <td>-80.7811</td> <td>-80.7759</td> <td>-80.7671</td> <td>-80.7642</td> <td>-80.7629</td> <td>-80.7627</td> <td>-80.7628</td> <td>-80.7641</td> <td>-80.7672</td> <td>-80.776</td> <td>-80.7808</td> <td>-80.7962</td> <td>-80.9767</td> <td>-80.6171</td> </tr> <tr> <td>28</td> <td>420</td> <td>-80.5713</td> <td>-80.9438</td> <td>-80.7755</td> <td>-80.7693</td> <td>-80.7684</td> <td>-80.7626</td> <td>-80.7605</td> <td>-80.7595</td> <td>-80.7592</td> <td>-80.7595</td> <td>-80.7605</td> <td>-80.7627</td> <td>-80.7685</td> <td>-80.7755</td> <td>-80.9438</td> <td>-80.5713</td> </tr> <tr> <td>29</td> <td>435</td> <td>-80.5368</td> <td>-80.9023</td> <td>-80.7519</td> <td>-80.7562</td> <td>-80.7603</td> <td>-80.7579</td> <td>-80.7568</td> <td>-80.7563</td> <td>-80.7562</td> <td>-80.7562</td> <td>-80.7568</td> <td>-80.7568</td> <td>-80.7604</td> <td>-80.756</td> <td>-80.752</td> <td>-80.9024</td> <td>-80.5368</td> </tr> <tr> <td>30</td> <td>450</td> <td>-80.5172</td> <td>-80.8519</td> <td>-80.7257</td> <td>-80.7419</td> <td>-80.7515</td> <td>-80.7531</td> <td>-80.7529</td> <td>-80.7529</td> <td>-80.7529</td> <td>-80.7529</td> <td>-80.7529</td> <td>-80.7529</td> 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<td>-80.7413</td> <td>-80.7373</td> <td>-80.7216</td> <td>-80.6916</td> <td>-80.632</td> <td>-80.6443</td> <td>-80.5408</td> </tr> <tr> <td>34</td> <td>510</td> <td>-80.5949</td> <td>-80.5565</td> <td>-80.5965</td> <td>-80.672</td> <td>-80.7105</td> <td>-80.7319</td> <td>-80.7374</td> <td>-80.7397</td> <td>-80.7397</td> <td>-80.7397</td> <td>-80.7397</td> <td>-80.7397</td> <td>-80.7397</td> <td>-80.7397</td> <td>-80.7397</td> <td>-80.5565</td> <td>-80.5949</td> </tr> <tr> <td>35</td> <td>525</td> <td>-80.6887</td> <td>-80.4993</td> <td>-80.5592</td> <td>-80.6514</td> <td>-80.6988</td> <td>-80.7262</td> <td>-80.7334</td> <td>-80.7364</td> <td>-80.7364</td> <td>-80.7364</td> <td>-80.7333</td> <td>-80.726</td> <td>-80.6985</td> <td>-80.6519</td> <td>-80.5591</td> <td>-80.4991</td> <td>-80.6885</td> </tr> <tr> <td>36</td> <td>540</td> <td>-80.8423</td> <td>-80.3536</td> <td>-80.5203</td> <td>-80.6296</td> <td>-80.6984</td> <td>-80.7203</td> <td>-80.7293</td> <td>-80.731</td> <td>-80.7334</td> <td>-80.7331</td> <td>-80.7293</td> <td>-80.72</td> <td>-80.6861</td> <td>-80.6292</td> <td>-80.5202</td> <td>-80.3532</td> <td>-80.842</td> </tr> <tr> <td>37</td> <td>555</td> <td>-80.6742</td> </tr> <tr> <td>38</td> <td>570</td> <td>81.491</td> <td>-80.1204</td> <td>-80.4388</td> <td>-80.5821</td> <td>-80.6599</td> <td>-80.7081</td> <td>-80.7211</td> <td>-80.7266</td> <td>-80.7271</td> <td>-80.7266</td> <td>-80.7211</td> <td>-80.7076</td> <td>-80.6594</td> <td>-80.583</td> <td>-80.4386</td> <td>-80.1198</td> <td>-81.4905</td> </tr> <tr> <td>39</td> <td>585</td> <td>-82.221</td> <td>-79.9958</td> <td>-80.3967</td> <td>-80.5564</td> <td>-80.6457</td> <td>-80.7017</td> <td>-80.7169</td> <td>-80.7234</td> <td>-80.7239</td> <td>-80.7234</td> <td>-80.7169</td> <td>-80.7012</td> <td>-80.6451</td> <td>-80.556</td> <td>-80.3964</td> <td>-79.9952</td> <td>-82.2219</td> </tr> <tr> <td>40</td> <td>600</td> <td>-83.0619</td> <td>-79.8683</td> <td>-80.3539</td> <td>-80.5294</td> <td>-80.6309</td> <td>-80.6952</td> <td>-80.7128</td> <td>-80.7202</td> <td>-80.7208</td> <td>-80.7203</td> <td>-80.7128</td> <td>-80.6946</td> <td>-80.6302</td> <td>-80.5308</td> <td>-80.3535</td> <td>-79.8676</td> <td>-83.0613</td> </tr> <tr> <td colspan="15"> <table border="1"> <tr> <td>N, GMNIA, bf [kN]</td> <td>51.072705</td> <td>53.90409</td> <td>54.08214</td> <td>53.51188</td> <td>53.22066</td> <td>53.06961</td> <td>53.03415</td> <td>53.01816</td> <td>53.01733</td> <td>53.01816</td> <td>53.03936</td> <td>53.070405</td> <td>53.221785</td> <td>53.54016</td> <td>54.08202</td> <td>53.90508</td> <td>51.07377</td> </tr> <tr> <td>N, GMNIA, bf / (Npl, bf) [-]</td> <td>-0.01198891</td> <td>-0.01263534</td> <td>-0.01269534</td> <td>-0.01256835</td> <td>-0.01249931</td> <td>-0.01245765</td> <td>-0.01244916</td> <td>-0.01244558</td> <td>-0.01244538</td> <td>-0.01244558</td> <td>-0.01244538</td> <td>-0.01244521</td> <td>-0.01244521</td> <td>-0.01244521</td> <td>-0.01244521</td> <td>-0.01244521</td> <td>-0.01198915</td> </tr> <tr> <td>N, GMNIA, bf / Neff, bf [-]</td> <td>-0.01467596</td> </tr></table></td></tr></table> | | | | | | | | | | | | | | | 0 | 0 | -80.8268 | -79.8867 | -80.3905 | -80.5996 | -80.7263 | -80.8058 | -80.8275 | -80.8366 | -80.8375 | -80.8367 | -80.8276 | -80.8053 | -80.7255 | -80.601 | -80.3901 | -79.886 | -80.8261 | 1 | 15 | -82.2236 | -80.0134 | -80.4313 | -80.6229 | -80.7361 | -80.8067 | -80.8259 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | 2 | 30 | -81.4947 | -80.1371 | -80.4715 | -80.6445 | -80.7454 | -80.8074 | -80.8242 | -80.8312 | -80.8318 | -80.8312 | -80.8242 | -80.8071 | -80.7449 | -80.6446 | -80.4713 | -80.1366 | -81.4942 | 3 | 45 | -81.0959 | -80.2561 | -80.5109 | -80.6658 | -80.7542 | -80.808 | -80.8225 | -80.8285 | -80.8291 | -80.8286 | -80.8225 | -80.8077 | -80.7538 | -80.6666 | -80.5107 | -80.2557 | -81.0955 | 4 | 60 | -80.8471 | -80.3687 | -80.5493 | -80.6853 | -80.7623 | -80.8085 | -80.8208 | -80.8259 | -80.8264 | -80.826 | -80.8208 | -80.8082 | -80.762 | -80.6859 | -80.5491 | -80.3683 | -80.8468 | 5 | 75 | -80.6937 | -80.4735 | -80.5863 | -80.7036 | -80.7699 | -80.8088 | -80.8191 | -80.8233 | -80.8237 | -80.8233 | -80.8191 | -80.8086 | -80.7696 | -80.7041 | -80.5862 | -80.4733 | -80.6935 | 6 | 90 | -80.5999 | -80.5698 | -80.6218 | -80.7207 | -80.7768 | -80.8089 | -80.8173 | -80.8208 | -80.8211 | -80.8208 | -80.8173 | -80.8088 | -80.7767 | -80.721 | -80.6217 | -80.5696 | -80.5997 | 7 | 105 | -80.5487 | -80.657 | -80.6554 | -80.7365 | -80.7832 | -80.8089 | -80.8156 | -80.8182 | -80.8185 | -80.8182 | -80.8155 | -80.8088 | -80.7831 | -80.7367 | -80.6554 | -80.6569 | -80.5485 | 8 | 120 | -80.5188 | -80.7347 | -80.6871 | -80.7511 | -80.789 | -80.8088 | -80.8137 | -80.8157 | -80.8159 | -80.8157 | -80.8137 | -80.8087 | -80.7891 | -80.7517 | -80.6871 | -80.7346 | -80.5188 | 9 | 135 | -80.5119 | -80.8029 | -80.7165 | -80.7644 | -80.7941 | -80.8084 | -80.8119 | -80.8132 | -80.8133 | -80.8132 | -80.8118 | -80.8084 | -80.7942 | -80.7644 | -80.7166 | -80.8029 | -80.5119 | 10 | 150 | -80.5204 | -80.8617 | -80.7436 | -80.7765 | -80.7987 | -80.8099 | -80.8107 | -80.8107 | -80.8107 | -80.8107 | -80.8099 | -80.808 | -80.7988 | -80.7644 | -80.7436 | -80.8618 | -80.5204 | 11 | 165 | -80.5416 | -80.9113 | -80.768 | -80.7873 | -80.8027 | -80.8073 | -80.808 | -80.8082 | -80.8082 | -80.8082 | -80.8079 | -80.8073 | -80.8028 | -80.7871 | -80.7681 | -80.9114 | -80.5417 | 12 | 180 | -80.5747 | -80.9519 | -80.7897 | -80.8006 | -80.8064 | -80.806 | -80.8062 | -80.8062 | -80.8062 | -80.8062 | -80.8059 | -80.8056 | -80.7897 | -80.7896 | -80.9512 | -80.5748 | 13 | 195 | -80.6199 | -80.9837 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.9839 | -80.6201 | 14 | 210 | -80.6795 | -81.007 | -80.8246 | -80.8123 | -80.8109 | -80.8042 | -80.8018 | -80.8007 | -80.8007 | -80.8006 | -80.8006 | -80.8007 | -80.8043 | -80.8111 | -80.8247 | -81.0071 | -80.6796 | 15 | 225 | -27.5073 | -27.7718 | -27.5875 | -27.5681 | -27.5624 | -27.5528 | -27.5495 | -27.5481 | -27.548 | -27.5481 | -27.548 | -27.5481 | -27.548 | -27.548 | -27.548 | -27.7712 | -27.5075 | 16 | 240 | 132.143 | 131.971 | 132.153 | 132.177 | 132.187 | 132.199 | 132.203 | 132.204 | 132.205 | 132.204 | 132.203 | 132.199 | 132.187 | 132.177 | 132.153 | 131.971 | 132.143 | 17 | 255 | 291.768 | 291.723 | 291.896 | 291.924 | 291.936 | 291.951 | 291.955 | 291.957 | 291.957 | 291.957 | 291.955 | 291.951 | 291.936 | 291.924 | 291.896 | 291.723 | 291.768 | 18 | 270 | 344.862 | 344.982 | 345.142 | 345.172 | 345.187 | 345.203 | 345.208 | 345.21 | 345.21 | 345.21 | 345.21 | 345.208 | 345.203 | 345.187 | 345.172 | 345.142 | 344.862 | 19 | 285 | 344.636 | 344.999 | 345.141 | 345.171 | 345.188 | 345.205 | 345.21 | 345.213 | 345.213 | 345.213 | 345.213 | 345.205 | 345.188 | 345.171 | 345.141 | 344.999 | 344.636 | 20 | 300 | 344.375 | 345.025 | 345.144 | 345.171 | 345.189 | 345.207 | 345.213 | 345.215 | 345.215 | 345.215 | 345.215 | 345.207 | 345.189 | 345.171 | 345.144 | 345.025 | 344.375 | 21 | 315 | 344.636 | 345 | 345.143 | 345.174 | 345.192 | 345.21 | 345.218 | 345.218 | 345.218 | 345.218 | 345.218 | 345.218 | 345.218 | 