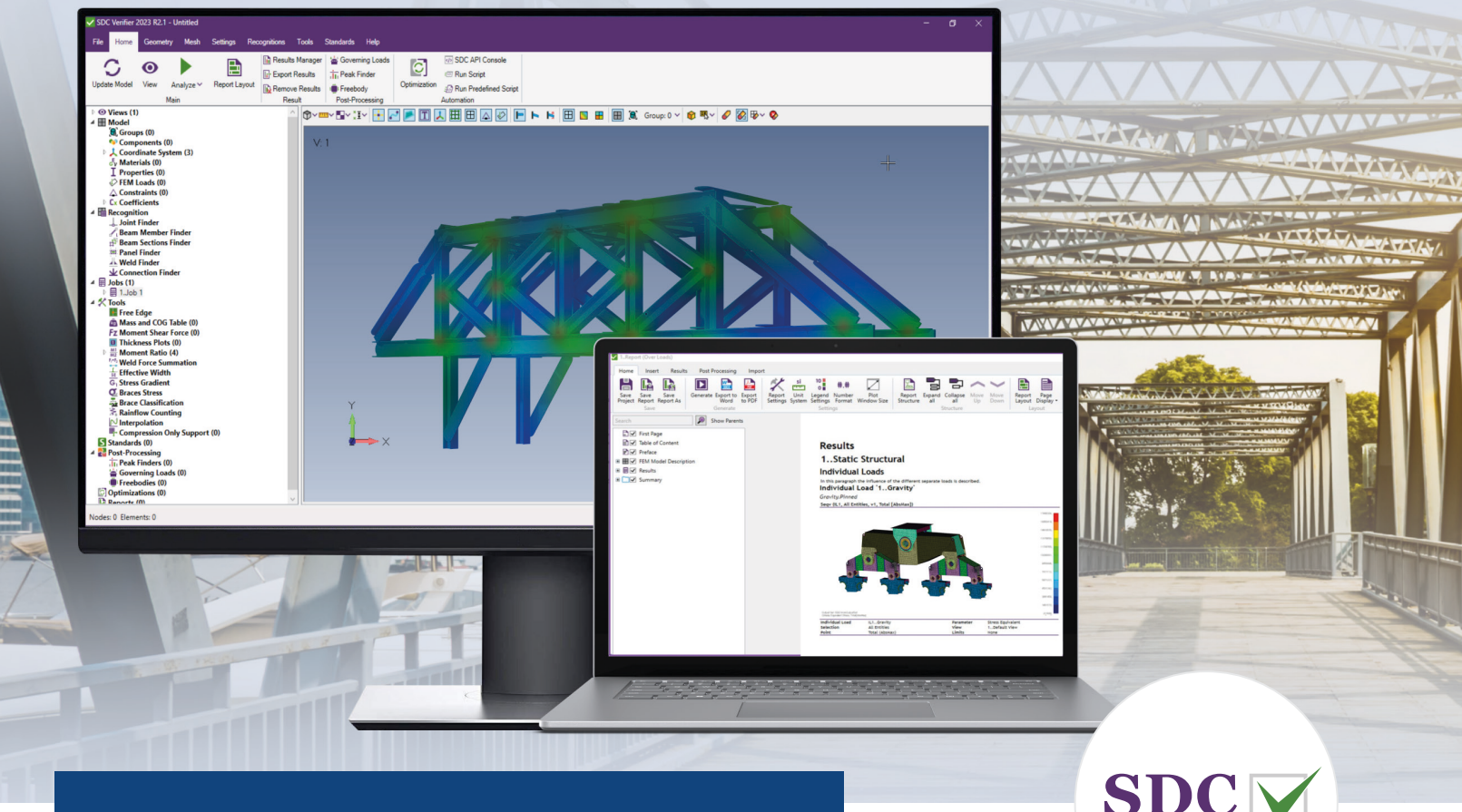


Accuracy in steel connection design: A practical look at SDC Verifier

by Oleg Ischchuk
SDC Verifier

Steel connections are the backbone of civil and structural engineering, ensuring the safe transfer of loads throughout a structure. However, designing and verifying these connections can be a time-consuming and error-prone process due to complex calculations and compliance with various codes and regulations.

This article explores SDC Verifier, a software solution that streamlines steel connection design.

