Advanced Computational Analysis

ACA

REPORT

REPORT NO: S1778-1

Title: Structural Verification Of Portable 4-Person Bungee Trampoline Amusement Device

Client: Eurojumper

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Summary

This report describes the structural verification of the 4-person, bungee trampoline amusement device, as manufactured by Eurojumper.

The structural model of the bungee trampoline device was generated from drawings provided by Eurojumper. The design review verification was performed against the initial analysis carried out by mgr inż. Jerzy Szymański.

The analysis detailed below was carried out based on loadings from various combinations of ride operation, based on a maximum single passenger mass of 90 kg, bouncing with a maximum inertial acceleration equivalent to 2g.

The results of the analysis and the comparison of these results with those determined by mgr inż. Jerzy Szymański, show that all structural and mechanical components have adequate load-carrying capacity, based on the loading prescribed above.

Index Page

Description Of Ride

The 4-person bungee trampoline is an amusement device capable for use either by adult or child participants. The ride is lightweight and fully transportable and is trailer-mounted. It can easily be erected and dismantled for use on any suitable site, either outdoors or indoors (providing adequate headroom is available).

The ride operates by first positioning the passenger on the trampoline. The passenger harness is then fitted and attached to the bungee ropes, on either side of the passenger. The number of bungee ropes used is adjusted, depending on the estimated passenger mass, to give the appropriate ‘feel’ to the bounce of the participant, without exerting excessive inertial forces on the passenger. This is carried out based on the experience of the ride operator.

During the ride the participant bounces vertically until reaching a maximum height of approximately 6.5 m. At this point the participant experiences a feeling of partial weightlessness. As the passenger moves progressively higher with each bounce, the winding motor reduces the effective length of the ropes, to permit the passenger to release progressively more potential energy with each bounce.

The downwards motion of the participant, at the lowest point, is arrested by a combination of the contact between the participant and the trampoline and the moderate tension in the flexible bungee ropes. Note that it is not always necessary for the participant to make full contact with the trampoline; in some instances the vertical motion is arrested only by the bungee ropes. In this case the flexibility of the bungee ropes would ensure that the maximum inertial forces are reduced.

It is difficult to estimate the maximum passenger forces exerted by the device, due principally to the wide variation possible in participant mass. However an acceptable guide would be approximately 2g absolute maximum inertial acceleration, which would give the ride participant a sensation of twice body mass when bouncing.

A typical view of the 4-person bungee trampoline is shown in figure 1.1.

Method Of Analysis

The analysis of the 4-person bungee trampoline device was performed using the ANSYS finite element program. The structural model of the device was generated from measurements taken from the manufactured device.

The analysis of the bungee-trampoline structure was performed with regard to the initial design analysis carried out by mgr inż. Jerzy Szymański.

1) Structural Analysis

i) Main Structure

The finite element model of the main structure was generated using a combination of BEAM4, LINK10, CONTACT52 and SHELL63 element types. The BEAM4, 3-dimensional prismatic beam elements were used to model the steel base frame of the device and the aluminium support poles. The cross-sectional properties of these elements were set to those of the frame and support pole members, as appropriate. The LINK10, 3-dimensional, tension-only elements were used to model the steel guy ropes which constrained the top of each support pole. This element type can sustain only tensile loads and is removed from the element formulation if the forces are equal to, or less than zero. The cross-sectional area of the element was set to that of the steel rope, as appropriate. The CONTACT52, 3-dimensional, compression-only contact elements were used to model the contact between the base frame and ground. The stiffness of these elements was set to ensure that there was no interpenetration between the frame and the ground. Also this ensured that should the frame lift from the ground during loading these elements would be removed from the element formulation. The SHELL63, 3-dimensional plate elements, were used to model the steel and aluminium plates on the trailer chassis. The thickness of this element was set to the appropriate thickness as used in the construction of the device.

The finite element model comprised a total of 2792 elements (1550 beam elements, 8 tension-only elements, 4 contact elements and 1230 shell elements) and 2543 nodes. The finite element model of the device is shown in figure 2.1.

Note that due to the inherent flexibility of the structure a large deflexion analysis was performed, to ensure increased accuracy in predicting deflexions and also to include any secondary bending or tension effects in the results. Hence the analysis was non-linear (due to the use of large deflexion effects and non-linear element types) and the model reached convergence to within 0.5% of the overall load on the structure.

A total of 4 load cases were analysed for the structure, as follows:

i) Load Case 1

This load case represented the first of two out-of-balance load conditions. In this load case a single passenger loading was applied at one passenger station. The loading on the passenger was equivalent to 2g, based on a passenger mass of 90 kg and as a worst case, the bungee ropes were assumed to be in the position where the participant would be in contact with the trampoline. This position would be concomitant with a passenger reaching these accelerations at the bottom of the bounce. Further details of the passenger loading are shown in calculation sheet 1.

In addition to the maximum load applied to the bungee ropes, a load equal to a ride participant of mass 90 kg, bouncing with a force equivalent to 2g was applied to the trampoline directly beneath the passenger loading on the bungee ropes, for all load cases (hence the effective force at the centre of each of the trampoline mats was 1765.8 N). The forces applied to the trampoline frames are verified in calculation sheets 1 to 3

In addition to the loads described above, the self-weight loading of the structure was included automatically by the finite element program, for all load cases, based on the steel and aluminium densities shown below and an acceleration due to gravity of 9.81 m/s^2

ii) Load Case 2

This load cases represented the second of two out-of-balance load conditions for the complete frame. This load case was similar to load case 1 except that the loading on the structure was derived from two passengers, positioned on adjacent sides of the structure. The purpose of this load case was to examine the effects on the structure due to unbalanced loading on the support poles, at adjacent sides of the frame.

iii) Load Case 3

This load case was again similar to load case 1, but with passenger loading applied at two opposite passenger stations. The purpose of this load case was to examine the effects on the structure due to extreme opposing loads

iv) Load Case 4

The purpose of this load case was to examine the effects on the structure due to the maximum imposed loading. Therefore forces were applied at all four stations.

ii) Trampoline Structure

In addition to the main structure a finite element analysis was also undertaken for the trampoline frame. The finite element model of the trampoline frame was generated using a combination of BEAM4 and CONTACT52 element types. The BEAM4, 3-dimensional prismatic beam elements were used to model the steel base frame of the device and the support poles. The cross-sectional properties of these elements were set to those of the frame and support pole members, as appropriate. The CONTACT52, 3-dimensional, compression-only contact elements were used to model the contact between the base frame and ground. The stiffness of these elements was set to ensure that there was no interpenetration between the frame and the ground. Also this ensured that should the frame lift from the ground during loading these elements would be removed from the element formulation.

The finite element model of the trampoline frame comprised a total of 331 elements (328 beam elements and 3 contact elements) and 330 nodes. The finite element model of the device is shown in figure 2.2.

A single load case was analysed for the trampoline structure, as follows:

i) Load Case 1

For this load case an extreme loading condition was assumed, by applying loads equal to a ride participant of mass 90 kg effecting a bounce on the trampoline bed equivalent to 2g loading (hence the effective force at the centre of each of the 4 trampoline mats was 1765.8 N).

2) Material Properties And Component Capacities

a) The material properties for the aluminium sections used for the analysis were based on grade 6082 T6 aluminium, as follows:

$E = 70000$ N/mm^2 (Young's modulus)

$\nu = 0.316$ (Poisson's ratio)

$\sigma_{0.2} = 240$ N/mm^2 (0.2% Proof strength)

$\rho = 2710$ kg/m^3 (Density)

The material certificate for the aluminium sections is shown in Appendix A

b) The material properties for the steel sections used for the analysis were based on grade S235 structural steel (as specified by the device manufacturer), as follows:

$E = 207000$ N/mm^2 (Young's modulus)

$\nu = 0.28$ (Poisson's ratio)

$\sigma_y = 235$ N/mm^2 (Yield strength)

$\rho = 7850$ kg/m^3 (Density)

The material certificate for the steel sections is shown in Appendix D

c) The steel ropes are a standard 6x19 configuration, with a fibre core, to DIN 3060. The certificate of conformity for the steel rope is shown in Appendix B.

d) The certificate of conformity for the carabiner is shown in Appendix C. A carabiner of size 6mm or above must be used to provide the required loading capacity.

e) The certificate of conformity for the bungee harness is shown in Appendix E.

f) The certificate of conformity for the D-shackle is shown in Appendix F. A D-shackle of size 10mm or above must be used to provide the required loading capacity.

g) The certificate of conformity for the eye-nut is shown in Appendix G. An eye-nut of size 12mm or above must be used to provide the required loading capacity.

h) The certificate of conformity for the rope clip is shown in Appendix H.

i) The certificate of conformity for the turnbuckle is shown in Appendix I. A turnbuckle of size 12mm or above must be used to provide the required loading capacity.

j) The test certificate for the bungee cord is shown in Appendix J. Whilst the breaking load is less than the maximum load determined in this analysis, the breaking point is at a minimum elongation of 7.23. Since the maximum elongation can only reach approximately 6m the breaking conditions will not be met.

k) The worst case condition for alternating stress in a weld is 84 N/mm^2, as detailed in calculation sheet 6. This weld has been verified and given a fatigue life expectancy of 2 years.

The results of the analysis are presented below.

Results

i) Main Structure

Load Case No.	Stresses In Steel Beams Structure (N/mm^2)	Stresses In Aluminium Beam Structure (N/mm^2)	Stresses In Steel Sheet Structure (N/mm^2)	Forces in Steel Ropes (N)	Overall Deflexion (mm)	Maximum Reaction Forces (N)		
						Fx	Fy	Fz
1	117.7 *(figure 3.1)*	-44.8 *(figure 3.2)*	22.5*(figure 3.3)*	2252	217.73 *(figure 3.4)*	671	253	66
2	114.6*(figure 3.5)*	-29.1*(figure 3.6)*	22.0*(figure 3.7)*	1004	76.38*(figure 3.8)*	786	4303	851
3	114.8*(figure 3.9)*	-58.2*(figure 3.10)*	21.4*(figure 3.11)*	2526	272.28*(figure 3.12)*	-908	2142	61
4	91.8*(figure 3.13)*	-24.2*(figure 3.14)*	17.7*(figure 3.15)*	1393	66.97*(figure 3.16)*	439	3415	497

Table 1 – Summary Of Results For Stresses, Deflexions And Base Reaction Forces

ii) Trampoline Structure

Load Case No.	Stresses In Steel Beams Structure (N/mm^2)	Overall Deflexion (mm)	Maximum Reaction Forces (N)		
			Fx	Fy	Fz
1	-118.1 *(figure 3.17)*	5.12 *(figure 3.18)*	-23	1698	0

Table 2 – Summary Of Results For Stresses, Deflexions And Base Reaction Forces

Note:

i) The stresses quoted in tables 1 and 2 above for the beam structures are the most severe combination of bending and axial stress in any structural component.

ii) The stresses quoted in tables 1 and 2 above for the plate structures are the von-Mises stress components and should be compared directly with the material yield or proof strength, when examining for elastic failure, i.e.

$$\sigma_{vM} = \frac{1}{\sqrt{2}}\sqrt{\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right]}$$

where σ_1, σ_2, σ_3 are the principal stresses at a point in the continuum.

iii) The deflexions quoted in tables 1 and 2 represents the vector sum of the Cartesian deflexion components, at any point in the continuum.

iv) The deflexions quoted in tables 1 and 2 are the vector sum of the individual Cartesian deflexion components.

v) The determination of the structural capacities of the various components of the device, the assessment of the critical joints and the fatigue assessment of the critical welds are shown in calculation sheets 2 to 3.

vi) The max reaction of 3415 N is equivalent to an average pressure on the ground of 85.4 kN/m^2 when a 200x200 mm packing point has been used.