345.218 | 345.143 | 345 | 344.636 | 22 | 330 | 344.863 | 344.984 | 345.146 | 345.179 | 345.196 | 345.213 | 345.219 | 345.221 | 345.221 | 345.221 | 345.219 | 345.213 | 345.196 | 345.179 | 345.146 | 344.984 | 344.863 | 23 | 345 | 291.769 | 291.726 | 291.901 | 291.924 | 291.936 | 291.951 | 291.955 | 291.957 | 291.957 | 291.957 | 291.955 | 291.951 | 291.936 | 291.924 | 291.901 | 291.726 | 291.769 | 24 | 360 | 132.144 | 131.976 | 132.16 | 132.191 | 132.205 | 132.221 | 132.225 | 132.227 | 132.227 | 132.227 | 132.225 | 132.221 | 132.205 | 132.191 | 132.16 | 131.976 | 132.144 | 25 | 375 | -27.5053 | -27.7666 | -27.5786 | -27.551 | -27.539 | -27.525 | -27.523 | -27.5194 | -27.5192 | -27.5194 | -27.5192 | -27.5194 | -27.5192 | -27.5194 | -27.5192 | -27.5787 | -27.5053 | 26 | 390 | -80.677 | -81.0008 | -80.8139 | -80.7917 | -80.7827 | -80.7714 | -80.7677 | -80.7661 | -80.766 | -80.7661 | -80.766 | -80.7661 | -80.7661 | -80.7661 | -80.7661 | -81.0008 | -80.677 | 27 | 405 | -80.617 | -80.9766 | -80.7962 | -80.7811 | -80.7759 | -80.7671 | -80.7642 | -80.7629 | -80.7627 | -80.7628 | -80.7641 | -80.7672 | -80.776 | -80.7808 | -80.7962 | -80.9767 | -80.6171 | 28 | 420 | -80.5713 | -80.9438 | -80.7755 | -80.7693 | -80.7684 | -80.7626 | -80.7605 | -80.7595 | -80.7592 | -80.7595 | -80.7605 | -80.7627 | -80.7685 | -80.7755 | -80.9438 | -80.5713 | 29 | 435 | -80.5368 | -80.9023 | -80.7519 | -80.7562 | -80.7603 | -80.7579 | -80.7568 | -80.7563 | -80.7562 | -80.7562 | -80.7568 | -80.7568 | -80.7604 | -80.756 | -80.752 | -80.9024 | -80.5368 | 30 | 450 | -80.5172 | -80.8519 | -80.7257 | -80.7419 | -80.7515 | -80.7531 | -80.7529 | -80.7529 | -80.7529 | -80.7529 | -80.7529 | -80.7529 | -80.7515 | -80.7418 | -80.7257 | -80.8519 | -80.5172 | 31 | 465 | -80.5075 | -80.7922 | -80.6968 | -80.7263 | -80.7422 | -80.7481 | -80.7492 | -80.7496 | -80.7496 | -80.7496 | -80.7492 | -80.748 | -80.7422 | -80.7263 | -80.6968 | -80.7922 | -80.5075 | 32 | 480 | -80.5141 | -80.7231 | -80.6656 | -80.7095 | -80.7323 | -80.7428 | -80.7453 | -80.7463 | -80.7463 | -80.7463 | -80.7428 | -80.7322 | -80.7095 | -80.6656 | -80.7231 | -80.7231 | -80.5141 | 33 | 495 | -80.5408 | -80.6445 | -80.6321 | -80.6914 | -80.7217 | -80.7375 | -80.7414 | -80.743 | -80.7431 | -80.743 | -80.7413 | -80.7373 | -80.7216 | -80.6916 | -80.632 | -80.6443 | -80.5408 | 34 | 510 | -80.5949 | -80.5565 | -80.5965 | -80.672 | -80.7105 | -80.7319 | -80.7374 | -80.7397 | -80.7397 | -80.7397 | -80.7397 | -80.7397 | -80.7397 | -80.7397 | -80.7397 | -80.5565 | -80.5949 | 35 | 525 | -80.6887 | -80.4993 | -80.5592 | -80.6514 | -80.6988 | -80.7262 | -80.7334 | -80.7364 | -80.7364 | -80.7364 | -80.7333 | -80.726 | -80.6985 | -80.6519 | -80.5591 | -80.4991 | -80.6885 | 36 | 540 | -80.8423 | -80.3536 | -80.5203 | -80.6296 | -80.6984 | -80.7203 | -80.7293 | -80.731 | -80.7334 | -80.7331 | -80.7293 | -80.72 | -80.6861 | -80.6292 | -80.5202 | -80.3532 | -80.842 | 37 | 555 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | 38 | 570 | 81.491 | -80.1204 | -80.4388 | -80.5821 | -80.6599 | -80.7081 | -80.7211 | -80.7266 | -80.7271 | -80.7266 | -80.7211 | -80.7076 | -80.6594 | -80.583 | -80.4386 | -80.1198 | -81.4905 | 39 | 585 | -82.221 | -79.9958 | -80.3967 | -80.5564 | -80.6457 | -80.7017 | -80.7169 | -80.7234 | -80.7239 | -80.7234 | -80.7169 | -80.7012 | -80.6451 | -80.556 | -80.3964 | -79.9952 | -82.2219 | 40 | 600 | -83.0619 | -79.8683 | -80.3539 | -80.5294 | -80.6309 | -80.6952 | -80.7128 | -80.7202 | -80.7208 | -80.7203 | -80.7128 | -80.6946 | -80.6302 | -80.5308 | -80.3535 | -79.8676 | -83.0613 | <table border="1"> <tr> <td>N, GMNIA, bf [kN]</td> <td>51.072705</td> <td>53.90409</td> <td>54.08214</td> <td>53.51188</td> <td>53.22066</td> <td>53.06961</td> <td>53.03415</td> <td>53.01816</td> <td>53.01733</td> <td>53.01816</td> <td>53.03936</td> <td>53.070405</td> <td>53.221785</td> <td>53.54016</td> <td>54.08202</td> <td>53.90508</td> <td>51.07377</td> </tr> <tr> <td>N, GMNIA, bf / (Npl, bf) [-]</td> <td>-0.01198891</td> <td>-0.01263534</td> <td>-0.01269534</td> <td>-0.01256835</td> <td>-0.01249931</td> <td>-0.01245765</td> <td>-0.01244916</td> <td>-0.01244558</td> <td>-0.01244538</td> <td>-0.01244558</td> <td>-0.01244538</td> <td>-0.01244521</td> <td>-0.01244521</td> <td>-0.01244521</td> <td>-0.01244521</td> <td>-0.01244521</td> <td>-0.01198915</td> </tr> <tr> <td>N, GMNIA, bf / Neff, bf [-]</td> <td>-0.01467596</td> </tr></table> | | | | | | | | | | | | | | | N, GMNIA, bf [kN] | 51.072705 | 53.90409 | 54.08214 | 53.51188 | 53.22066 | 53.06961 | 53.03415 | 53.01816 | 53.01733 | 53.01816 | 53.03936 | 53.070405 | 53.221785 | 53.54016 | 54.08202 | 53.90508 | 51.07377 | N, GMNIA, bf / (Npl, bf) [-] | -0.01198891 | -0.01263534 | -0.01269534 | -0.01256835 | -0.01249931 | -0.01245765 | -0.01244916 | -0.01244558 | -0.01244538 | -0.01244558 | -0.01244538 | -0.01244521 | -0.01244521 | -0.01244521 | -0.01244521 | -0.01244521 | -0.01198915 | N, GMNIA, bf / Neff, bf [-] | -0.01467596 |
| 0 | 0 | -80.8268 | -79.8867 | -80.3905 | -80.5996 | -80.7263 | -80.8058 | -80.8275 | -80.8366 | -80.8375 | -80.8367 | -80.8276 | -80.8053 | -80.7255 | -80.601 | -80.3901 | -79.886 | -80.8261 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 15 | -82.2236 | -80.0134 | -80.4313 | -80.6229 | -80.7361 | -80.8067 | -80.8259 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | -80.8346 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | 30 | -81.4947 | -80.1371 | -80.4715 | -80.6445 | -80.7454 | -80.8074 | -80.8242 | -80.8312 | -80.8318 | -80.8312 | -80.8242 | -80.8071 | -80.7449 | -80.6446 | -80.4713 | -80.1366 | -81.4942 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 45 | -81.0959 | -80.2561 | -80.5109 | -80.6658 | -80.7542 | -80.808 | -80.8225 | -80.8285 | -80.8291 | -80.8286 | -80.8225 | -80.8077 | -80.7538 | -80.6666 | -80.5107 | -80.2557 | -81.0955 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | 60 | -80.8471 | -80.3687 | -80.5493 | -80.6853 | -80.7623 | -80.8085 | -80.8208 | -80.8259 | -80.8264 | -80.826 | -80.8208 | -80.8082 | -80.762 | -80.6859 | -80.5491 | -80.3683 | -80.8468 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | 75 | -80.6937 | -80.4735 | -80.5863 | -80.7036 | -80.7699 | -80.8088 | -80.8191 | -80.8233 | -80.8237 | -80.8233 | -80.8191 | -80.8086 | -80.7696 | -80.7041 | -80.5862 | -80.4733 | -80.6935 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | 90 | -80.5999 | -80.5698 | -80.6218 | -80.7207 | -80.7768 | -80.8089 | -80.8173 | -80.8208 | -80.8211 | -80.8208 | -80.8173 | -80.8088 | -80.7767 | -80.721 | -80.6217 | -80.5696 | -80.5997 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | 105 | -80.5487 | -80.657 | -80.6554 | -80.7365 | -80.7832 | -80.8089 | -80.8156 | -80.8182 | -80.8185 | -80.8182 | -80.8155 | -80.8088 | -80.7831 | -80.7367 | -80.6554 | -80.6569 | -80.5485 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | 120 | -80.5188 | -80.7347 | -80.6871 | -80.7511 | -80.789 | -80.8088 | -80.8137 | -80.8157 | -80.8159 | -80.8157 | -80.8137 | -80.8087 | -80.7891 | -80.7517 | -80.6871 | -80.7346 | -80.5188 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | 135 | -80.5119 | -80.8029 | -80.7165 | -80.7644 | -80.7941 | -80.8084 | -80.8119 | -80.8132 | -80.8133 | -80.8132 | -80.8118 | -80.8084 | -80.7942 | -80.7644 | -80.7166 | -80.8029 | -80.5119 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | 150 | -80.5204 | -80.8617 | -80.7436 | -80.7765 | -80.7987 | -80.8099 | -80.8107 | -80.8107 | -80.8107 | -80.8107 | -80.8099 | -80.808 | -80.7988 | -80.7644 | -80.7436 | -80.8618 | -80.5204 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | 165 | -80.5416 | -80.9113 | -80.768 | -80.7873 | -80.8027 | -80.8073 | -80.808 | -80.8082 | -80.8082 | -80.8082 | -80.8079 | -80.8073 | -80.8028 | -80.7871 | -80.7681 | -80.9114 | -80.5417 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | 180 | -80.5747 | -80.9519 | -80.7897 | -80.8006 | -80.8064 | -80.806 | -80.8062 | -80.8062 | -80.8062 | -80.8062 | -80.8059 | -80.8056 | -80.7897 | -80.7896 | -80.9512 | -80.5748 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | 195 | -80.6199 | -80.9837 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.8086 | -80.9839 | -80.6201 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | 210 | -80.6795 | -81.007 | -80.8246 | -80.8123 | -80.8109 | -80.8042 | -80.8018 | -80.8007 | -80.8007 | -80.8006 | -80.8006 | -80.8007 | -80.8043 | -80.8111 | -80.8247 | -81.0071 | -80.6796 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | 225 | -27.5073 | -27.7718 | -27.5875 | -27.5681 | -27.5624 | -27.5528 | -27.5495 | -27.5481 | -27.548 | -27.5481 | -27.548 | -27.5481 | -27.548 | -27.548 | -27.548 | -27.7712 | -27.5075 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | 240 | 132.143 | 131.971 | 132.153 | 132.177 | 132.187 | 132.199 | 132.203 | 132.204 | 132.205 | 132.204 | 132.203 | 132.199 | 132.187 | 132.177 | 132.153 | 131.971 | 132.143 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | 255 | 291.768 | 291.723 | 291.896 | 291.924 | 291.936 | 291.951 | 291.955 | 291.957 | 291.957 | 291.957 | 291.955 | 291.951 | 291.936 | 291.924 | 291.896 | 291.723 | 291.768 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | 270 | 344.862 | 344.982 | 345.142 | 345.172 | 345.187 | 345.203 | 345.208 | 345.21 | 345.21 | 345.21 | 345.21 | 345.208 | 345.203 | 345.187 | 345.172 | 345.142 | 344.862 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | 285 | 344.636 | 344.999 | 345.141 | 345.171 | 345.188 | 345.205 | 345.21 | 345.213 | 345.213 | 345.213 | 345.213 | 345.205 | 345.188 | 345.171 | 345.141 | 344.999 | 344.636 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 300 | 344.375 | 345.025 | 345.144 | 345.171 | 345.189 | 345.207 | 345.213 | 345.215 | 345.215 | 345.215 | 345.215 | 345.207 | 345.189 | 345.171 | 345.144 | 345.025 | 344.375 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | 315 | 344.636 | 345 | 345.143 | 345.174 | 345.192 | 345.21 | 345.218 | 345.218 | 345.218 | 345.218 | 345.218 | 345.218 | 345.218 | 345.218 | 345.143 | 345 | 344.636 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | 330 | 344.863 | 344.984 | 345.146 | 345.179 | 345.196 | 345.213 | 345.219 | 345.221 | 345.221 | 345.221 | 345.219 | 345.213 | 345.196 | 345.179 | 345.146 | 344.984 | 344.863 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | 345 | 291.769 | 291.726 | 291.901 | 291.924 | 291.936 | 291.951 | 291.955 | 291.957 | 291.957 | 291.957 | 291.955 | 291.951 | 291.936 | 291.924 | 291.901 | 291.726 | 291.769 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | 360 | 132.144 | 131.976 | 132.16 | 132.191 | 132.205 | 132.221 | 132.225 | 132.227 | 132.227 | 132.227 | 132.225 | 132.221 | 132.205 | 132.191 | 132.16 | 131.976 | 132.144 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | 375 | -27.5053 | -27.7666 | -27.5786 | -27.551 | -27.539 | -27.525 | -27.523 | -27.5194 | -27.5192 | -27.5194 | -27.5192 | -27.5194 | -27.5192 | -27.5194 | -27.5192 | -27.5787 | -27.5053 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 26 | 390 | -80.677 | -81.0008 | -80.8139 | -80.7917 | -80.7827 | -80.7714 | -80.7677 | -80.7661 | -80.766 | -80.7661 | -80.766 | -80.7661 | -80.7661 | -80.7661 | -80.7661 | -81.0008 | -80.677 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | 405 | -80.617 | -80.9766 | -80.7962 | -80.7811 | -80.7759 | -80.7671 | -80.7642 | -80.7629 | -80.7627 | -80.7628 | -80.7641 | -80.7672 | -80.776 | -80.7808 | -80.7962 | -80.9767 | -80.6171 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | 420 | -80.5713 | -80.9438 | -80.7755 | -80.7693 | -80.7684 | -80.7626 | -80.7605 | -80.7595 | -80.7592 | -80.7595 | -80.7605 | -80.7627 | -80.7685 | -80.7755 | -80.9438 | -80.5713 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | 435 | -80.5368 | -80.9023 | -80.7519 | -80.7562 | -80.7603 | -80.7579 | -80.7568 | -80.7563 | -80.7562 | -80.7562 | -80.7568 | -80.7568 | -80.7604 | -80.756 | -80.752 | -80.9024 | -80.5368 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | 450 | -80.5172 | -80.8519 | -80.7257 | -80.7419 | -80.7515 | -80.7531 | -80.7529 | -80.7529 | -80.7529 | -80.7529 | -80.7529 | -80.7529 | -80.7515 | -80.7418 | -80.7257 | -80.8519 | -80.5172 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | 465 | -80.5075 | -80.7922 | -80.6968 | -80.7263 | -80.7422 | -80.7481 | -80.7492 | -80.7496 | -80.7496 | -80.7496 | -80.7492 | -80.748 | -80.7422 | -80.7263 | -80.6968 | -80.7922 | -80.5075 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32 | 480 | -80.5141 | -80.7231 | -80.6656 | -80.7095 | -80.7323 | -80.7428 | -80.7453 | -80.7463 | -80.7463 | -80.7463 | -80.7428 | -80.7322 | -80.7095 | -80.6656 | -80.7231 | -80.7231 | -80.5141 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 33 | 495 | -80.5408 | -80.6445 | -80.6321 | -80.6914 | -80.7217 | -80.7375 | -80.7414 | -80.743 | -80.7431 | -80.743 | -80.7413 | -80.7373 | -80.7216 | -80.6916 | -80.632 | -80.6443 | -80.5408 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 34 | 510 | -80.5949 | -80.5565 | -80.5965 | -80.672 | -80.7105 | -80.7319 | -80.7374 | -80.7397 | -80.7397 | -80.7397 | -80.7397 | -80.7397 | -80.7397 | -80.7397 | -80.7397 | -80.5565 | -80.5949 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 35 | 525 | -80.6887 | -80.4993 | -80.5592 | -80.6514 | -80.6988 | -80.7262 | -80.7334 | -80.7364 | -80.7364 | -80.7364 | -80.7333 | -80.726 | -80.6985 | -80.6519 | -80.5591 | -80.4991 | -80.6885 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 36 | 540 | -80.8423 | -80.3536 | -80.5203 | -80.6296 | -80.6984 | -80.7203 | -80.7293 | -80.731 | -80.7334 | -80.7331 | -80.7293 | -80.72 | -80.6861 | -80.6292 | -80.5202 | -80.3532 | -80.842 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 37 | 555 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | -80.6742 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 38 | 570 | 81.491 | -80.1204 | -80.4388 | -80.5821 | -80.6599 | -80.7081 | -80.7211 | -80.7266 | -80.7271 | -80.7266 | -80.7211 | -80.7076 | -80.6594 | -80.583 | -80.4386 | -80.1198 | -81.4905 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 39 | 585 | -82.221 | -79.9958 | -80.3967 | -80.5564 | -80.6457 | -80.7017 | -80.7169 | -80.7234 | -80.7239 | -80.7234 | -80.7169 | -80.7012 | -80.6451 | -80.556 | -80.3964 | -79.9952 | -82.2219 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 40 | 600 | -83.0619 | -79.8683 | -80.3539 | -80.5294 | -80.6309 | -80.6952 | -80.7128 | -80.7202 | -80.7208 | -80.7203 | -80.7128 | -80.6946 | -80.6302 | -80.5308 | -80.3535 | -79.8676 | -83.0613 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <table border="1"> <tr> <td>N, GMNIA, bf [kN]</td> <td>51.072705</td> <td>53.90409</td> <td>54.08214</td> <td>53.51188</td> <td>53.22066</td> <td>53.06961</td> <td>53.03415</td> <td>53.01816</td> <td>53.01733</td> <td>53.01816</td> <td>53.03936</td> <td>53.070405</td> <td>53.221785</td> <td>53.54016</td> <td>54.08202</td> <td>53.90508</td> <td>51.07377</td> </tr> <tr> <td>N, GMNIA, bf / (Npl, bf) [-]</td> <td>-0.01198891</td> <td>-0.01263534</td> <td>-0.01269534</td> <td>-0.01256835</td> <td>-0.01249931</td> <td>-0.01245765</td> <td>-0.01244916</td> <td>-0.01244558</td> <td>-0.01244538</td> <td>-0.01244558</td> <td>-0.01244538</td> <td>-0.01244521</td> <td>-0.01244521</td> <td>-0.01244521</td> <td>-0.01244521</td> <td>-0.01244521</td> <td>-0.01198915</td> </tr> <tr> <td>N, GMNIA, bf / Neff, bf [-]</td> <td>-0.01467596</td> </tr></table> | | | | | | | | | | | | | | | N, GMNIA, bf [kN] | 51.072705 | 53.90409 | 54.08214 | 53.51188 | 53.22066 | 53.06961 | 53.03415 | 53.01816 | 53.01733 | 53.01816 | 53.03936 | 53.070405 | 53.221785 | 53.54016 | 54.08202 | 53.90508 | 51.07377 | N, GMNIA, bf / (Npl, bf) [-] | -0.01198891 | -0.01263534 | -0.01269534 | -0.01256835 | -0.01249931 | -0.01245765 | -0.01244916 | -0.01244558 | -0.01244538 | -0.01244558 | -0.01244538 | -0.01244521 | -0.01244521 | -0.01244521 | -0.01244521 | -0.01244521 | -0.01198915 | N, GMNIA, bf / Neff, bf [-] | -0.01467596 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N, GMNIA, bf [kN] | 51.072705 | 53.90409 | 54.08214 | 53.51188 | 53.22066 | 53.06961 | 53.03415 | 53.01816 | 53.01733 | 53.01816 | 53.03936 | 53.070405 | 53.221785 | 53.54016 | 54.08202 | 53.90508 | 51.07377 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N, GMNIA, bf / (Npl, bf) [-] | -0.01198891 | -0.01263534 | -0.01269534 | -0.01256835 | -0.01249931 | -0.01245765 | -0.01244916 | -0.01244558 | -0.01244538 | -0.01244558 | -0.01244538 | -0.01244521 | -0.01244521 | -0.01244521 | -0.01244521 | -0.01244521 | -0.01198915 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N, GMNIA, bf / Neff, bf [-] | -0.01467596 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Anhang B