Steel connections are critical components of civil and structural engineering, ensuring the transfer of loads throughout a structure. However, the design and testing of these connections can be time-consuming and error-prone due to:

1. The intricate calculations for factors such as bolt and weld strength to test the durability and behaviour of connections, especially complex connections.
2. The comprehensive set of codes and standards that govern failure modes in aspects such as material properties, weld configurations, and bolt capacities.

This article explores SDC Verifier, a software solution designed to address these challenges in steel connection design. We will discuss how the software automates tasks, simplifies code compliance, and ultimately enhances efficiency and accuracy for engineers working on steel connection projects.

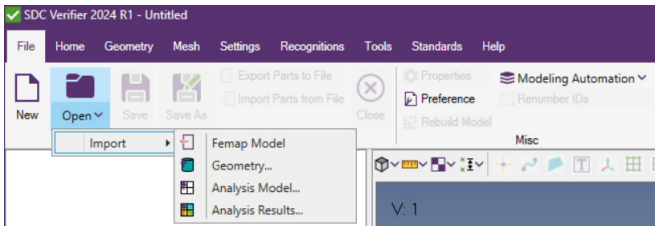
Steel connection design with SDC Verifier

Designing steel connections often involves manual calculations and juggling separate software for modelling, simulating, and checking codes. This disjointed approach can be slow and error prone, especially for complex projects.

SDC Verifier tackles these challenges by offering a comprehensive software solution specifically designed for steel connection design. It integrates key functionality within a single, user-friendly platform:

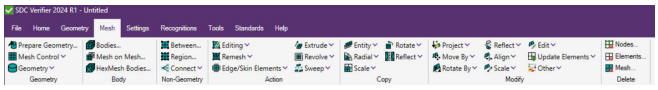
Simplified modelling

No more tedious data entry! Import existing CAD models of your steel connections directly into SDC Verifier. Alternatively, create new models within the software. This ensures consistency between your design and analysis.



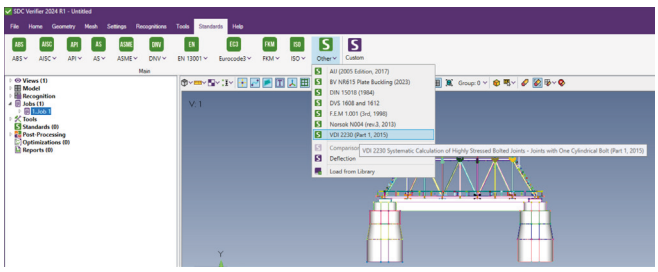
Powerful simulation

SDC Verifier uses advanced finite element analysis (FEA) to simulate connection behaviour under various loads. This allows you to visualize stress distribution, strain, and potential failure points, to support informed design decisions.



Automated code checking

Keeping up with ever-changing engineering codes can be time-consuming. SDC Verifier integrates a vast library of pre-built codes relevant to steel connections, covering material properties, weld configurations, and bolt capacities. The software automatically checks your design against these standards, ensuring code compliance and minimizing errors.



By combining these features, SDC Verifier empowers engineers to design and verify steel connections with greater efficiency and accuracy.

Automating steel connection analysis

Traditionally, bolt checks involve tedious manual calculations and the referencing of separate design codes. SDC Verifier eliminates this burden by offering:

Pre-built code libraries encompassing popular standards for civil engineering like Eurocode 3 (EC3, EN 1993-1-8), AISC 360-10 and VDI 2230 ¾ the software seamlessly integrates the relevant provisions for bolt checks.

Definitions for bolt diameter, material properties, and other characteristics directly within the software ¾ no need to juggle separate spreadsheets or data tables.

- **Shear strength:** Includes standard requirements for the shear capacity of the bolt(s) considering factors like thread area and material properties.
- **Bearing strength:** Verifies that the connected materials can withstand the bearing force exerted by the bolt(s).