Conclusions

The stresses determined from the present analysis are concomitant with those predicted by the mgr inż. Jerzy Szymański design verification report of this ride. The small discrepancies between the predictions from the mgr inż. Jerzy Szymański report and this analysis arise mainly from the method of analysis used in each case. The analysis carried out in the present study uses a non-linear approach, which more accurately predicts stresses and deflexions. Notwithstanding this, the stresses resulting from each individual analysis are sufficiently close to ensure that there is no major discrepancy in the resulting stresses and deflexions.

The stresses predicted in the aluminium support poles provide an utilisation factor of approximately 15.3 % on the buckling capacity of the poles (based on a limit state analysis to BS 8118), which clearly is adequate.

For the base frame, the stresses in the steel plate members provide a minimum factor of safety of approximately 9.4 (for load case 1), based on a permissible equivalent strength of 213 N/mm^2. In addition the maximum utilisation factor calculated for any of the structural steel sections did not exceed unity. This again is adequate, based on the maximum loading prescribed.

The maximum deflexion in the structure represents approximately $^1/_{30}$ of the overall height of the device (for load case 3). Whilst this would be excessive for a static structure the deflexions result from dynamic loads and sway of the structure, rather than static vertical deflexion. Hence, since the stresses are relatively low in this component the dynamic deflexion is fully recoverable and will be acceptable.

The welds connecting the 40x40x3 SHS at the corner of the base frame, shown in figure 4.1, were identified as the critical welds on the structure. They have been given a predicted fatigue life of approximately 2 years, based on a Miner's rule summation for operation of the device for 240 days per year at 5 working hours per day (see calculation sheet 4). It should be noted also that this fatigue life assessment is based on the worst case, out-of-balance loading condition for the device. It is clear that under normal operation the fatigue life will be extended beyond 2 years. Hence the 2 year fatigue life is presented as a minimum fatigue life condition.

The analysis of the critical pin connections, shown in calculation sheet 16, demonstrates that the stresses in the pin connection have adequate strength for the proposed maximum loading.

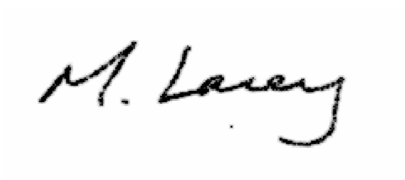
The material and component certificates provided by the manufacturer and owner demonstrate that those components have adequate load–carrying capacity for the proposed maximum loading, provided the sizes for the D-Shackle, Eye-Nut and Turn Buckles used are as stipulated in section 2 of this report.

Whilst the axial forces and moments predicted in the trampoline structure are within the permissible limit of unity and will therefore be acceptable, it is the responsibility of the operator to ensure the participants are using the device correctly within the confines of the trampoline.

Note finally whilst the steel and aluminium structure has been verified for a maximum passenger mass of 90 kg the bungee harness is limited to a maximum of 85 kg. Therefore the operator should be vigilant to ensure no passengers greater than 85 kg in mass are allowed to use the ride.

It is clear therefore that all components have sufficient strength to provide a satisfactory working life for the device, based on the assumed maximum loading, providing the recommendations detailed below are adopted.

Richard Anderson



Dr. M. Lacey

Recommendations

From the results of the analysis clearly there are no principal structural components on the device which require specific detailed periodic inspection or other detailed investigation, other than the critical welds detailed below.

Nevertheless it would be prudent to periodically check the integrity of all components on a regular basis. Hence the operator should periodically (daily) inspect for parent material or weld cracks. The critical weld on the support legs should be inspected non-destructively on an annual basis.

Additionally, all fixing ropes and bungee ropes should be inspected daily and replaced as necessary if there is any evidence of damage and/or fraying.

Whilst the ride could not be classed as extremely boisterous there would be a category of people for which the ride would not be suitable. For example it would be suggested that the following should not be allowed to participate in the ride experience:

Very small children (unless under strict supervision from the operator).

People with a history of neck/back or other skeletal injuries, or other medical problems.

People with a history of heart problems.

Pregnant women.

People with obvious physical and/or mental disabilities, for whom the ride clearly would not be suitable and whose use of the ride would be likely to cause injury (this is the responsibility of the operator, who clearly must be experienced in making this judgment).

It would be appropriate to display signage at the ride atrium, indicating the ride would not be suitable for the above category of participants.

The maximum ground bearing pressure, beneath the ride base, is predicted to be an average of 85.4 kN/m^2, based on a 200 mm x 200 mm footprint. This bearing pressure is adequate for most sites on consolidated ground. However it is the responsibility of the ride operator to ensure that the site is capable of carrying this ground pressure.

For passenger safety and to prevent overturning, the device should not be operated in wind speeds greater than 8 m/s.

By the nature of the ride, the inertial forces experienced by the ride participants are governed by the set-up of the bungee rope arrangement, which is strictly under the control of the operator. It is imperative therefore that only very experienced operators should be allowed to control the ride.

Additionally, to prevent collision with spectators, suitable barriers must be placed at least 1.5 m from the extreme outer edges of the trampolines or operating envelope of the bungee. Also the operator must be vigilant to misuse by the participants and/or spectators. If this should occur the device must be halted immediately.