a. Eigenformen der Platte ohne Dickensprung

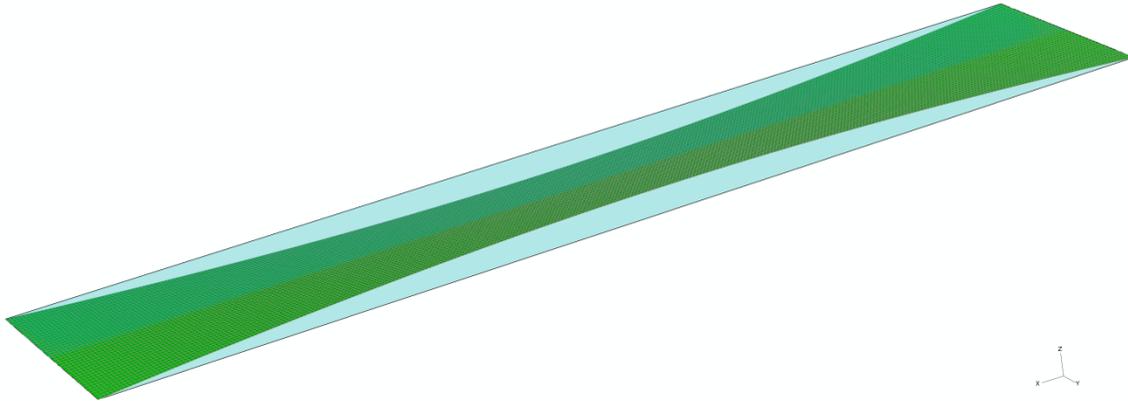


Abbildung 278: Platte $B=600$, $\alpha=10$, 1.Eigenform, $EV1=1.055$, $k_{\sigma}=0.427$, $\sigma_{crit,ABQ}=360.16 \text{ N/mm}^2$

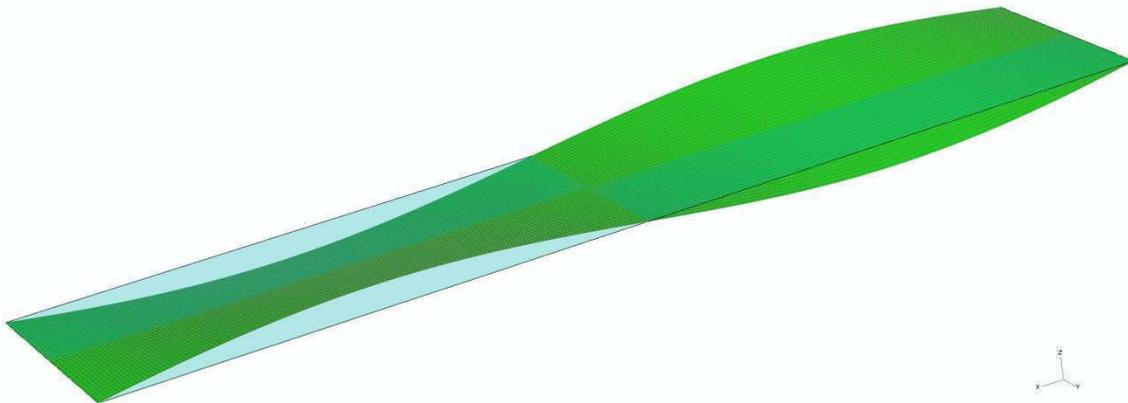


Abbildung 279: Platte $B=600$, $\alpha=10$, 2.Eigenform, $EV2=1.1237$, $k_{\sigma}=0.455$, $\sigma_{crit,ABQ}=383.61 \text{ N/mm}^2$

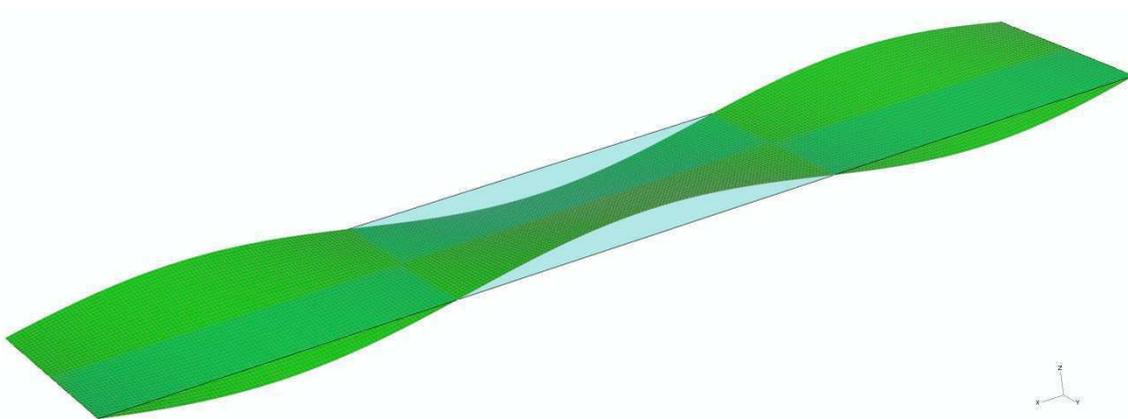


Abbildung 280: Platte $B=600$, $\alpha=10$, 3.Eigenform, $EV3=1.2405$, $k_{\sigma}=0.502$, $\sigma_{crit,ABQ}=423.48 \text{ N/mm}^2$

b. Eigenformen der Platte mit Dickensprung OB

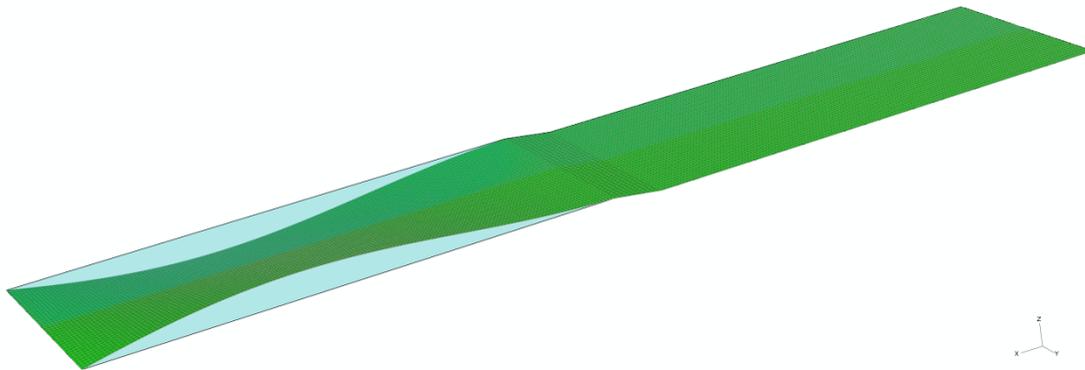


Abbildung 281: Platte OB $B=600$, $\alpha=10$, $t1/t2=3.00$, 1.Eigenform, $EV1=1.2201$, $k_{\sigma}=0.494$, $\sigma_{crit,ABQ}=416.52 \text{ N/mm}^2$

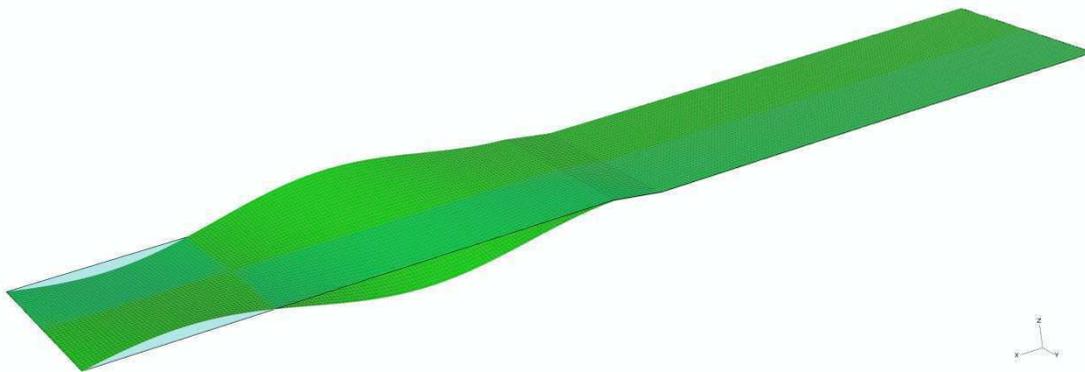


Abbildung 282: Platte OB $B=600$, $\alpha=10$, $t1/t2=3.00$, 2.Eigenform, $EV2=1.6185$, $k_{\sigma}=0.655$, $\sigma_{crit,ABQ}=552.53 \text{ N/mm}^2$