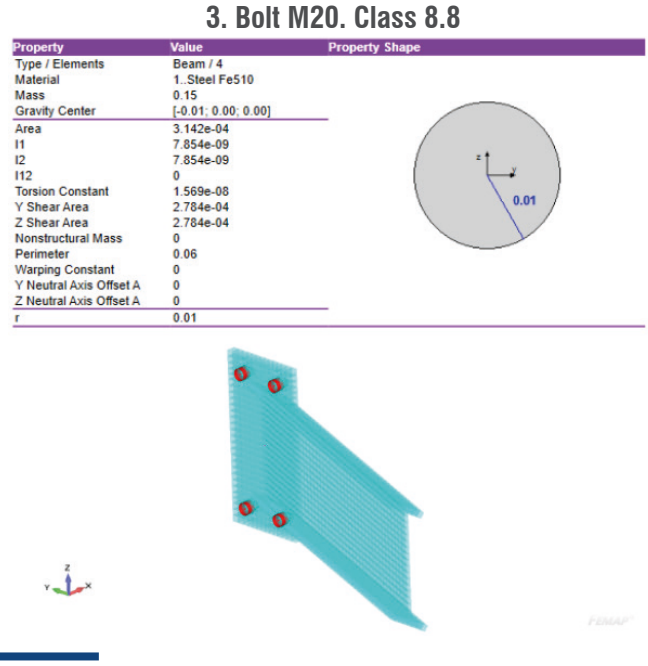


Fig. 1. Verification of Class 8.8 M20 bolts in SDC Verifier.

- **Minimum fastener tension:** Ensures sufficient tension in the bolt(s) to maintain a secure connection, preventing gaps and loosening under normal loads. This indirectly contributes to axial strength and slip resistance.
- **Axial strength:** Analyses the bolt's capacity to resist forces acting along its length (tension or compression), preventing bolt failure under excessive pulling or pushing forces.
- **Slip resistance:** Assesses the clamped joint's ability to resist shear forces that tend to make the connected parts slide past each other. By ensuring sufficient clamping force (achieved through minimum fastener tension), SDC Verifier helps mitigate slip resistance failures.

The integrity of steel connections relies heavily on the strength of the welds. SDC Verifier simplifies weld strength checks by:
Selecting from pre-built code libraries like EC3 (EN 1993-1-8) for weld strength calculations, like bolt checks.

The software automatically assesses the weld strength based on the selected standard, considering factors like:

- **Weld size and geometry:** The weld dimensions and configuration, including its type, size, and quality, are factored into the analysis.
- **Material properties:** The properties of the base metal and weld material are considered.

SDC Verifier can visualize stress distribution around the weld, providing valuable insights into potential weak points for further design optimization.

By automating these tasks, the software helps ensure that your welds meet the necessary strength requirements, leading to more reliable and secure steel connections.

Code compliance for steel connections

Code compliance is non-negotiable in designing these connections. Cutting corners can lead to catastrophic consequences, jeopardizing lives, causing operational downtime, and incurring significant financial losses.

SDC Verifier empowers you to achieve industrial-grade safety by offering a comprehensive solution for navigating the complexities of engineering codes. The software boasts a vast library specifically tailored to the demands of industrial civil engineering projects.

This includes:

Eurocode 3 (EC3): A cornerstone for steel structures in Europe, with a specific focus on bolt design:

- Standard used: EN 1993-1-8:2005 ¾ Actions on structures ¾ Part 1-8: Design of joints
- Key features:
  - Bolt checks according to Section 3: Connections made with bolts, rivets or pins.
  - Considers factors like bolt position, thread pitch, shear plane location, countersunk bolts, class of friction surfaces, etc.
  - Analyses both bolt capacity and slip resistance.
  - Users can define material properties, safety factors, and other relevant parameters.

AISC 360-10 Bolts (14th Edition, 2010): The gold standard for steel construction in North America:

- Standard used: AISC 360-10 Specification for Structural Steel Buildings (Chapter J3: Bolts and Threaded Parts)
- Key features:
  - Bolt checks based on Chapter J3 provisions.
  - Considers factors like nominal bolt diameter, thread influence on shear strength, minimum fastener tension, and nominal tensile/shear strength.
  - Capability for slip-critical connection design (Chapter J3.8).
  - Integrates safety factors based on hole type.
  - Users can override default values for various properties.

VDI 2230 (Part 1, 2015): A German engineering standard for calculating single-bolt joints:

- Standard used: VDI 2230 Beiblatt 1: Berechnung von Einzelbolzverbindungen (calculation of single-bolt joints)
- Key features:
  - Systematic method for calculating bolted joints using a step-by-step approach.
  - Considers factors like bolt type (through-bolt, socket head), rolled bolts, temperature loading, Young's modulus of materials, forces, number of loading cycles, nut dimensions, etc.
  - Analyses various aspects like sealing area, clamping length, friction radius, edge distances, and more.
  - Users can define material properties, tightening factors, friction coefficients, strength limits, and bolt dimensions.
  - A library of bolts to choose from.

In addition to these core standards, SDC Verifier offers an extensive library catering to specific industrial needs.