Figure 1.1 – Typical View Of 4-Person, Bungee Trampoline Device

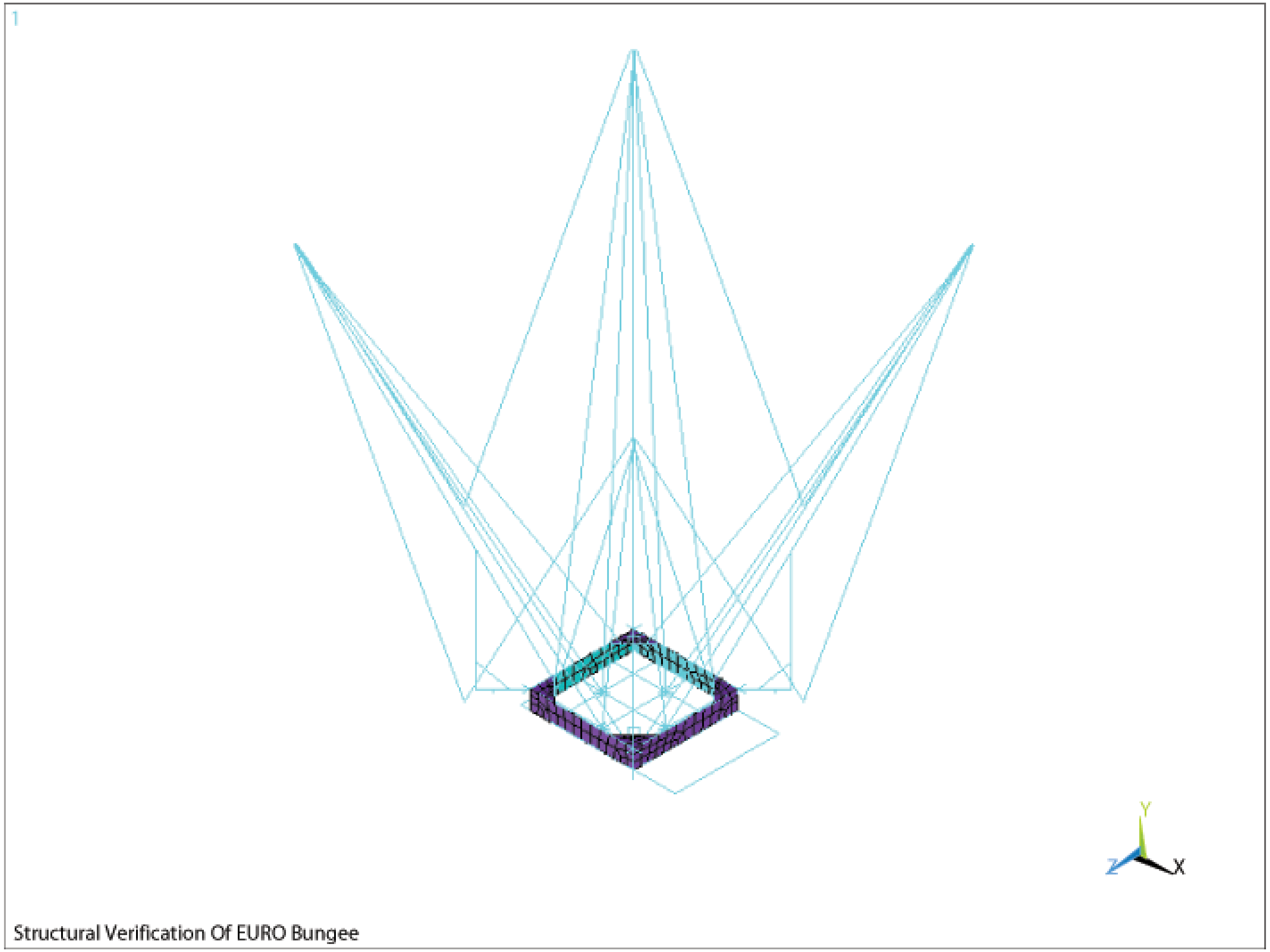


Figure 2.1 – Finite Element Model Of 4-Person Bungee Trampoline

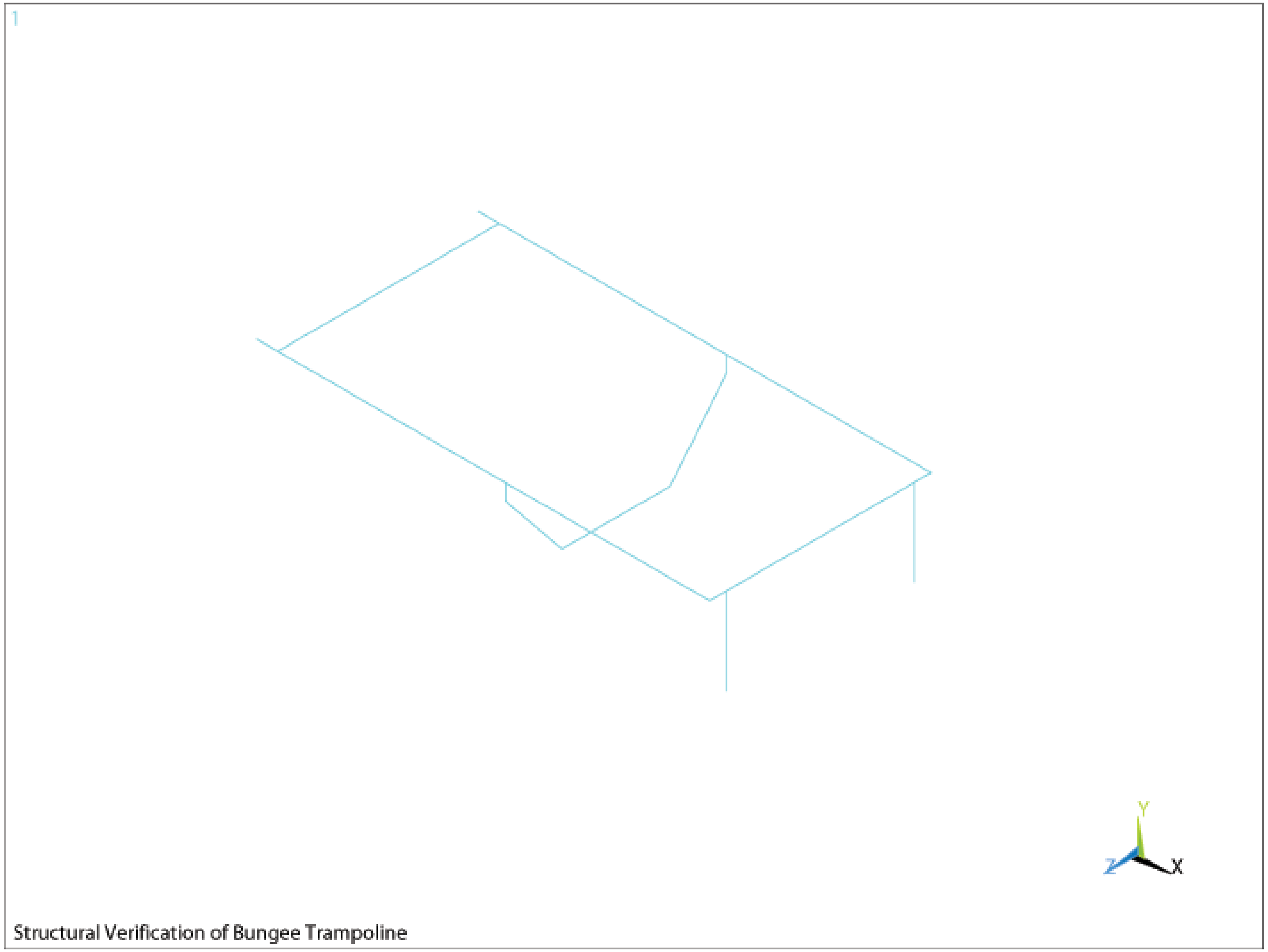


Figure 2.2 – Finite Element Model Of Trampoline Frame

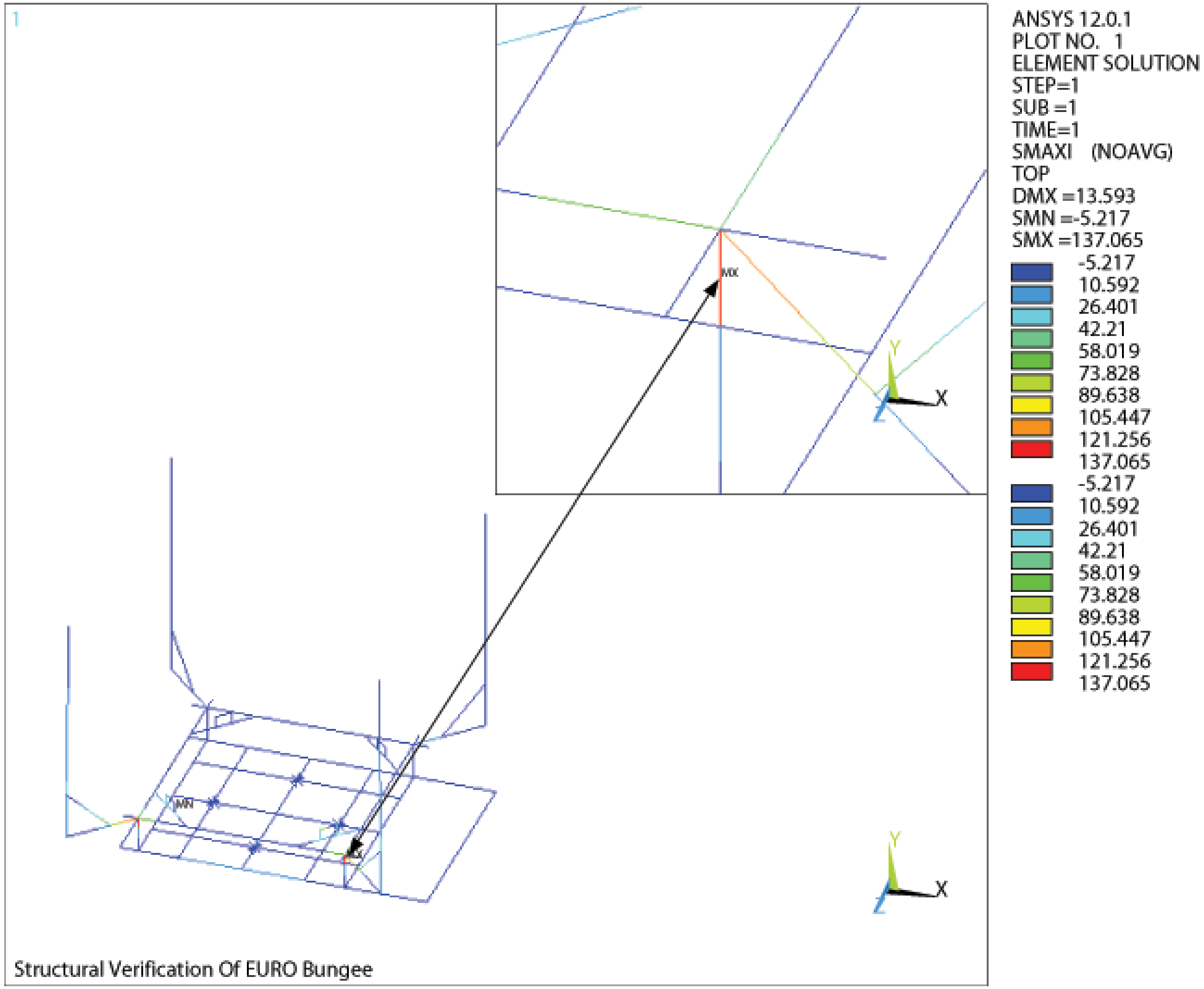


Figure 3.1 – Stresses In Steel Beam Structure, Due To Load Case 1

Maximum Stress = 137.1 N/mm^2

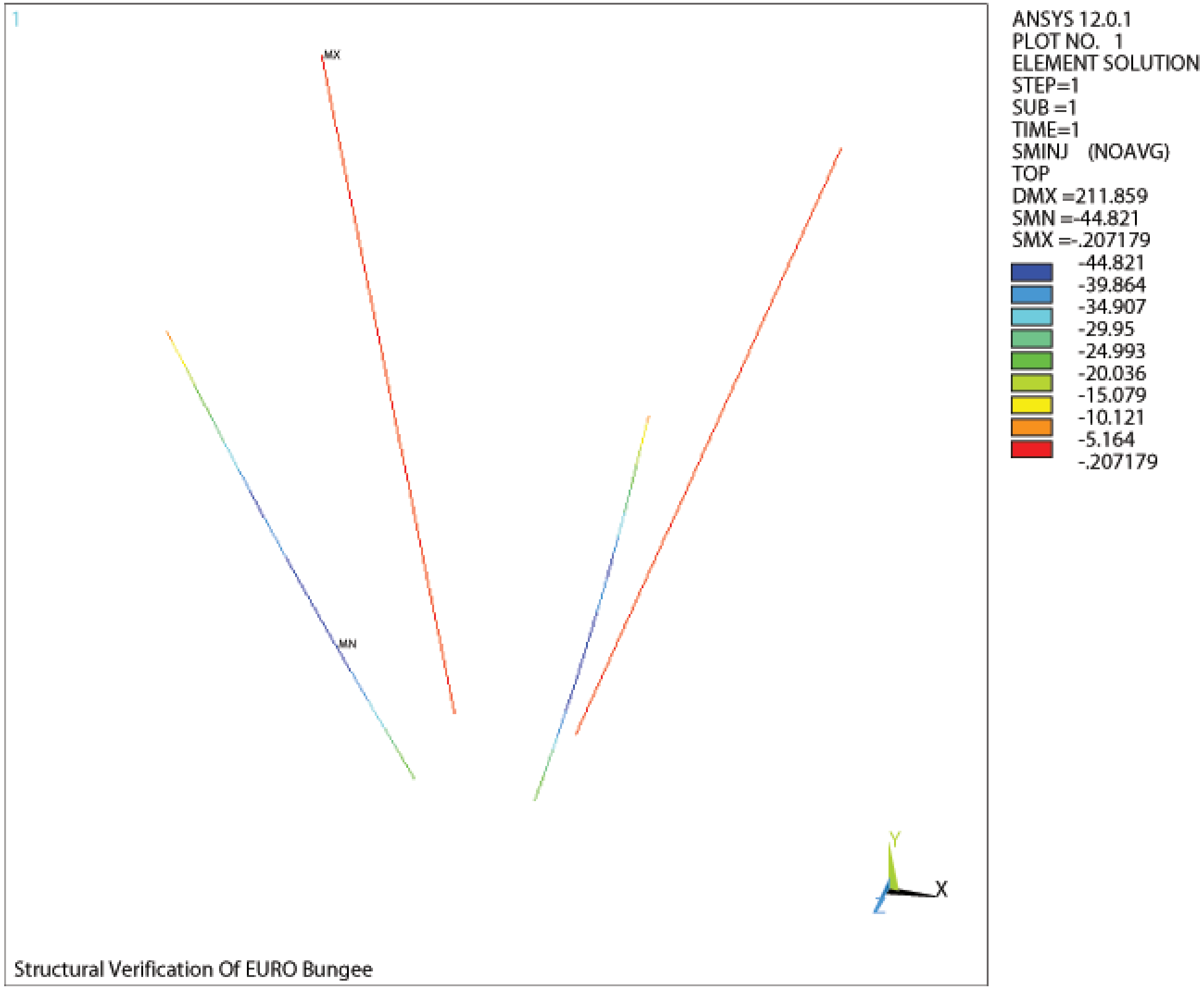