Abbildung 283: Platte OB $B=600$, $\alpha=10$, $t1/t2=3.00$, 3.Eigenform, $EV3=2.2311$, $k_{\sigma}=0.903$, $\sigma_{crit,ABQ}=761.66 \text{ N/mm}^2$

c. Eigenformen des Trägers ohne Dickensprung

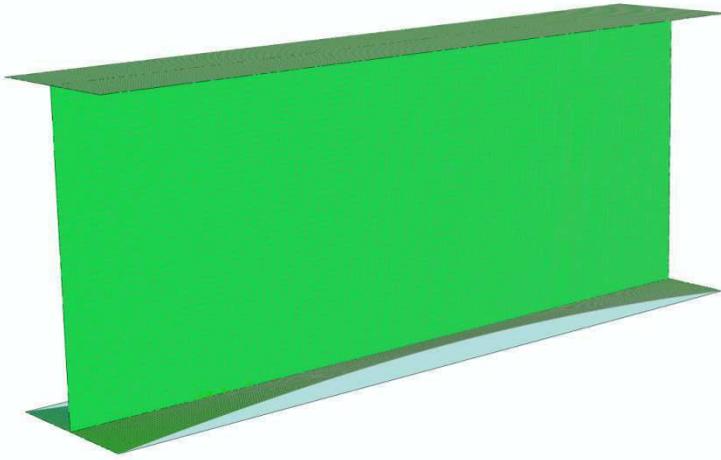


Abbildung 284: Träger $H=1200$, $t1/t2=1.0$, $\alpha=10$, $EV1=1.0492$, $k_{\sigma}=0.423$, $\sigma_{crit,ABQ}=356.82 \text{ N/mm}^2$

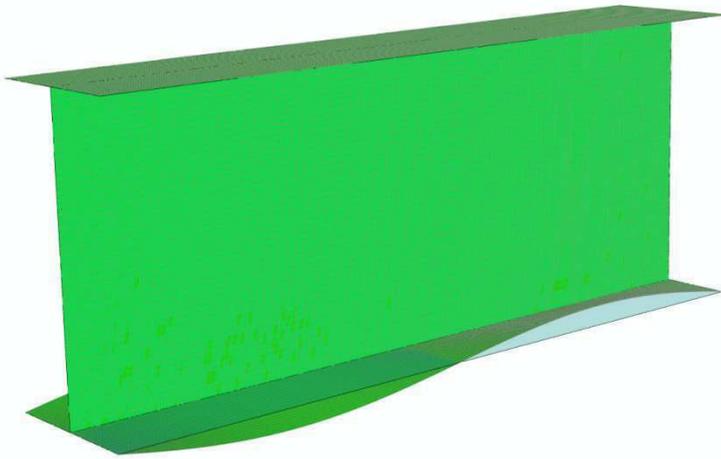


Abbildung 285: Träger $H=1200$, $t1/t2=1.0$, $\alpha=10$, $EV2=1.1180$, $k_{\sigma}=0.451$, $\sigma_{crit,ABQ}=380.22 \text{ N/mm}^2$

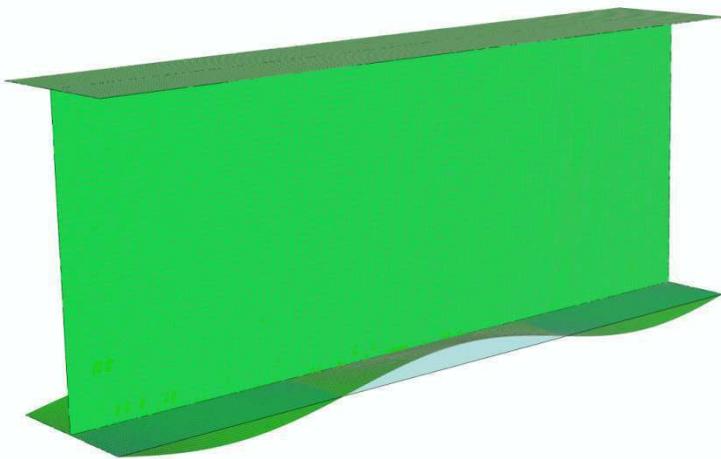


Abbildung 286: Träger $H=1200$, $t1/t2=1.0$, $\alpha=10$, $EV3=1.2359$, $k_{\sigma}=0.498$, $\sigma_{crit,ABQ}=420.32 \text{ N/mm}^2$

d. Eigenformen des Trägers mit Dickensprung

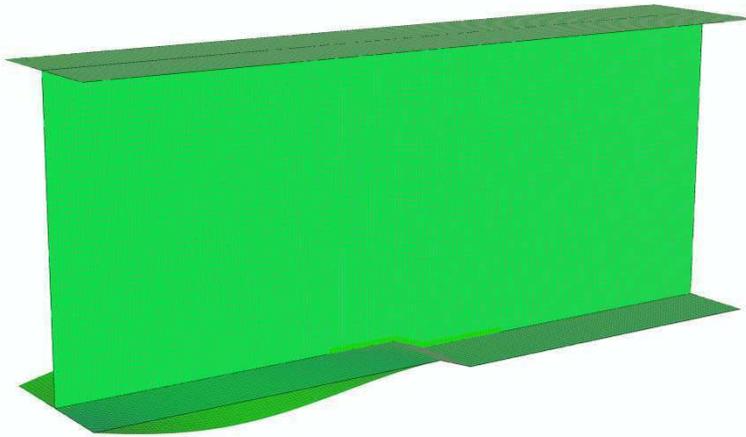


Abbildung 287: Träger $H=1200$, $t1/t2=6.0$, $\alpha=10$, OB , $EV1=1.2106$, $k\sigma=0.488$, $\sigma_{crit,ABQ}=411.71 \text{ N/mm}^2$

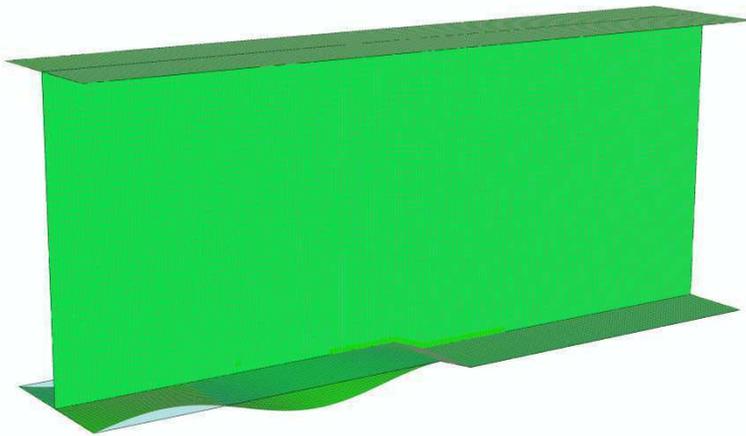


Abbildung 288: Träger $H=1200$, $t1/t2=6.0$, $\alpha=10$, OB , $EV2=1.6259$, $k\sigma=0.656$, $\sigma_{crit,ABQ}=552.95 \text{ N/mm}^2$

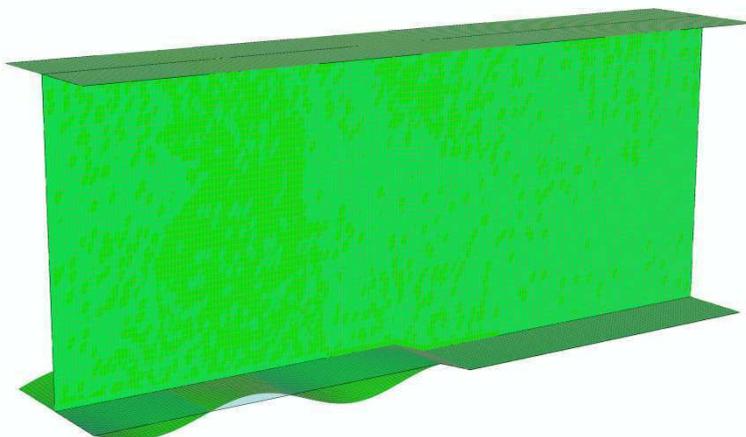


Abbildung 289: Träger $H=1200$, $t1/t2=6.0$, $\alpha=10$, OB , $EV3=1.2225$, $k\sigma=0.896$, $\sigma_{crit,ABQ}=755.85 \text{ N/mm}^2$

Anhang C

a. Ergebnisse Platte mit Dickensprung

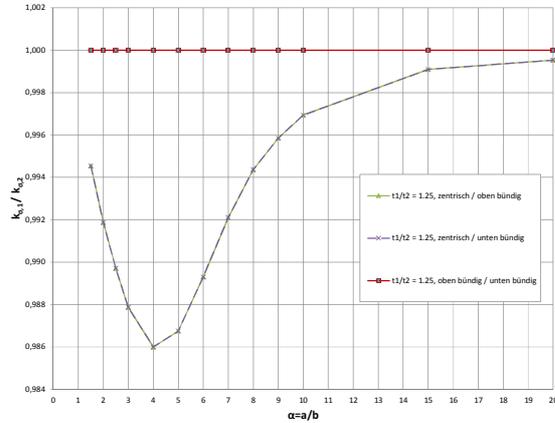


Abbildung 290: Platte, $B=600\text{mm}$, Darstellung des Unterschiedes der Dickensprungvarianten OB/UB/Z für $t_1/t_2=1.25$

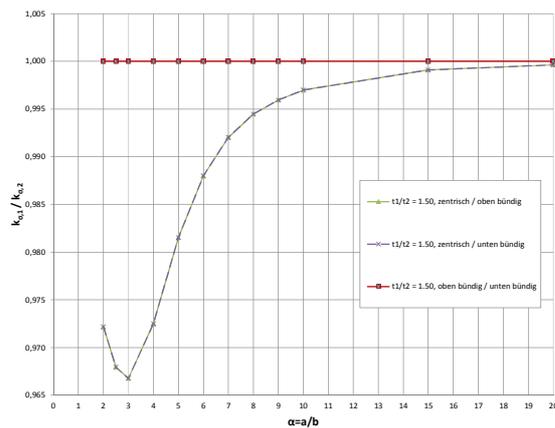


Abbildung 291: Platte, $B=600\text{mm}$, Darstellung des Unterschiedes der Dickensprungvarianten OB/UB/Z für $t_1/t_2=1.50$