By integrating these essential standards, the software streamlines the code compliance process. The software automates code checks, meticulously evaluating your connection design against the selected standard's provisions.

SDC Verifier offers additional functionalities to complement its core code checking capabilities.

For instance, the Beam Member and Joint Checks App enables comprehensive analysis of connections in large, complex structures, especially those found in offshore applications. This app performs critical checks according to various industry standards, including:

- AISC 360-10 (American Institute of Steel Construction standards for member design)
- Eurocode 3 (EN 1993-1-1)

The Beam Member and Joint Checks App also leverages a Beam Member Finder tool. This tool automatically detects the buckling lengths of beam members in three directions (Y, Z, and torsional), ensuring accurate analysis independent of the model mesh.

Optimizing steel connection design

While SDC Verifier excels at ensuring code compliance for connections, the software also empowers you to optimize your steel connection design through a range of additional features:

Member design checks (EC3, EN 1993-1-1): This feature allows you to analyse individual steel members like beams and columns against the provisions of Eurocode 3 (EC3), specifically EN 1993-1-1. This check ensures these members possess the necessary strength and stability to carry their intended loads. By performing member design checks alongside connection analysis, you gain a more holistic understanding of your entire structural system, potentially revealing opportunities to optimize connection design.

Plate buckling checks (EC3, EN 1993-1-5): This functionality assesses the susceptibility of steel plates within your connections to buckling under compressive loads. Understanding buckling behaviour is crucial for optimizing connection design. For instance, identifying a plate prone to buckling might prompt you to modify the connection geometry or to introduce stiffeners for greater resistance.

Furthermore, SDC Verifier offers comprehensive fatigue analysis tools to optimize your steel structure designs for long-term performance. This is especially critical for industrial applications where connections undergo repeated loading and unloading cycles from machinery and equipment.

Built-in fatigue analysis capabilities:

- Standards support: Conduct fatigue checks according to established industry standards, including Eurocode 3 Fatigue (EN 1993-1-9) and DNV-RP-C203 Fatigue.
- Streamlined workflow: The fatigue analysis module employs the Palmgren-Miner rule and S-N curves for efficient fatigue life estimation.
- Automated weld identification: The Weld Finder tool automatically locates welded sections within your connection model. This eliminates the need for manual weld modelling and allows direct assignment of weld properties for a more accurate analysis.

The software also allows you to define Fatigue Groups for advanced users, enabling even more precise fatigue analysis. This feature is particularly useful for complex loading scenarios where you want to group similar load cases for a more granular assessment of fatigue damage.

This allows you to analyse both the connections themselves and the connected members, fostering a more informed and efficient design process.

This can potentially optimize the connection design by using holistic analysis to enable the use of less material while still achieving the required strength and stability.

Moreover, well-optimized connection design can lead to a more efficient structure, potentially reducing the need for overly robust connections or members.
SDC Verifier does not just ensure compliant connections; it also unlocks the potential to create efficient and cost-effective steel structures.

Example: a steel structure using M24 bolts in the connections

Consider a steel structure using M24 bolts in the connections with a FEA model created in a compatible software like Ansys or Femap. The goal is to verify the adequacy of the M24 bolts under AISC 360-10.

15. Bolts_M24

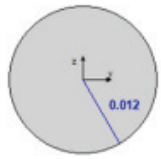
Property	Value	Property Shape
Type / Elements	Beam / 154	
Material	12..Bridge girders_detailed	
Mass [kg]	29.8	
Gravity Center [m]	[15.2; 10.6; 20.0]	
Area, [m^2]	4.524e-04	
I1, [m^4]	1.629e-08	
I2, [m^4]	1.629e-08	
I12, [m^4]	0	
Torsion Contrast, [m^4]	3.254e-08	
Y Shear Area, [m^2]	4.009e-04	
Z Shear Area, [m^2]	4.009e-04	
Nonstructural Mass, [kg]	0	
Perimeter, [m]	0.1	
Warping Constant, [m^6]	0	
Y Neutral Axis Offset A, [m]	0	
Z Neutral Axis Offset A, [m]	0	
r [m]	0.0120	

Table J3.2
Nominal Strength of Fasteners and Threaded Parts, ksi (MPa)