Figure 3.2 – Stresses In Aluminium Beam Structure, Due To Load Case 1

Maximum Stress = -44.8 N/mm^2

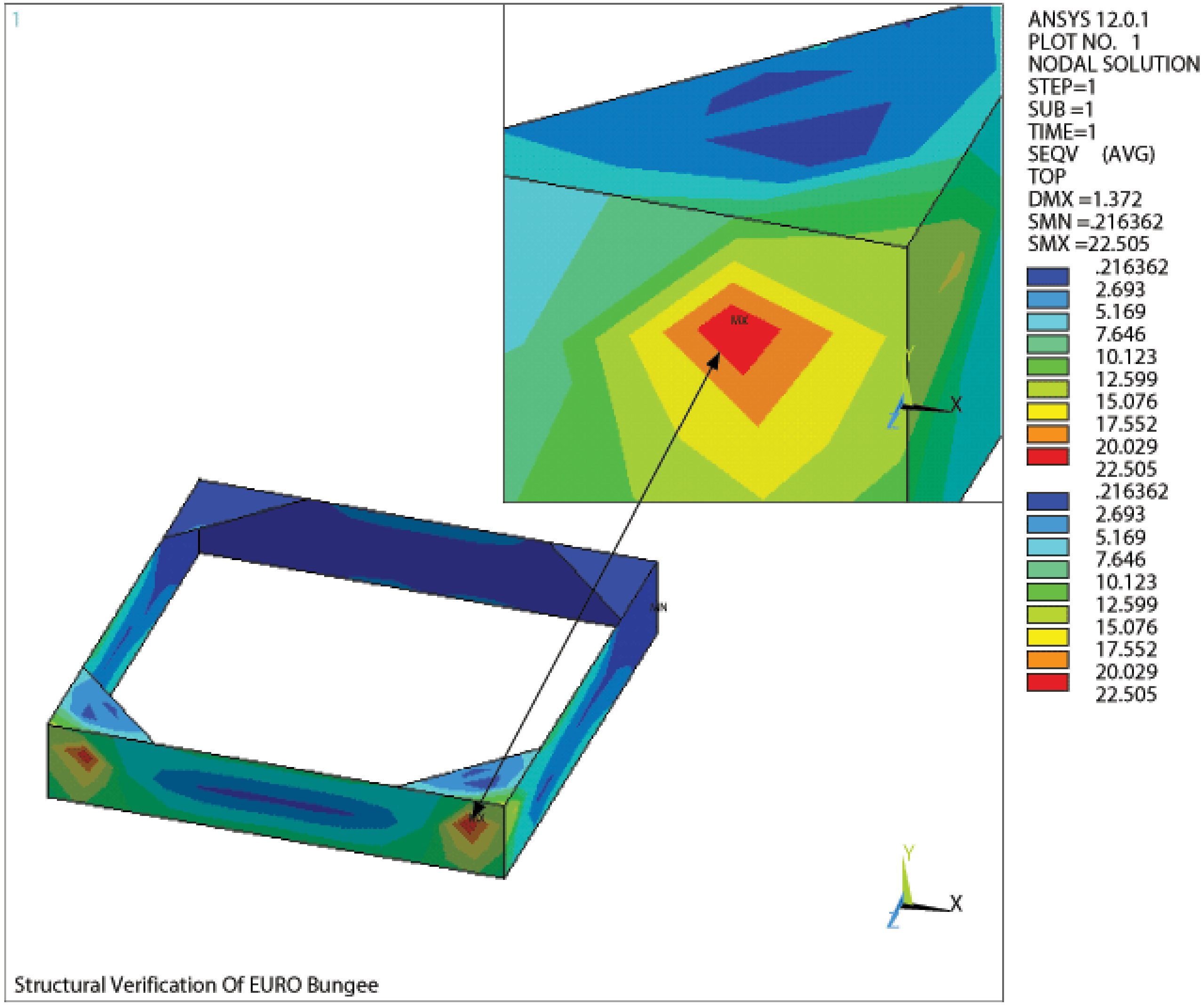


Figure 3.3 – Stresses In Steel Plate Structure, Due To Load Case 1

Maximum Stress = 22.5 N/mm^2

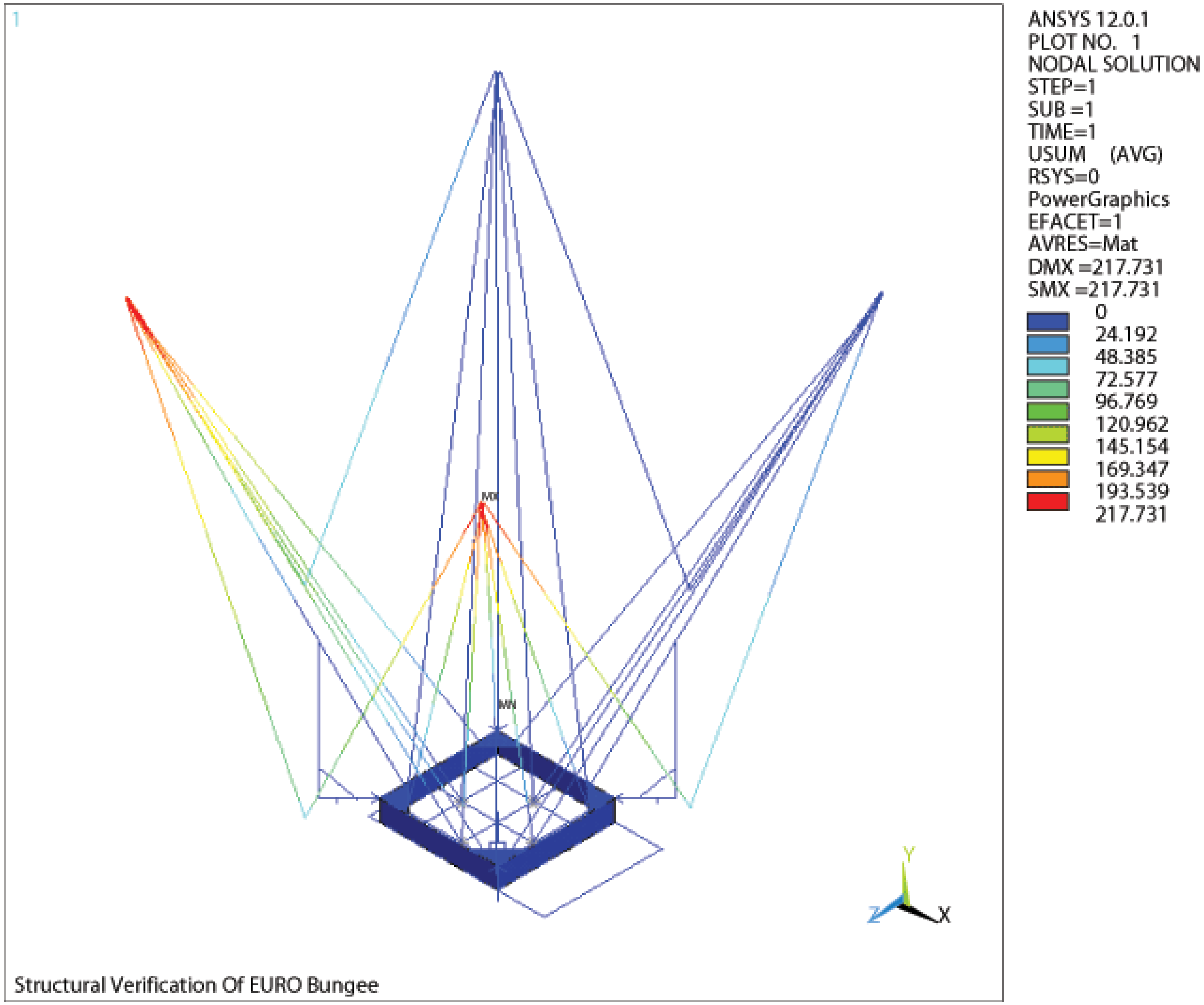


Figure 3.4 – Overall Deflexion In Structure, Due To Load Case 1

Maximum Deflexion = 217.73 mm

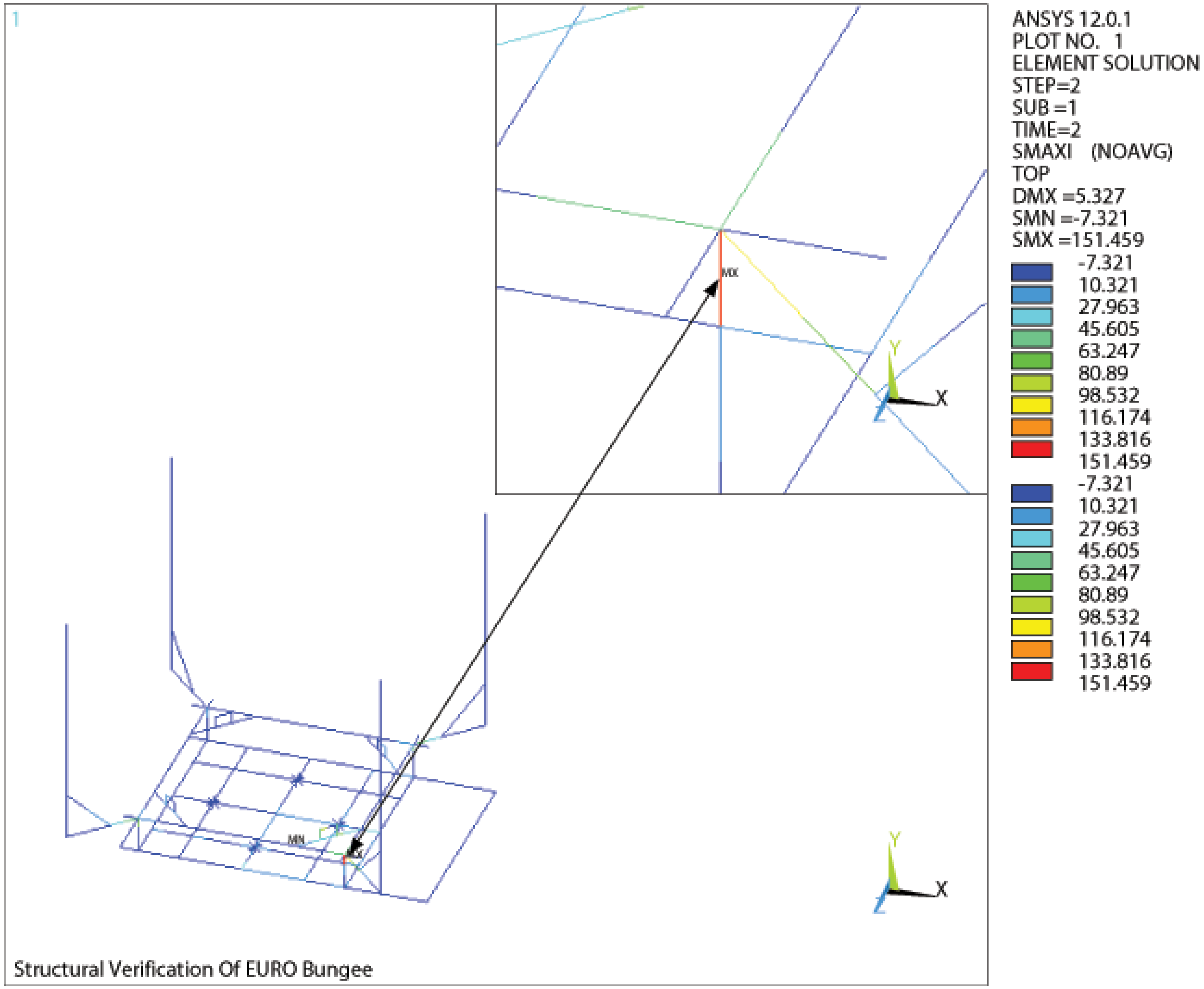


Figure 3.5 – Stresses In Steel Beam Structure, Due To Load Case 2