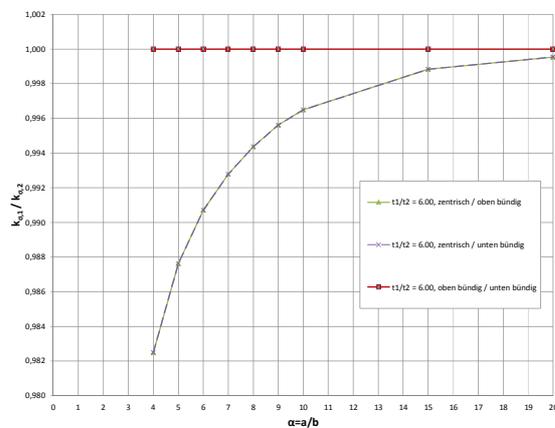


Abbildung 292: Platte, $B=600\text{mm}$, Darstellung des Unterschiedes der Dickensprungvarianten OB/UB/Z für $t_1/t_2=6.00$

b. Dickensprungvarianten Träger H=1200 mm

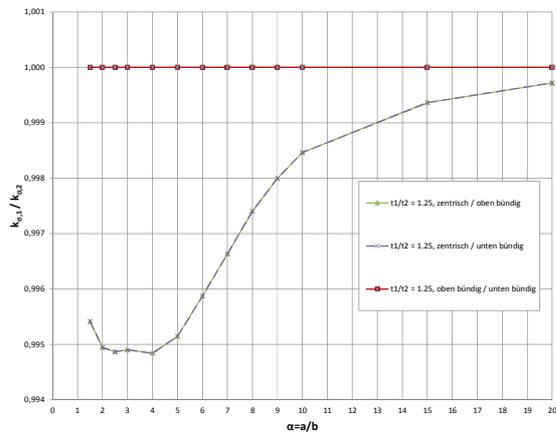


Abbildung 293: Darstellung des Unterschiedes der Dickensprungvarianten OB/UB/Z für $t_1/t_2=1.25$, $H=1200$ mm

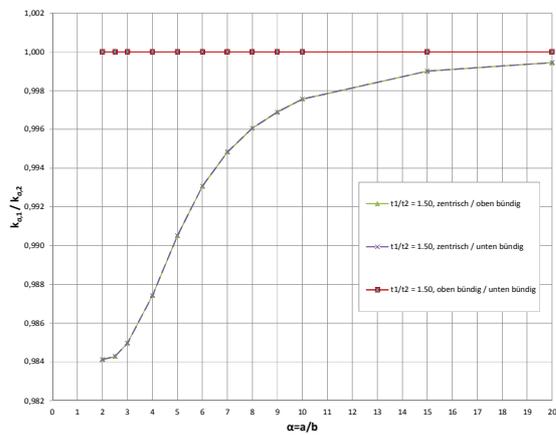


Abbildung 294: Darstellung des Unterschiedes der Dickensprungvarianten OB/UB/Z für $t_1/t_2=1.50$, $H=1200$ mm

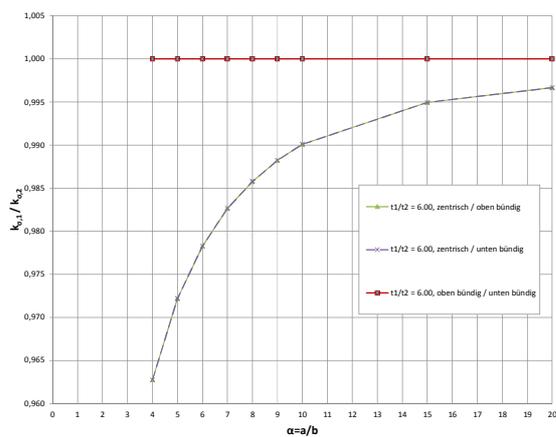
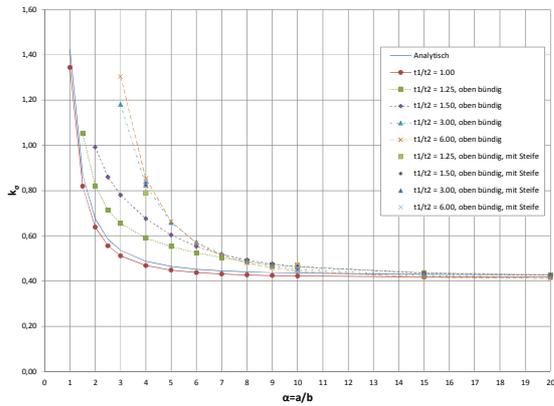
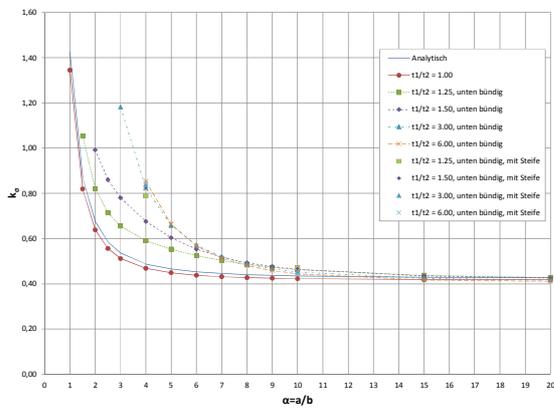
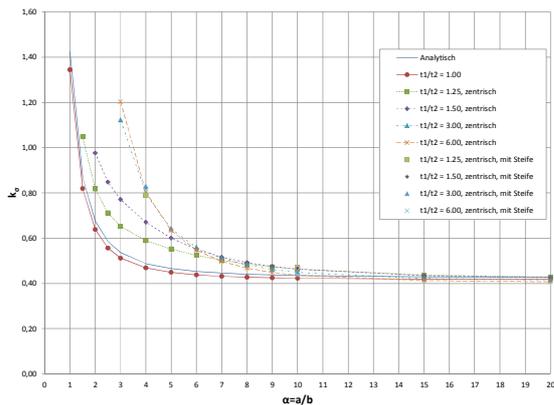


Abbildung 295: Darstellung des Unterschiedes der Dickensprungvarianten OB/UB/Z für $t_1/t_2=6.00$, $H=1200$ mm

c. Ergebnisse Träger H=3910 mm mit Dickensprung

Abbildung 296: Darstellung der k_{σ} -Werte für den Dickensprung OB, $H=3910$ mmAbbildung 297: Darstellung der k_{σ} -Werte für den Dickensprung UB, $H=3910$ mmAbbildung 298: Darstellung der k_{σ} -Werte für den Dickensprung Z, $H=3910$ mm

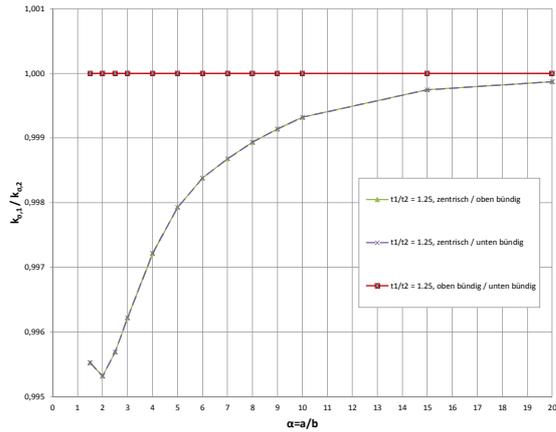


Abbildung 299: Darstellung des Unterschiedes der Dicksprungvarianten OB/UB/Z für $t_1/t_2=1.25$, $H=3910$ mm

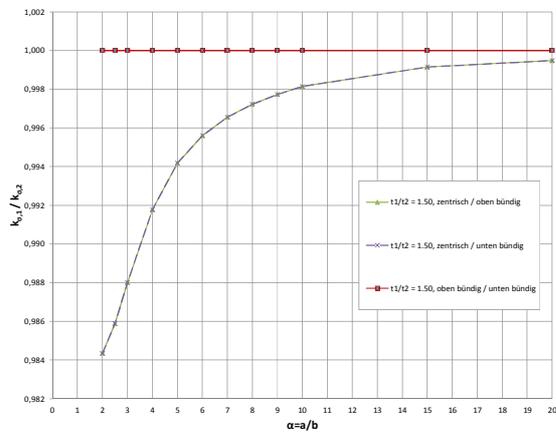


Abbildung 300: Darstellung des Unterschiedes der Dicksprungvarianten OB/UB/Z für $t_1/t_2=1.50$, $H=3910$ mm

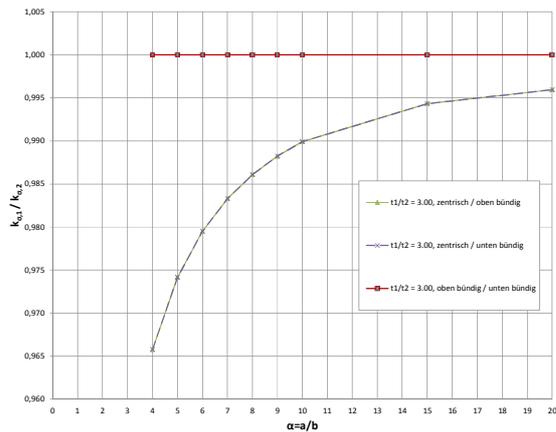


Abbildung 301: Darstellung des Unterschiedes der Dicksprungvarianten OB/UB/Z für $t_1/t_2=3.00$, $H=3910$ mm

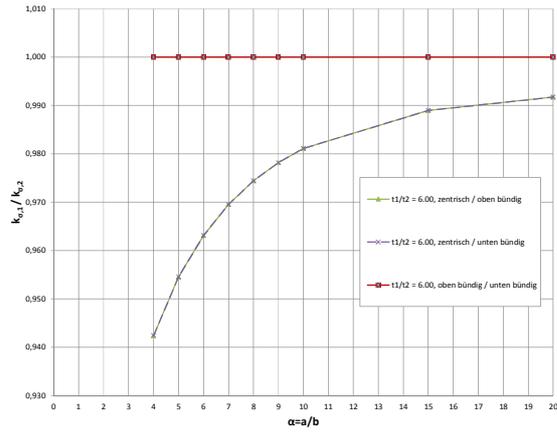


Abbildung 302: Darstellung des Unterschiedes der Dickensprungvarianten OB/UB/Z für $t1/t2=6.00$, $H=3910$ mm