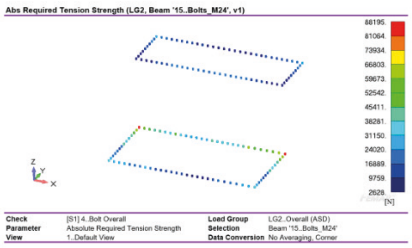
Description of Fasteners	Nominal Tensile Strength, F_{nt}, ksi (MPa) [a]	Nominal Shear Strength in Bearing-Type Connections, , F_{nv}, ksi (MPa) [b]
A307 bolts	45 (310)	27 (188) [c] [d]
Group A (e.g., A325) bolts, when threads are not excluded from shear planes	90 (620)	54 (372)
Group A (e.g., A325) bolts, when threads are not excluded from shear planes	90 (620)	68 (457)
Group B (e.g., A490) bolts, when threads are not excluded from shear planes	113 (780)	68 (457)
Group B (e.g., A490) bolts, when threads are not excluded from shear planes	113 (780)	84 (579)
Threaded parts meeting the requirement of Section A3.4, when threads are not excluded from shear planes	$0.75F_u$	$0.450\ F_u$
Threaded parts meeting the requirement of Section A3.4, when threads are not excluded from shear planes	$0.75F_u$	$0.563\ F_u$

SDC Verifier analysis:

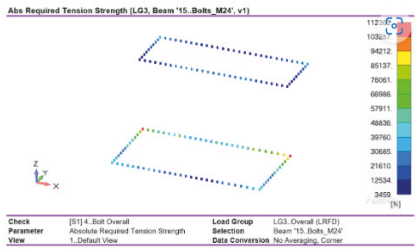
- **Bolt force extraction:** SDC Verifier automatically extracts the internal axial and shear forces acting on the M24 bolt elements within the FEA model.
- **Material properties:** The software considers the bolt diameter (24 mm) and retrieves the material properties (likely yield strength) from the FEA model or allows user-defined values if needed.
- **AISC 360-10 checks:** SDC Verifier performs various AISC 360-10 checks based on the extracted forces and material properties:
  - **Tensile and shear strength:** The software compares the extracted bolt forces with the allowable tensile strength (F_t,Rd) and shear capacity (F_v,Rd) as specified in AISC 360-10 Table J3.2. These values are based on the bolt material grade.
  - **Combined tension and shear:** If the connection experiences both tension and shear, SDC Verifier performs interaction checks considering the combined effect on bolt capacity. This adheres to the provisions of AISC 360-10 Section J3.
  - **Bearing strength at bolt holes:** The software assesses the bearing strength of the material surrounding the M24 bolt holes based on AISC 360-10. This ensures the material can manage the applied shear stress without failure.

Required Tension Strength

ASD Method

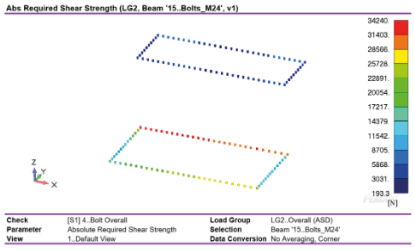


LRFD Method

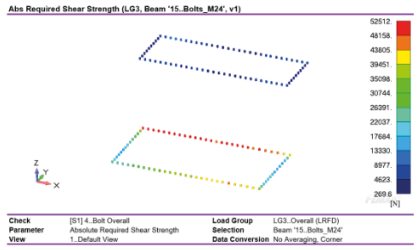


Required Shear Strength

ASD Method



LRFD Method



- **Results and reporting:** SDC Verifier presents the results in a clear and concise format. This might include:
  - **Utilization factor (UF):** The ratio between the calculated bolt stress and allowable stress for each bolt. A UF less than 1 indicates a safe design.
  - **Required vs. Available bolt strength:** Plots or tables comparing the calculated tensile and shear force demands on the bolts with their allowable capacities according to AISC 360-10.
- **Multiple load cases:** If the FEA model considers multiple load cases, SDC Verifier can analyse the results based on load groups. This identifies the worst-case scenario (absolute maximum utilization) for each bolt across all load combinations.

Conclusion

SDC Verifier offers a comprehensive suite of tools to streamline the process, enhance accuracy, and promote informed decision-making for engineers working on steel connection design projects. In summary, its key benefits include:

- Automated efficiency. Repetitive tasks like bolt checks and weld strength analysis become automated, saving engineers valuable time and minimizing the risk of errors associated with manual calculations.
- Code compliance assurance. With a vast library of pre-built engineering standards, including a strong focus on Eurocode 3 (EC3) for steel connections, SDC Verifier ensures your designs comply with the latest regulations and safety requirements.
- Holistic design analysis. The software goes beyond connection checks, offering functionalities like member design and plate buckling considerations. This fosters a more comprehensive understanding of the entire structural system, facilitating informed design choices.
- Enhanced communication and documentation. Automated reports and clear visualizations within SDC Verifier contribute to improved communication and collaboration within engineering teams, resulting in well-documented design decisions.