Maximum Stress = 151.5 N/mm^2

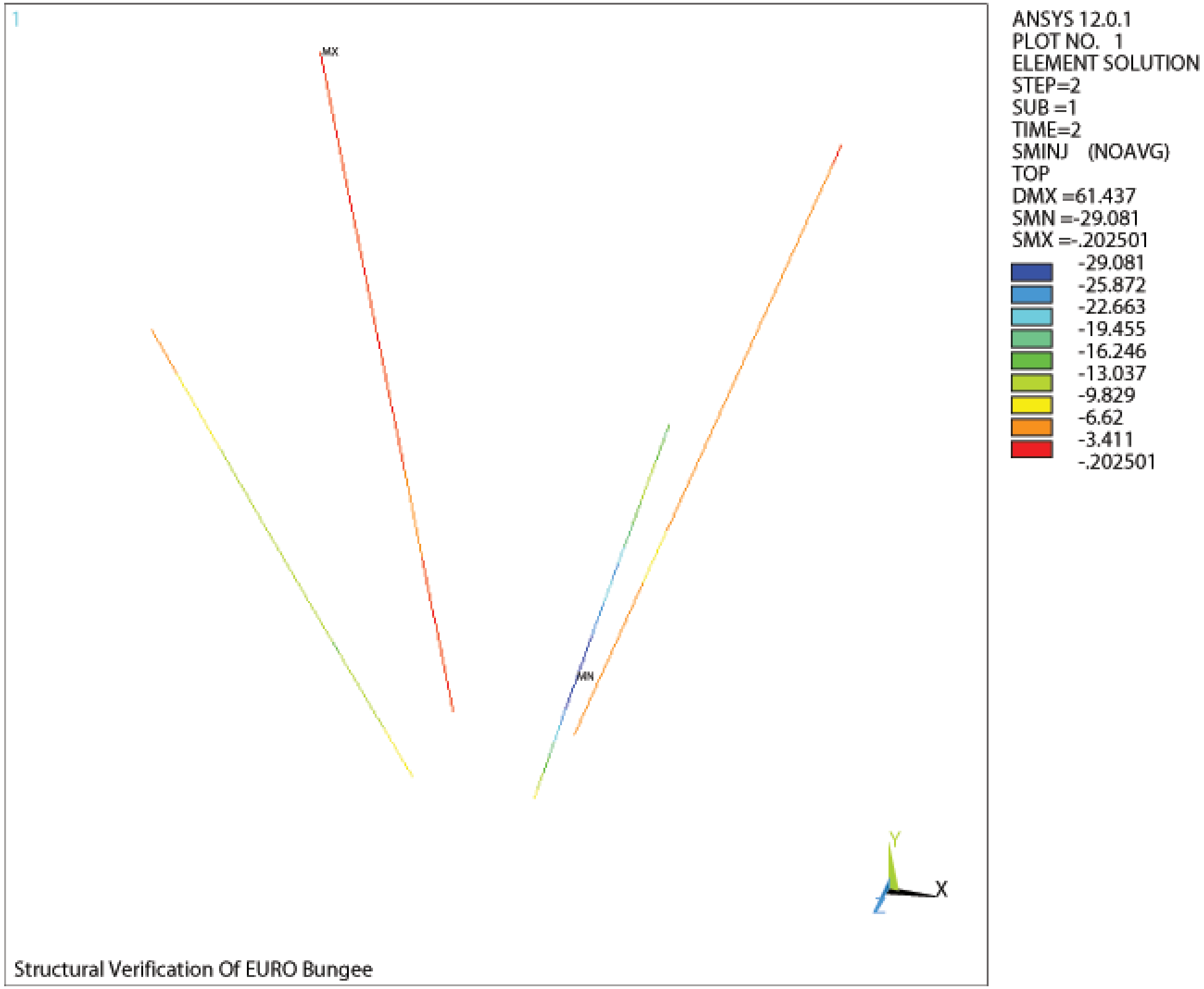


Figure 3.6 – Stresses In Aluminium Beam Structure, Due To Load Case 2

Maximum Stress = -29.1 N/mm^2

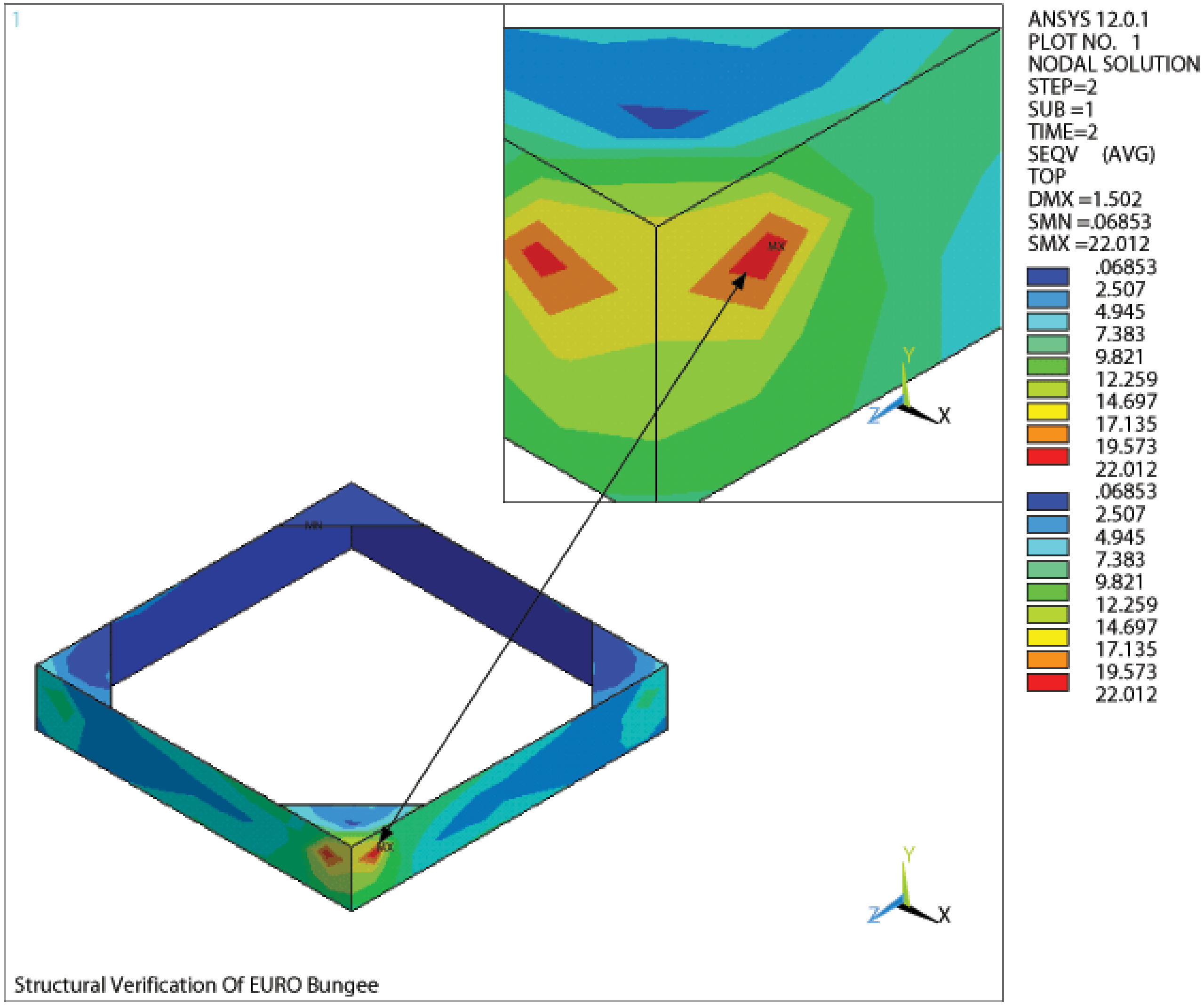


Figure 3.7 – Stresses In Steel Beam Structure, Due To Load Case 2

Maximum Stress = 22.0 N/mm^2

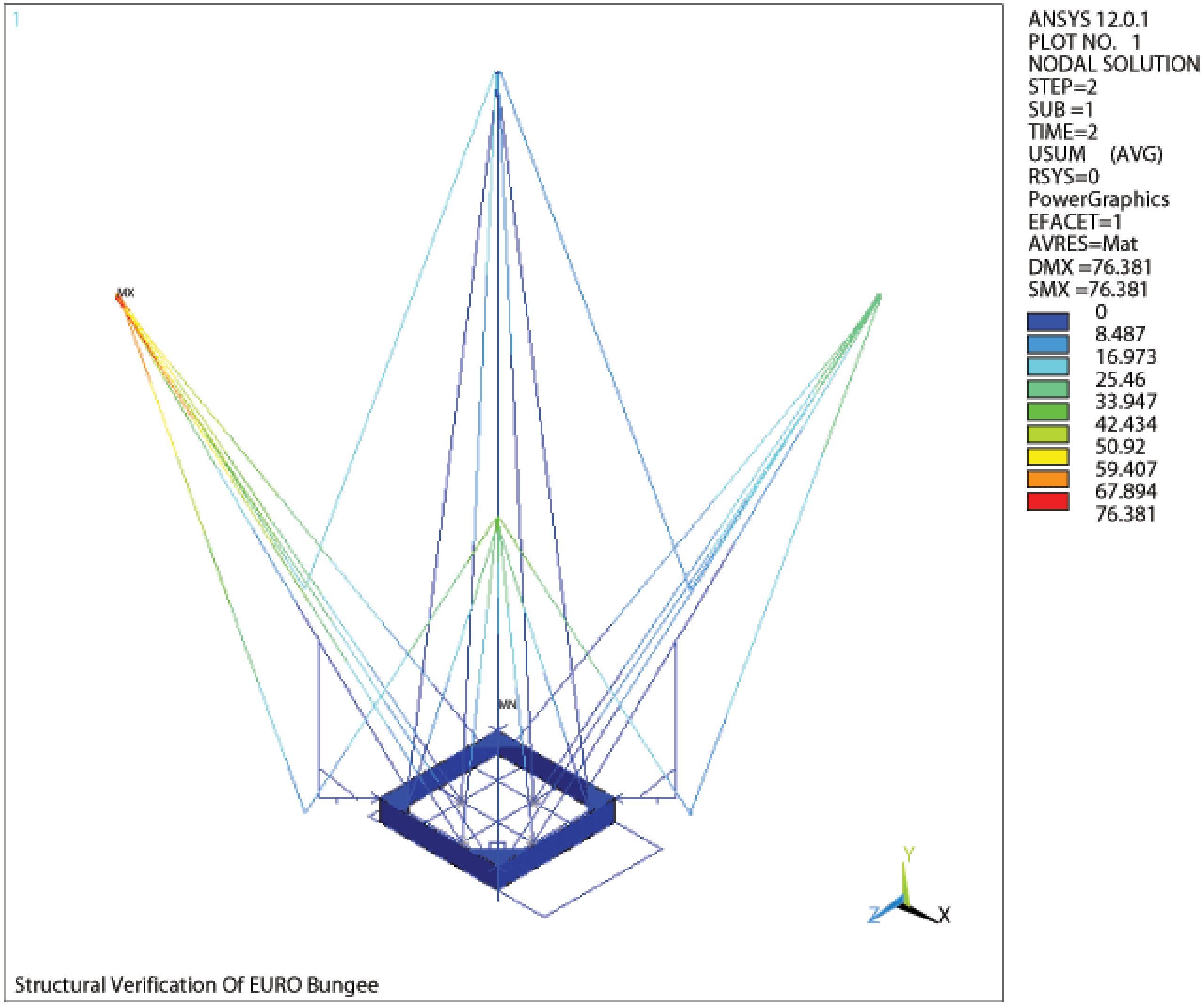


Figure 3.8 – Overall Deflexion In Structure, Due To Load Case 2

Maximum Deflexion = 76.38 N