Anhang D

ABAQUS INP - FILE

Als Beispiel soll ein ABAQUS INP-File für die nichtlineare Berechnung des Trägers H = 1200, $t_1/t_2 = 3.0$, $\alpha = 20$, UB gezeigt werden.

```

*PARAMETER
****kNm und kN
M=-6000.
f=1.5
****
L_ges=6000.
Lm=140.
t_fu1=60.
t_fu2=20.
t_fo1=20.
t_fo2=20.
t_w1=15.
t_w2=15.
b_u=600.0
b_o=600.0
h1=1200.
h2=1200.
fy=355.
E=210000.
nu=0.3
G=E/(2*(1+nu))
*****GEOMETRIC CALCULATIONS
L_t1=(L_ges/2)-(Lm/2)
L_t2=(L_ges/2)-(Lm/2)
L1a=(L_t1/2.)
L1=L_t1
L2=L1+Lm
L3=L2+L_t2
bu_05=0.5*b_u
bo_05=0.5*b_o
t_w05_1=t_w1
t_w05_2=t_w2
Flu2=-(t_fu2/2)
ho_in=h1-t_fu2-(t_fo1*0.5)
Flu1=-t_fu2+(t_fu1/2)
Flu2=-(t_fu2/2)
*****LOAD CALCULATIONS
mE1=f*M*1000000.
mE2=-mE1
*****
*HEADING
GMNIA, t2=60, alpha=20, UntenBündig
*PREPRINT, ECHO=NO, MODEL=YES, HISTORY=YES
*****NODES LOWER FLANGE
*NODE
100,0.,<bu_05>,<Flu1>
140,0.,<bu_05>,<Flu1>
200,<L3>,<bu_05>,<Flu2>
240,<L3>,<bu_05>,<Flu2>
1000000,0.,<bu_05>,<Flu1>
1000300,<L3>,<bu_05>,<Flu2>
1000100,<L1>,<bu_05>,<Flu1>
1000200,<L2>,<bu_05>,<Flu2>
1400000,0.,<bu_05>,<Flu1>
1400300,<L3>,<bu_05>,<Flu2>
1400100,<L1>,<bu_05>,<Flu1>
1400200,<L2>,<bu_05>,<Flu2>
*****
*NGEN,NSET=PR
100,140,1
*NGEN,NSET=PL
200,240,1
*NGEN,NSET=N_flu_K1
1000000,1400000,10000
*NGEN,NSET=N_flu_K2
1000100,1400100,10000
*NGEN,NSET=N_flu_K3
1000200,1400200,10000
*NGEN,NSET=N_flu_K4
1000300,1400300,10000
*NIFILL,NSET=N_flu1
N_flu_K1,N_flu_K2,100,1
*NIFILL,NSET=N_flu2
N_flu_K2,N_flu_K3,10,10
*NIFILL,NSET=N_flu3
N_flu_K3,N_flu_K4,100,1
*NSET,NSET=N_flu
N_flu1,N_flu2,N_flu3
*****NODES UPPER FLANGE
*NODE
300,0.,<bu_05>,<ho_in>
340,0.,<bu_05>,<ho_in>
400,<L3>,<bu_05>,<ho_in>
440,<L3>,<bu_05>,<ho_in>
2000000,0.,<bo_05>,<ho_in>
2000300,<L3>,<bo_05>,<ho_in>
2000100,<L1>,<bo_05>,<ho_in>
2000200,<L2>,<bo_05>,<ho_in>
2400000,0.,<bo_05>,<ho_in>
2400300,<L3>,<bo_05>,<ho_in>
2400100,<L1>,<bo_05>,<ho_in>
2400200,<L2>,<bo_05>,<ho_in>
*****
*NGEN,NSET=PR1
300,340,1
*NGEN,NSET=PL1
400,440,1
*NGEN,NSET=N_flo_K1
2000000,2400000,10000
*NGEN,NSET=N_flo_K2
2000100,2400100,10000
*NGEN,NSET=N_flo_K3
2000200,2400200,10000
*NGEN,NSET=N_flo_K4
2000300,2400300,10000
*NIFILL,NSET=N_flo1
N_flo_K1,N_flo_K2,100,1
*NIFILL,NSET=N_flo2
N_flo_K2,N_flo_K3,10,10
*NIFILL,NSET=N_flo3
N_flo_K3,N_flo_K4,100,1
*NSET,NSET=N_flo
N_flo1,N_flo2,N_flo3
*****NODES WEB - SHELL
*NODE
500,0.,0.,<Flu1>
550,0.,0.,<ho_in>
600,<L3>,0.,<Flu2>
650,<L3>,0.,<ho_in>
3000000,0.,0.,<Flu1>
3000100,<L1>,0.,<Flu1>
3000200,<L2>,0.,<Flu2>
3000300,<L3>,0.,<Flu2>
3050000,0.,0.,<ho_in>
3050100,<L1>,0.,<ho_in>
3050200,<L2>,0.,<ho_in>
3050300,<L3>,0.,<ho_in>
*****
*NGEN,NSET=wr
500,550,1

```

```

*NGEN,NSET=w1
600,650,1
*NGEN,NSET=N_w_u
3000000,3000100,1
3000100,3000200,10
3000200,3000300,1
*NGEN,NSET=N_w_o
3050000,3050100,1
3050100,3050200,10
3050200,3050300,1
*NFill,NSET=N_w
N_w_u,N_w_o,50,1000
*****LOWER FLANGE ELEMENTS - SHELL
*ELEMENT,TYPE=S4
1000001,1000000,1010000,1010001,1000001
1000101,1000100,1010100,1010110,1000110
1000201,1000200,1010200,1010201,1000201
*ELGEN,ELSET=E_flu_1
1000001,100,1,1,40,10000,10000
***
*ELGEN,ELSET=E_flu_2
1000101,10,10,10,40,10000,10000
***
*ELGEN,ELSET=E_flu_3
1000201,100,1,1,40,10000,10000
*ELSET,ELSET=E_flu
E_flu_1,E_flu_2,E_flu_3
*ELEMENT,TYPE=B31
101,100,101
*ELGEN,ELSET=E_PR
101,40,1,1
*ELEMENT,TYPE=B31
201,200,201
*ELGEN,ELSET=E_PL
201,40,1,1
*****UPPER FLANGE ELEMENTS - SHELL
*ELEMENT,TYPE=S4
2000001,2000000,2010000,2010001,2000001
2000101,2000100,2010100,2010110,2000110
2000201,2000200,2010200,2010201,2000201
*ELGEN,ELSET=E_flo_1
2000001,100,1,1,40,10000,10000
***
*ELGEN,ELSET=E_flo_2
2000101,10,10,10,40,10000,10000
***
*ELGEN,ELSET=E_flo_3
2000201,100,1,1,40,10000,10000
*ELSET,ELSET=E_flo
E_flo_1,E_flo_2,E_flo_3
*ELEMENT,TYPE=B31
301,300,301
*ELGEN,ELSET=E_PR1
301,40,1,1
*ELEMENT,TYPE=B31
401,400,401
*ELGEN,ELSET=E_PL1
401,40,1,1
*****WEB ELEMENTS - SHELL
*ELEMENT,TYPE=S4
3000001,3000000,3000001,3001001,3001000
3000101,3000100,3000110,3001110,3001100
3000201,3000200,3000201,3001201,3001200
*ELGEN,ELSET=E_w1
3000001,100,1,1,50,1000,1000
*ELGEN,ELSET=E_w2
3000101,10,10,10,50,1000,1000
*ELGEN,ELSET=E_w3
3000201,100,1,1,50,1000,1000
*ELSET,ELSET=E_w
E_w1,E_w2,E_w3
*ELEMENT,TYPE=B31
501,500,501
*ELGEN,ELSET=E_wr
501,50,1,1
*ELEMENT,TYPE=B31
601,600,601
*ELGEN,ELSET=E_w1
601,50,1,1
*****Wall thickness
*SHELL SECTION,ELSET=E_flo,MATERIAL=STEEL, POISSON=0.0
<t_fu1>,19
*SHELL SECTION,ELSET=E_w,MATERIAL=STEEL, POISSON=0.0

```

```

<t_w05_1>,19
*SHELL SECTION,ELSET=E_flu,MATERIAL=STEEL,NODAL
THICKNESS, POISSON=0.0
<t_fu2>,19
*NODAL THICKNESS
N_flu_K1, <t_fu1>
N_flu_K2, <t_fu1>
N_flu_K3, <t_fu2>
N_flu_K4, <t_fu2>
*NODAL THICKNESS, GENERATE
N_flu_K1, N_flu_K2, 100, 1
*NODAL THICKNESS, GENERATE
N_flu_K2, N_flu_K3, 10, 10
*NODAL THICKNESS, GENERATE
N_flu_K3, N_flu_K4, 100, 1
*BEAM
SECTION,SECTION=RECT,ELSET=E_PR,MATERIAL=STEEL_B
2000.,2000.
*BEAM
SECTION,SECTION=RECT,ELSET=E_PL,MATERIAL=STEEL_B
2000.,2000.
*BEAM
SECTION,SECTION=RECT,ELSET=E_PR1,MATERIAL=STEEL_B
2000.,2000.
*BEAM
SECTION,SECTION=RECT,ELSET=E_PL1,MATERIAL=STEEL_B
2000.,2000.
*BEAM
SECTION,SECTION=RECT,ELSET=E_wr,MATERIAL=STEEL_B
2000.,2000.
0.,1.,0.
*BEAM
SECTION,SECTION=RECT,ELSET=E_w1,MATERIAL=STEEL_B
2000.,2000.
0.,1.,0.
*****MATERIAL
*MATERIAL,NAME=STEEL
*ELASTIC
<E>,<nu>
*PLASTIC
355.0,0.
355.0,0.20
1.,0.21
*MATERIAL,NAME=STEEL_B
*ELASTIC
<E>,<nu>
*****NODE SETS
*NSET,NSET=N_OUT
1200100
*NSET,NSET=NULL
N_flu,N_flo,N_w
*ELSET,ELSET=EALL
E_flu,E_flo,E_w
*****
*NSET,NSET=web_con_OG,GENERATE
3050000,3050100,1
3050100,3050200,10
3050200,3050300,1
*NSET,NSET=flog_con_OG,GENERATE
2200000,2200100,1
2200100,2200200,10
2200200,2200300,1
*****
*NSET,NSET=web_con_UG,GENERATE
3000000,3000100,1
3000100,3000200,10
3000200,3000300,1
*NSET,NSET=flog_con_UG,GENERATE
1200000,1200100,1
1200100,1200200,10
1200200,1200300,1
*****
*NSET,NSET=N_w_u1,GENERATE
3000000,3000100,1
3000100,3000200,10
3000200,3000300,1
*NSET,NSET=N_w_o1,GENERATE
3050000,3050100,1
3050100,3050200,10
3050200,3050300,1
*NFill,NSET=N_w1
N_w_u1,N_w_o1,50,1000
*NSET,NSET=N_SUP