For more information:
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ASD Method

All (9 loads, Beam '15..Bolts_M24')

Check [S1] 4..Bolt Overall — Loads Count 9
Selection Beam '15..Bolts_M24'

Load	Required Tension Strength [N]	Required Shear Strength [N]	Required Tension Stress [Pa]	Required Shear Stress [Pa]	Uf ASD Overall
Load Set '1..Load Set 1.1 - ASD'	35.1e+3	15.7e+3	77.6e+6	34.7e+6	0.39
Load Set '2..Load Set 1.2 - ASD'	70.9e+3	20.5e+3	156.7e+6	45.2e+6	0.53
Load Set '3..Load Set 1.3 - ASD'	36.1e+3	31.8e+3	79.8e+6	70.3e+6	0.69
Load Set '4..Load Set 1.4 - ASD'	88.2e+3	34.2e+3	194.9e+6	75.6e+6	1.10
Load Set '5..Load Set 1.5 - ASD'	36.1e+3	34.2e+3	79.8e+6	75.6e+6	0.74
Load Set '6..Load Set 1.6 - ASD'	82.8e+3	31.8e+3	183.0e+6	70.3e+6	0.97
Load Set '7..Load Set 1.7 - ASD'	33.5e+3	20.5e+3	73.9e+6	45.2e+6	0.51
Load Set '8..Load Set 1.8 - ASD'	72.9e+3	15.7e+3	161.0e+6	34.7e+6	0.61
Load Group '2..Overall (ASD)'	88.2e+3	34.2e+3	194.9e+6	75.6e+6	1.10

LRFD Method

All (9 loads, Beam '15..Bolts_M24')

Check [S1] 4..Bolt Overall — Loads Count 9
Selection Beam '15..Bolts_M24'

Load	Required Tension Strength [N]	Required Shear Strength [N]	Required Tension Stress [Pa]	Required Shear Stress [Pa]	Uf LRFD Overall
Load Set '9..Load Set 1.1 - LRFD'	44.2e+3	22.3e+3	97.7e+6	49.2e+6	0.36
Load Set '10..Load Set 1.2 - LRFD'	84.7e+3	30.5e+3	187.1e+6	67.3e+6	0.44
Load Set '11..Load Set 1.3 - LRFD'	45.8e+3	49.4e+3	101.2e+6	109.2e+6	0.71
Load Set '12..Load Set 1.4 - LRFD'	112.4e+3	52.5e+3	248.3e+6	116.1e+6	0.96
Load Set '13..Load Set 1.5 - LRFD'	46.4e+3	52.5e+3	102.5e+6	116.1e+6	0.76
Load Set '14..Load Set 1.6 - LRFD'	105.2e+3	49.4e+3	232.5e+6	109.2e+6	0.85
Load Set '15..Load Set 1.7 - LRFD'	42.2e+3	30.5e+3	93.1e+6	67.3e+6	0.48
Load Set '16..Load Set 1.8 - LRFD'	87.8e+3	22.3e+3	194.1e+6	49.2e+6	0.47
Load Group '3..Overall (LRFD)'	112.4e+3	52.5e+3	248.3e+6	116.1e+6	0.96

About SDC Verifier

SDC Verifier is a mechanical and structural design engineering company providing all-in-one design and code checking software and engineering consultancy services. Since 1998 we have won the trust of leading global companies in the Offshore and Maritime, Heavy Lifting, Oil and Gas, Defence, and other industries. SDC Verifier software is a powerful design and standard inspection tool that works independently of and within several FEA solutions such as Ansys, Femap, and Simcenter 3D. It helps to automatically verify FEA results against numerous industry standards such as DIN, EN, Eurocode, FEM, AISC, NORSOK, ISO, DNV, ABS, FKM Fatigue, and DVS code for weld checks. SDC Verifier is proven to increase the productivity of engineering teams and take them to a new level of comfort. Contact SDC Verifier when in need of consultancy on FEA, modelling, standards-based design review, or for your other specialized software needs related to FEA or to industry standards. **Visit sdcverifier.com or email info@sdcverifier.com**