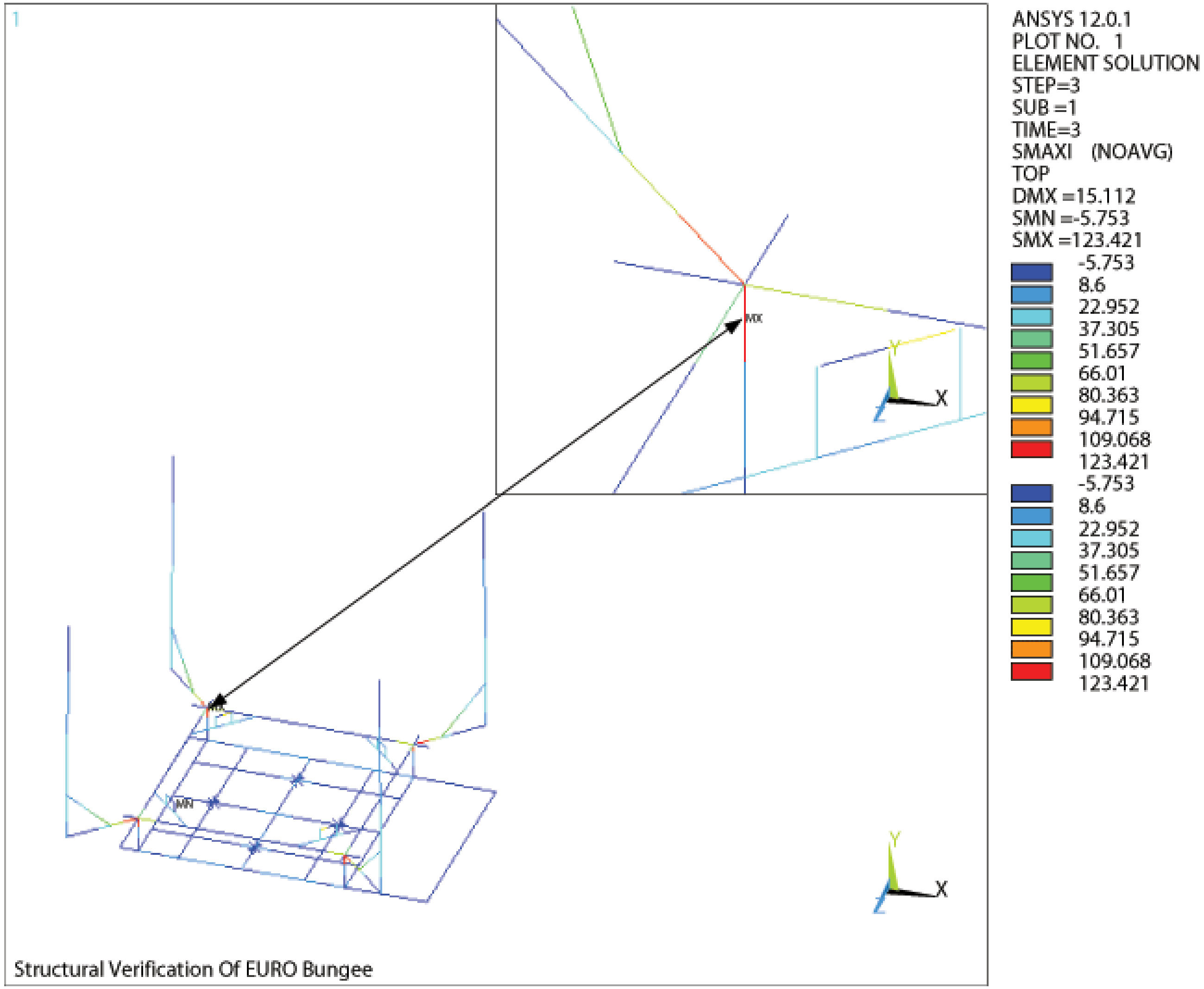


Figure 3.9 – Stresses In Steel Beam Structure, Due To Load Case 3

Maximum Stress = 123.4 N/mm^2

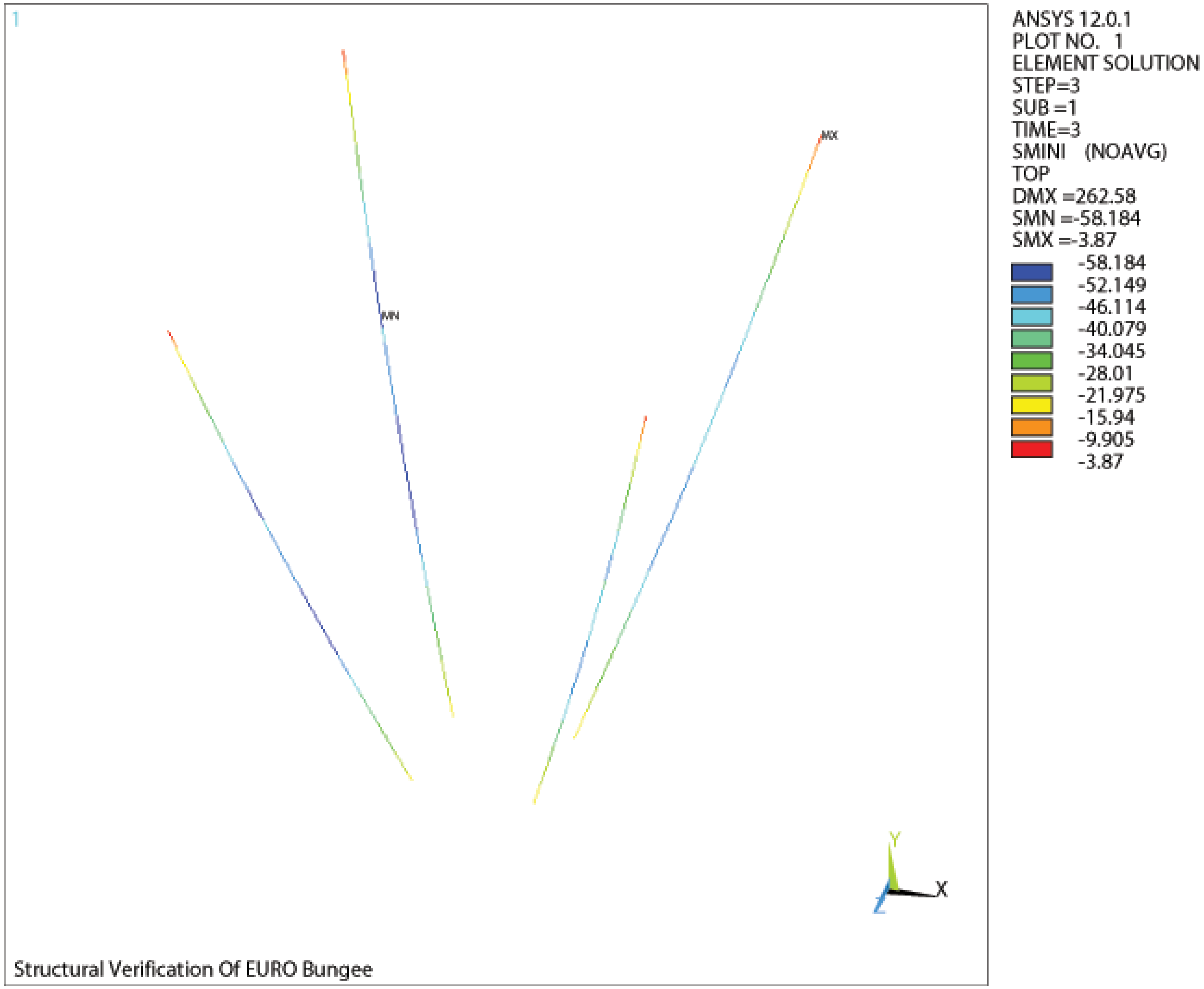


Figure 3.10 – Stresses In Aluminium Beam Structure, Due To Load Case 3

Maximum Stress = -58.2 N/mm^2

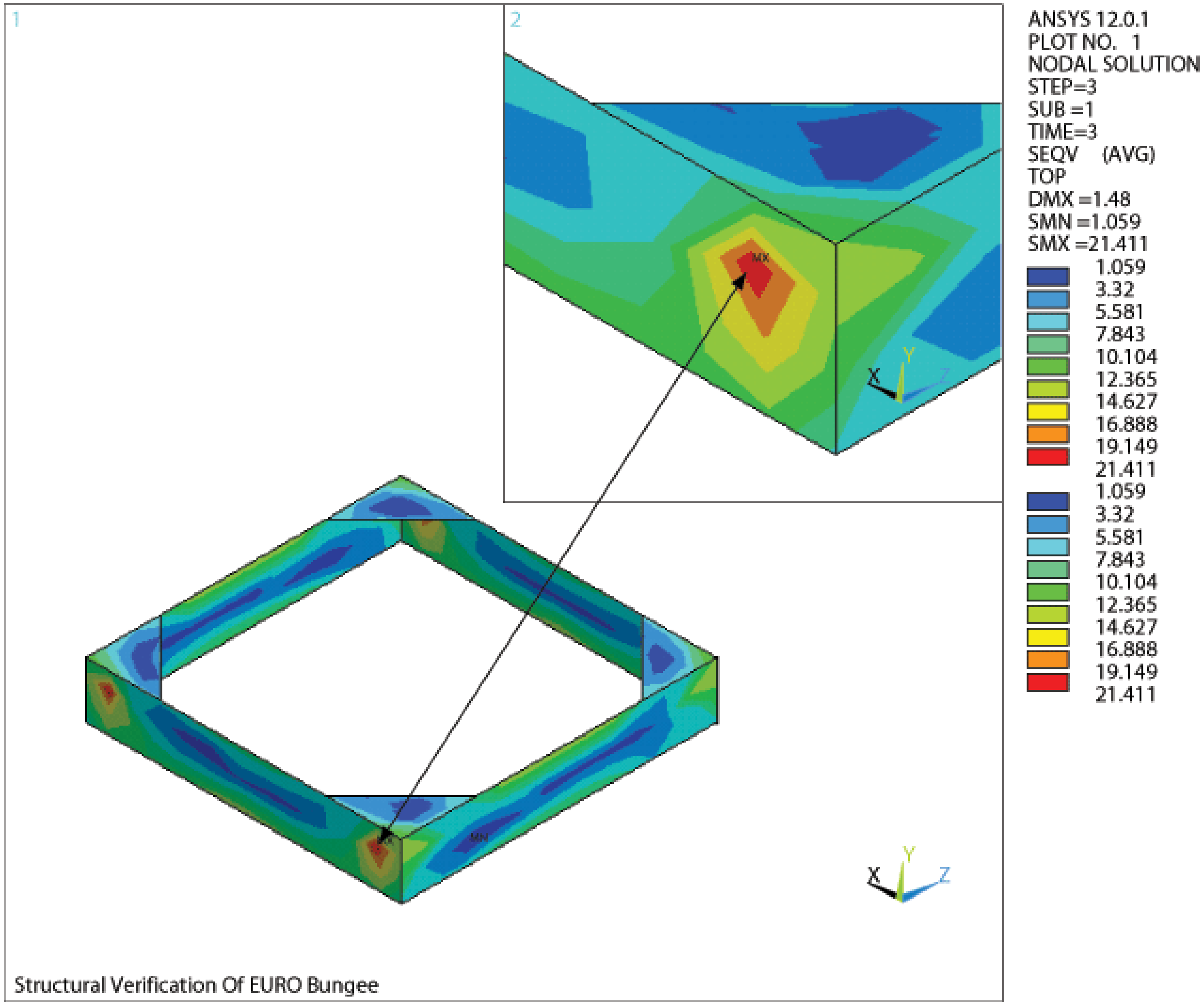


Figure 3.11 – Stresses In Steel Plate Structure, Due To Load Case 3

Maximum Stress = 21.4 N/mm^2

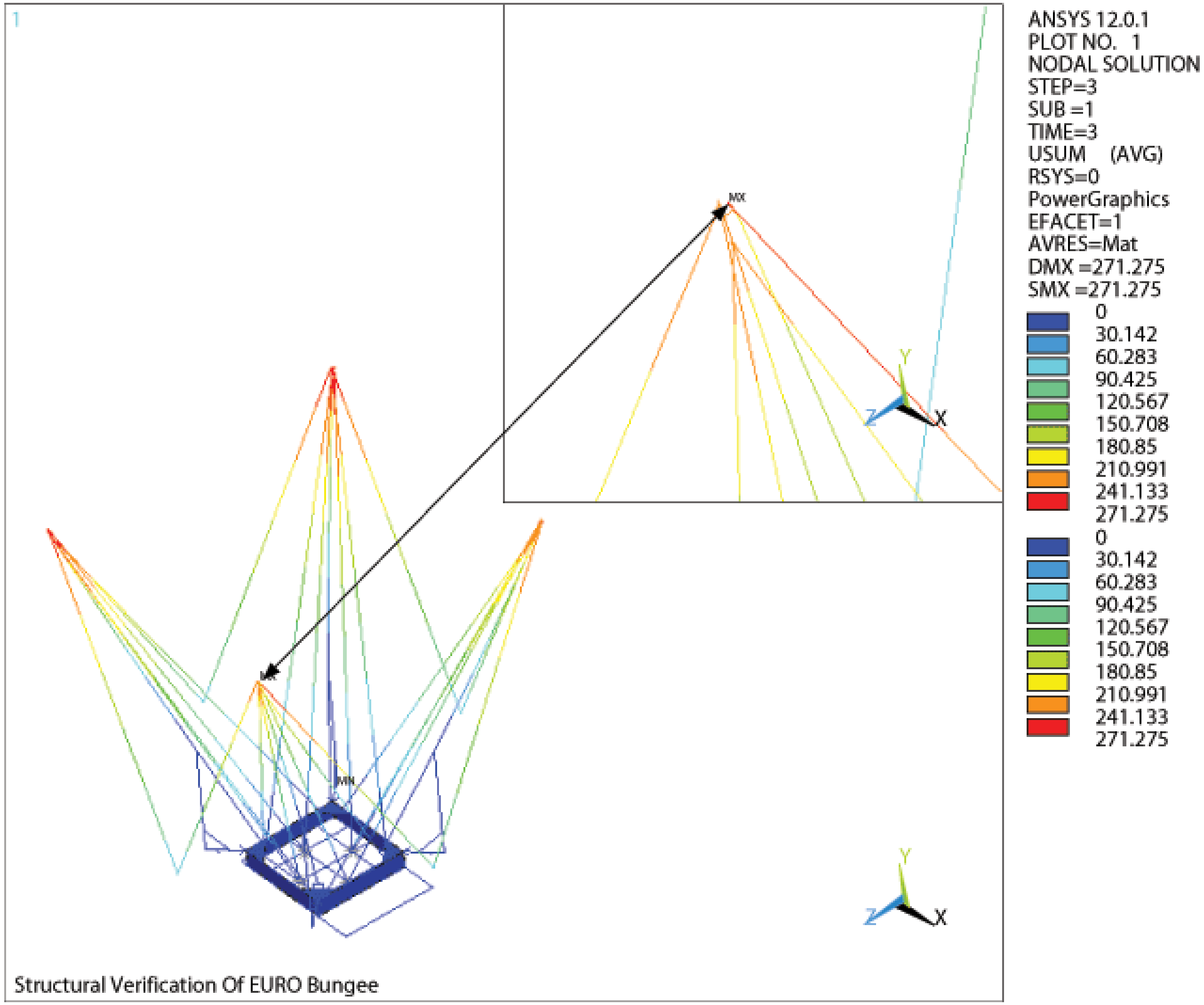