```

```

1000000,
1400000,
flog_con_OG,
flog_con_OG,
2200150,
1000300,
1400300

*****MPC
*MPC
PIN,web_con_OG,flog_con_OG
PIN,web_con_UG,flog_con_UG
BEAM,120,500
BEAM,220,600
BEAM,320,550
BEAM,420,650
*****CONNECTOR
*****Connect WebE1 to Point 2
*ELEMENT, TYPE=CONN3D2,ELSET=CONN_WebE2
63000,600,3000300
63050,601,3001300
63001,602,3002300
63002,603,3003300
63003,604,3004300
63004,605,3005300
63005,606,3006300
63006,607,3007300
63007,608,3008300
63008,609,3009300
63009,610,3010300
63010,611,3011300
63011,612,3012300
63012,613,3013300
63013,614,3014300
63014,615,3015300
63015,616,3016300
63016,617,3017300
63017,618,3018300
63018,619,3019300
63019,620,3020300
63020,621,3021300
63021,622,3022300
63022,623,3023300
63023,624,3024300
63024,625,3025300
63025,626,3026300
63026,627,3027300
63027,628,3028300
63028,629,3029300
63029,630,3030300
63030,631,3031300
63031,632,3032300
63032,633,3033300
63033,634,3034300
63034,635,3035300
63035,636,3036300
63036,637,3037300
63037,638,3038300
63038,639,3039300
63039,640,3040300
63040,641,3041300
63041,642,3042300
63042,643,3043300
63043,644,3044300
63044,645,3045300
63045,646,3046300
63046,647,3047300
63047,648,3048300
63048,649,3049300
63049,650,3050300
*CONNECTOR SECTION, ELSET=CONN_WebE2
JOIN,
*****Connect WebE2 to Point 1
*ELEMENT, TYPE=CONN3D2,ELSET=CONN_WebE1
53000,500,3000000
53050,501,3001000
53001,502,3002000
53002,503,3003000
53003,504,3004000

```

```

53004,505,3005000
53005,506,3006000
53006,507,3007000
53007,508,3008000
53008,509,3009000
53009,510,3010000
53010,511,3011000
53011,512,3012000
53012,513,3013000
53013,514,3014000
53014,515,3015000
53015,516,3016000
53016,517,3017000
53017,518,3018000
53018,519,3019000
53019,520,3020000
53020,521,3021000
53021,522,3022000
53022,523,3023000
53023,524,3024000
53024,525,3025000
53025,526,3026000
53026,527,3027000
53027,528,3028000
53028,529,3029000
53029,530,3030000
53030,531,3031000
53031,532,3032000
53032,533,3033000
53033,534,3034000
53034,535,3035000
53035,536,3036000
53036,537,3037000
53037,538,3038000
53038,539,3039000
53039,540,3040000
53040,541,3041000
53041,542,3042000
53042,543,3043000
53043,544,3044000
53044,545,3045000
53045,546,3046000
53046,547,3047000
53047,548,3048000
53048,549,3049000
53049,550,3050000
*CONNECTOR SECTION, ELSET=CONN_WebE1
JOIN,
*****JOIN POINTS SHELL
*ELEMENT, TYPE=CONN3D2,ELSET=CONN_JR
1000,100,1000000
1001,101,1010000
1002,102,1020000
1003,103,1030000
1004,104,1040000
1005,105,1050000
1006,106,1060000
1007,107,1070000
1008,108,1080000
1009,109,1090000
1010,110,1100000
1011,111,1110000
1012,112,1120000
1013,113,1130000
1014,114,1140000
1015,115,1150000
1016,116,1160000
1017,117,1170000
1018,118,1180000
1019,119,1190000
1020,120,1200000
1021,121,1210000
1022,122,1220000
1023,123,1230000
1024,124,1240000
1025,125,1250000
1026,126,1260000
1027,127,1270000
1028,128,1280000

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1029,129,1290000
1030,130,1300000
1031,131,1310000
1032,132,1320000
1033,133,1330000
1034,134,1340000
1035,135,1350000
1036,136,1360000
1037,137,1370000
1038,138,1380000
1039,139,1390000
1040,140,1400000
*CONNECTOR SECTION, ELSET=CONN_JR
JOIN,
*****JOIN POINTS SHELL
*ELEMENT, TYPE=CONN3D2,ELSET=CONN_JL
2000,200,1000300
2001,201,1010300
2002,202,1020300
2003,203,1030300
2004,204,1040300
2005,205,1050300
2006,206,1060300
2007,207,1070300
2008,208,1080300
2009,209,1090300
2010,210,1100300
2011,211,1110300
2012,212,1120300
2013,213,1130300
2014,214,1140300
2015,215,1150300
2016,216,1160300
2017,217,1170300
2018,218,1180300
2019,219,1190300
2020,220,1200300
2021,221,1210300
2022,222,1220300
2023,223,1230300
2024,224,1240300
2025,225,1250300
2026,226,1260300
2027,227,1270300
2028,228,1280300
2029,229,1290300
2030,230,1300300
2031,231,1310300
2032,232,1320300
2033,233,1330300
2034,234,1340300
2035,235,1350300
2036,236,1360300
2037,237,1370300
2038,238,1380300
2039,239,1390300
2040,240,1400300
*CONNECTOR SECTION, ELSET=CONN_JL
JOIN,
*****JOIN POINTS SHELL
*ELEMENT, TYPE=CONN3D2,ELSET=CONN_JR1
7000,300,2000000
7001,301,2010000
7002,302,2020000
7003,303,2030000
7004,304,2040000
7005,305,2050000
7006,306,2060000
7007,307,2070000
7008,308,2080000
7009,309,2090000
7010,310,2100000
7011,311,2110000
7012,312,2120000
7013,313,2130000
7014,314,2140000
7015,315,2150000
7016,316,2160000
7017,317,2170000
7018,318,2180000
7019,319,2190000
7020,320,2200000
7021,321,2210000

7022,322,2220000
7023,323,2230000
7024,324,2240000
7025,325,2250000
7026,326,2260000
7027,327,2270000
7028,328,2280000
7029,329,2290000
7030,330,2300000
7031,331,2310000
7032,332,2320000
7033,333,2330000
7034,334,2340000
7035,335,2350000
7036,336,2360000
7037,337,2370000
7038,338,2380000
7039,339,2390000
7040,340,2400000
*CONNECTOR SECTION, ELSET=CONN_JR1
JOIN,
*****JOIN POINTS SHELL
*ELEMENT, TYPE=CONN3D2,ELSET=CONN_JL1
8000,400,2000300
8001,401,2010300
8002,402,2020300
8003,403,2030300
8004,404,2040300
8005,405,2050300
8006,406,2060300
8007,407,2070300
8008,408,2080300
8009,409,2090300
8010,410,2100300
8011,411,2110300
8012,412,2120300
8013,413,2130300
8014,414,2140300
8015,415,2150300
8016,416,2160300
8017,417,2170300
8018,418,2180300
8019,419,2190300
8020,420,2200300
8021,421,2210300
8022,422,2220300
8023,423,2230300
8024,424,2240300
8025,425,2250300
8026,426,2260300
8027,427,2270300
8028,428,2280300
8029,429,2290300
8030,430,2300300
8031,431,2310300
8032,432,2320300
8033,433,2330300
8034,434,2340300
8035,435,2350300
8036,436,2360300
8037,437,2370300
8038,438,2380300
8039,439,2390300
8040,440,2400300
*CONNECTOR SECTION, ELSET=CONN_JL1
JOIN,
*****BOUNDARY CONDITIONS
*BOUNDARY
1000000,3
1400000,3
flog_con_OG,4
flog_con_OG,6
2200150,1
1000300,3
1400300,3
N_w1,2
*****IMPERFECTION
*IMPERFECTION,FILE=SH_600_LA_t20t60_1200_gel_web_20_uhnt
enbuend_ik,STEP=1,NSET=N_flu
1,0.485

*****INITIAL CONDITIONS
*INITIAL CONDITIONS,TYPE=STRESS,USER

```

```

*****STEP 1
*STEP,EXTRAPOLATION=PARABOLIC,NLGEOM
*STATIC
1,,,
*MONITOR,NODE=1000150,DOF=3,FREQ=1
*OUTPUT,FIELD,FREQ=0
*NODE OUTPUT,NSET=N_flu
U
*ELEMENT OUTPUT,ELSET=E_flu
S
*END STEP
*****STEP 2
*STEP,EXTRAPOLATION=PARABOLIC,NLGEOM,INC=200
*STATIC,RIKS
0.025,,,0.02
*CLOAD
525,5,<mE1>
625,5,<mE2>

*MONITOR,NODE=1000150,DOF=3,FREQ=1
*OUTPUT,FIELD,FREQ=5
*NODE OUTPUT
U
*ELEMENT OUTPUT
S,SSAVG,E
***NODE FILE,NSET=N_flu
**U
***OUTPUT,HISTORY
***NODE OUTPUT,NSET=N_OUT
**CF2
***NODE OUTPUT,NSET=N_OUT
**U3
*NODE PRINT,NSET=N_flu
U
*NODE PRINT,NSET=N_SUP,SUMMARY=YES
RF
*END STEP
    
```


Dies ist eine Veröffentlichung des

FACHBEREICHS INGENIEURBAUKUNST (IBK) AN DER TU GRAZ

Der Fachbereich Ingenieurbaukunst umfasst die dem konstruktiven Ingenieurbau nahe stehenden Institute für Baustatik, Betonbau, Stahlbau & Flächentragwerke, Holzbau & Holztechnologie, Materialprüfung & Baustofftechnologie, Baubetrieb & Bauwirtschaft, Hochbau & Industriebau, Bauinformatik und Allgemeine Mechanik der Fakultät für Bauingenieurwissenschaften an der Technischen Universität Graz.

Dem Fachbereich Ingenieurbaukunst ist das Bautechnikzentrum (BTZ) zugeordnet, welches als gemeinsame hochmoderne Laboreinrichtung zur Durchführung der experimentellen Forschung aller beteiligten Institute dient. Es umfasst die drei Laboreinheiten für konstruktiven Ingenieurbau, für Bauphysik und für Baustofftechnologie.

Der Fachbereich Ingenieurbaukunst kooperiert im gemeinsamen Forschungsschwerpunkt „Advanced Construction Technology“. Dieser Forschungsschwerpunkt umfasst sowohl Grundlagen- als auch praxisorientierte Forschungs- und Entwicklungsprogramme.

Weitere Forschungs- und Entwicklungskooperationen bestehen mit anderen Instituten der Fakultät, insbesondere mit der Gruppe Geotechnik, sowie nationalen und internationalen Partnern aus Wissenschaft und Wirtschaft.

Die Lehrinhalte des Fachbereichs Ingenieurbaukunst sind aufeinander abgestimmt. Aus gemeinsam betreuten Projektarbeiten und gemeinsamen Prüfungen innerhalb der Fachmodule können alle Beteiligten einen optimalen Nutzen ziehen.

Durch den gemeinsamen, einheitlichen Auftritt in der Öffentlichkeit präsentiert sich der Fachbereich Ingenieurbaukunst als moderne Lehr- und Forschungsgemeinschaft, welche die Ziele und Visionen der TU Graz umsetzt.

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Institutskenzahl:

1 – Allgemeine Mechanik | 2 – Baustatik | 3 – Betonbau
4 – Holzbau & Holztechnologie | 5 – Stahlbau & Flächentragwerke
6 – Materialprüfung & Baustofftechnologie | 7 – Baubetrieb & Bauwirtschaft
8 – Hochbau & Industriebau | 9 – Bauinformatik
10 – Labor für Konstruktiven Ingenieurbau

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