Figure 3.12 – Overall Deflexion In Structure, Due To Load Case 3

Maximum Stress = 271.23 mm

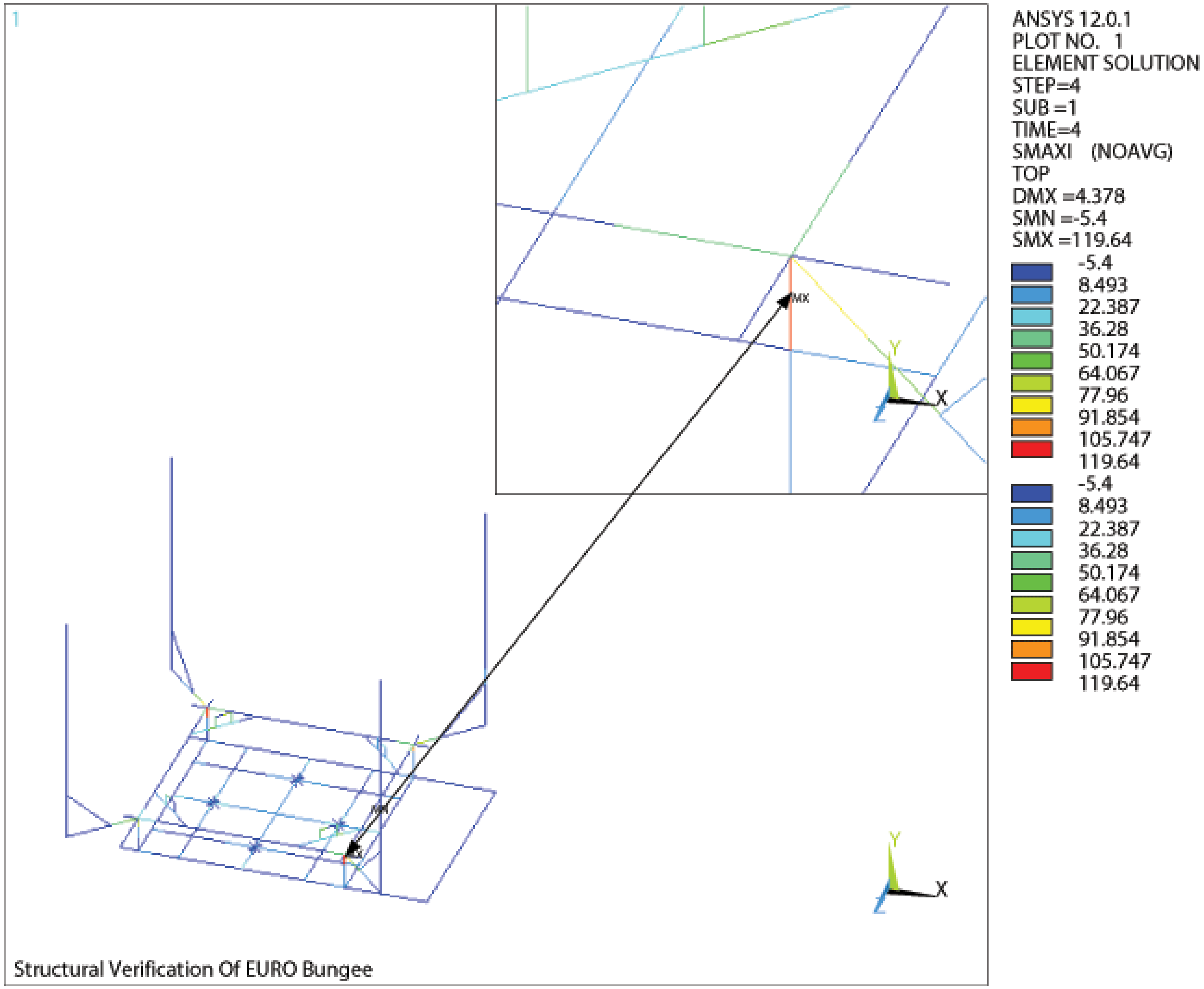


Figure 3.13 – Stresses In Steel beam Structure, Due To Load Case 4

Maximum Stress = 119.6 N/mm^2

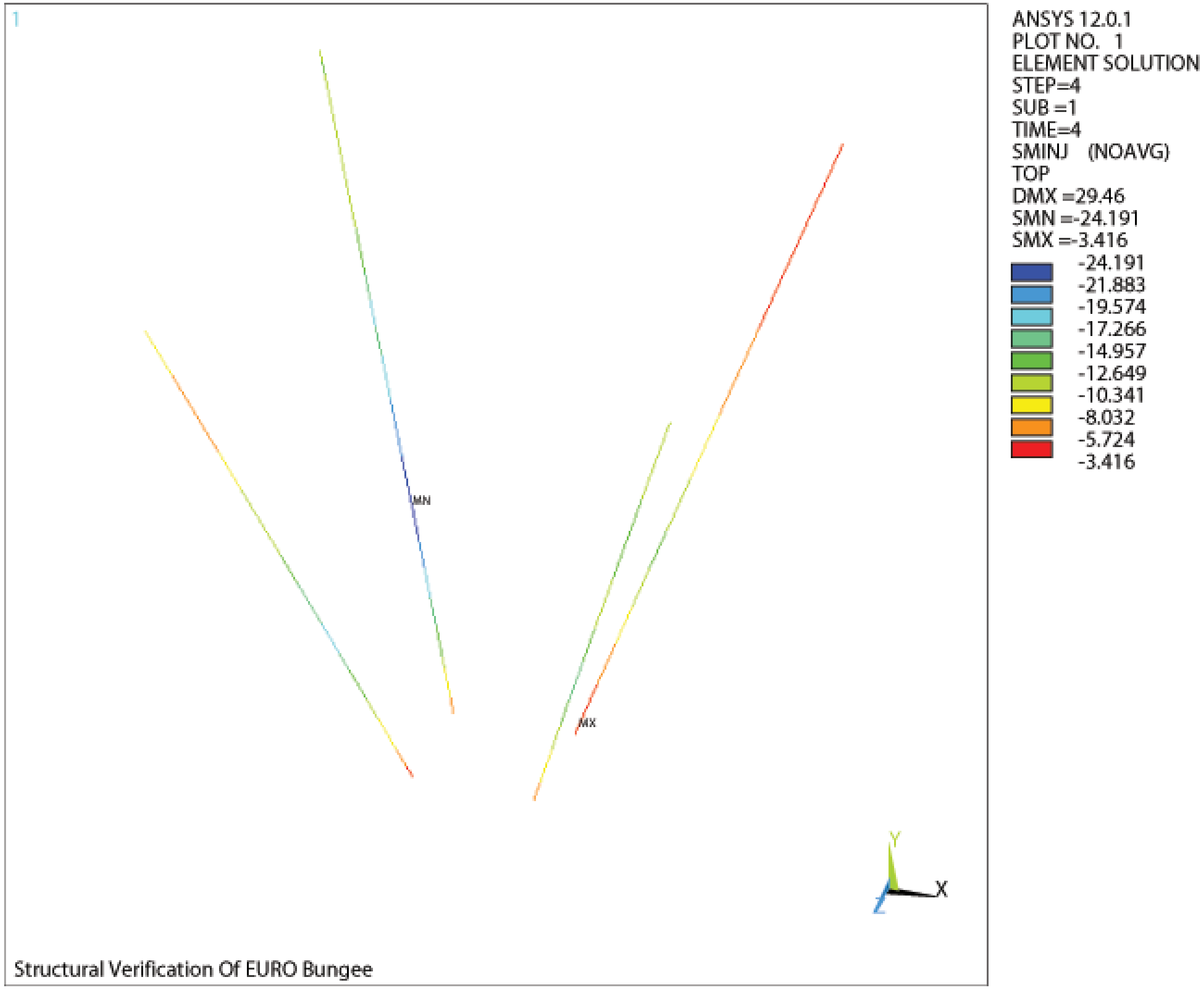


Figure 3.14 – Stresses In Aluminium Beam Structure, Due To Load Case 4

Maximum Stress = -24.2N/mm^2

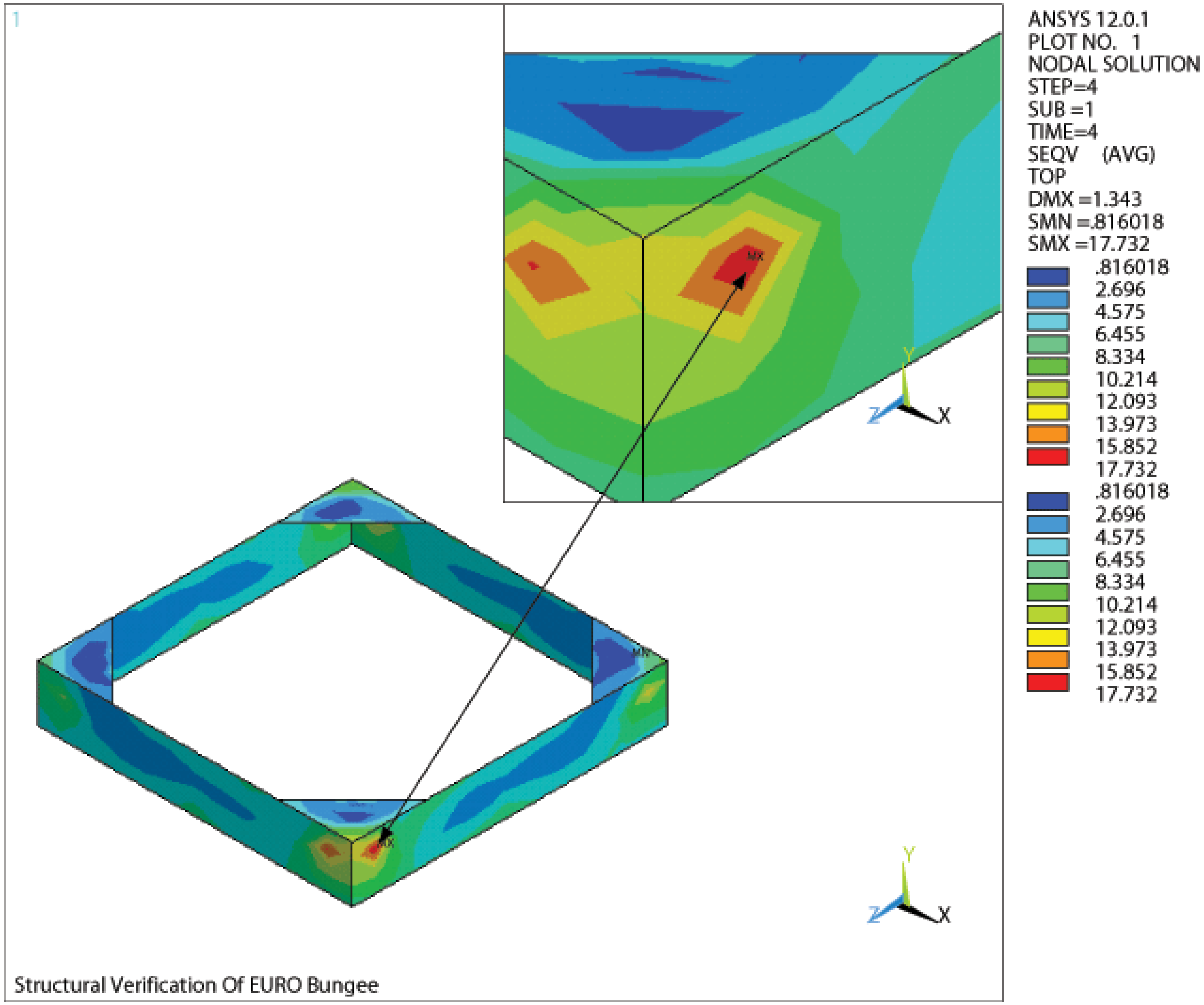


Figure 3.15 – Stresses In Steel Plate Structure, Due To Load Case 4

Maximum Stress = 17.7 N/mm^2

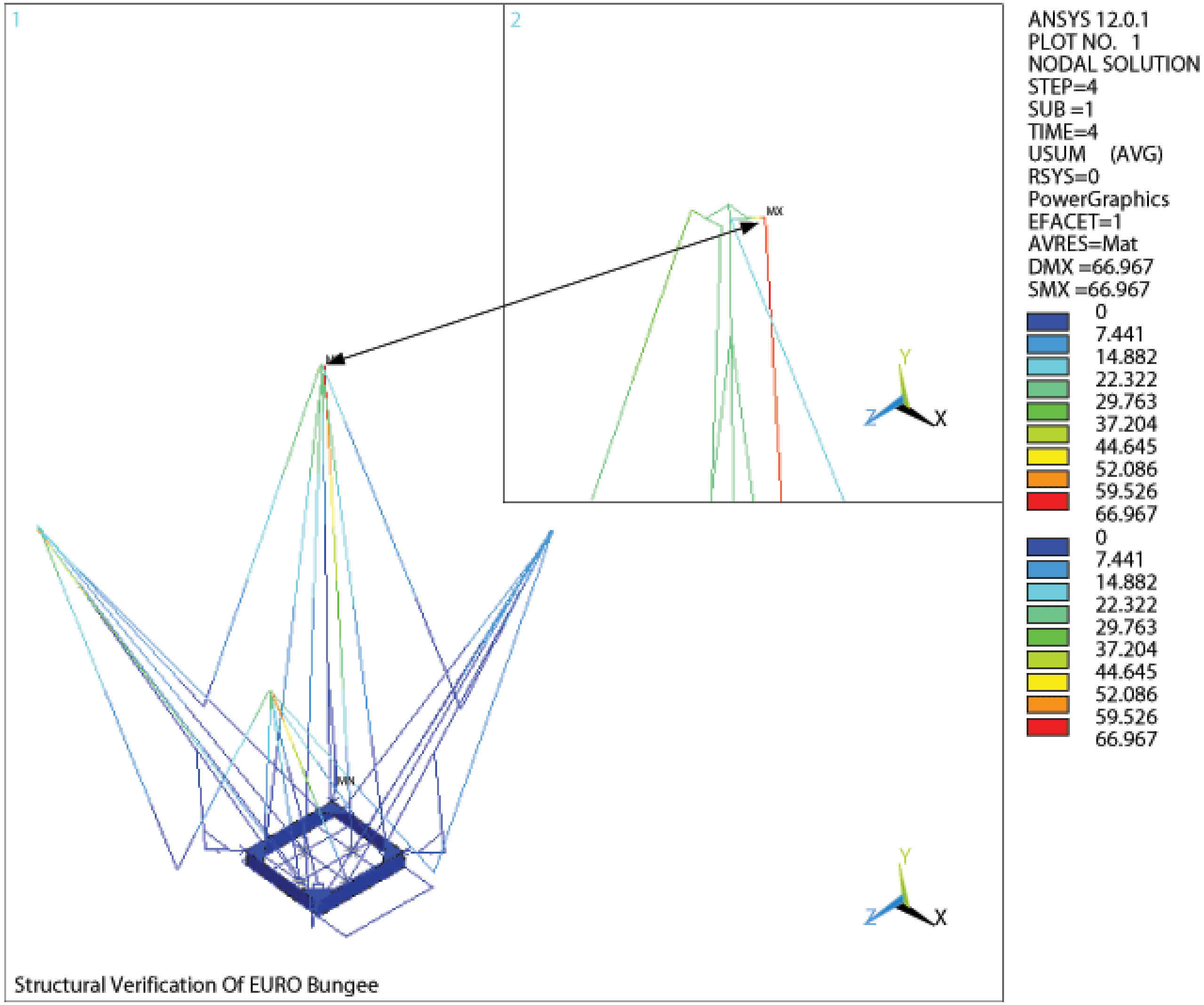


Figure 3.16 – Overall Deflexion In Structure, Due To Load Case 4

Maximum Deflexion = 66.97 mm

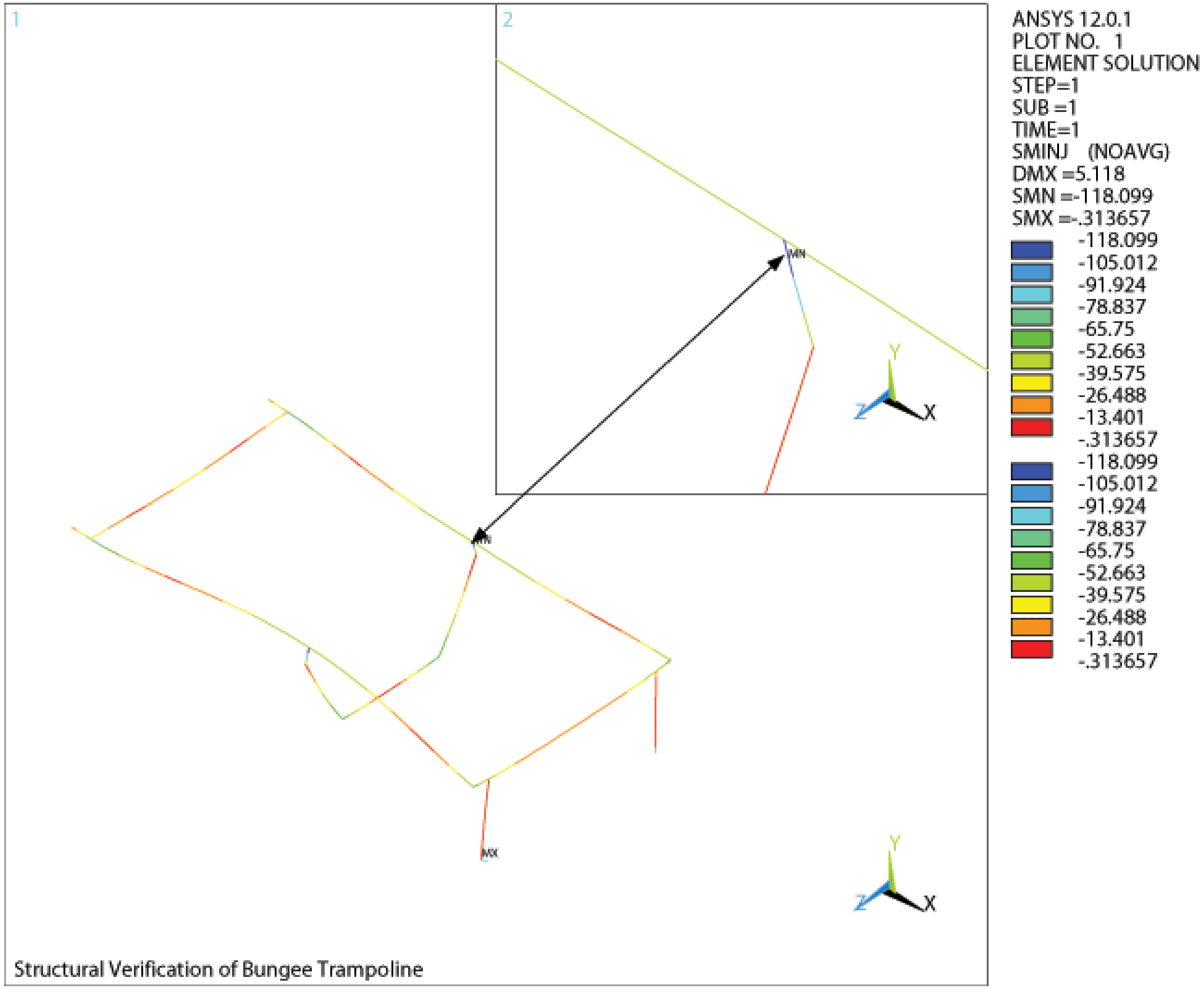


Figure 3.17 – Stress In Steel Beam Structure, Due To Load Case 1

Maximum Stress = -118.1 mm

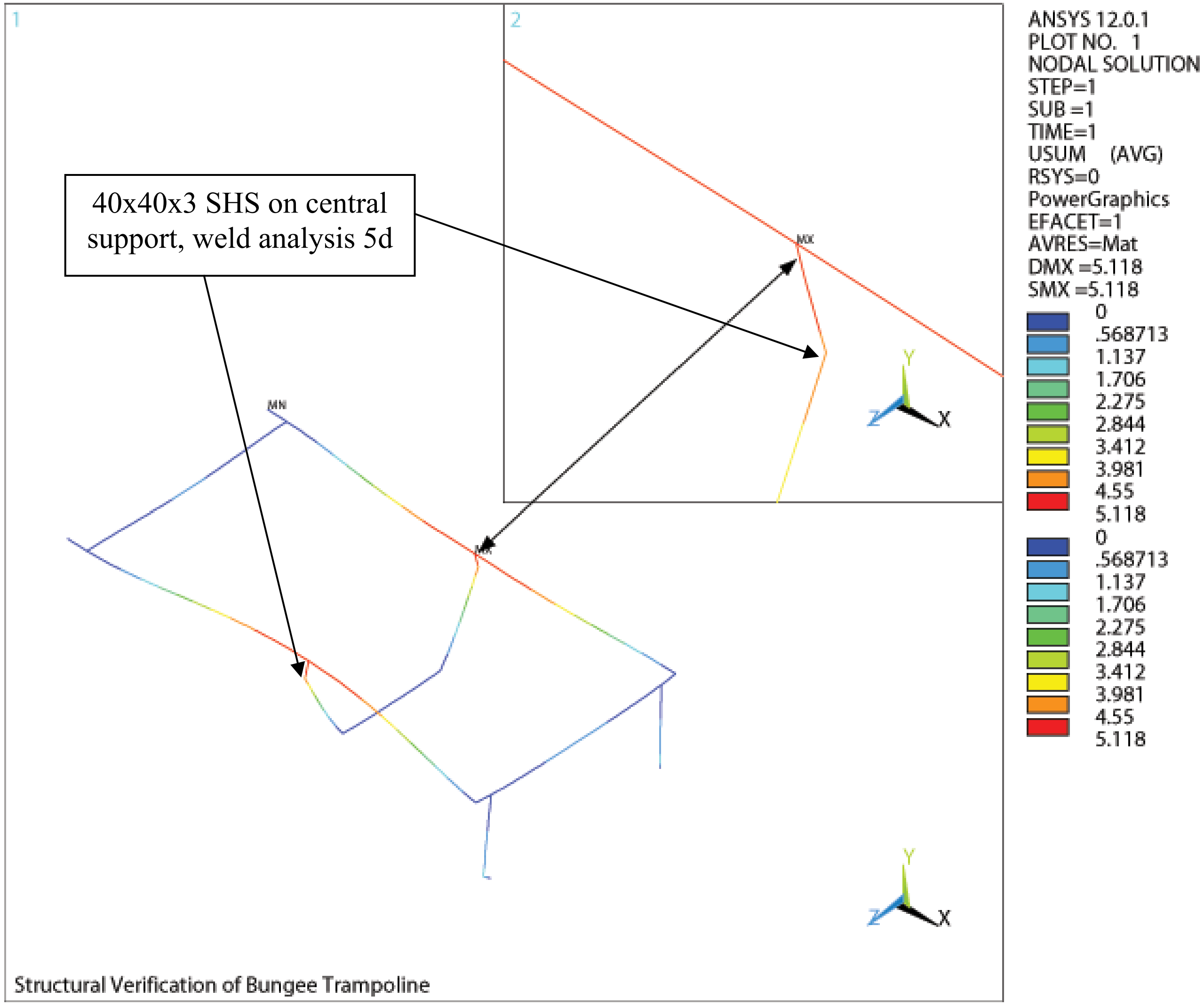


Figure 3.18 – Overall Deflexion In Structure, Due To Load Case 1

Maximum Deflexion = 5.12 mm

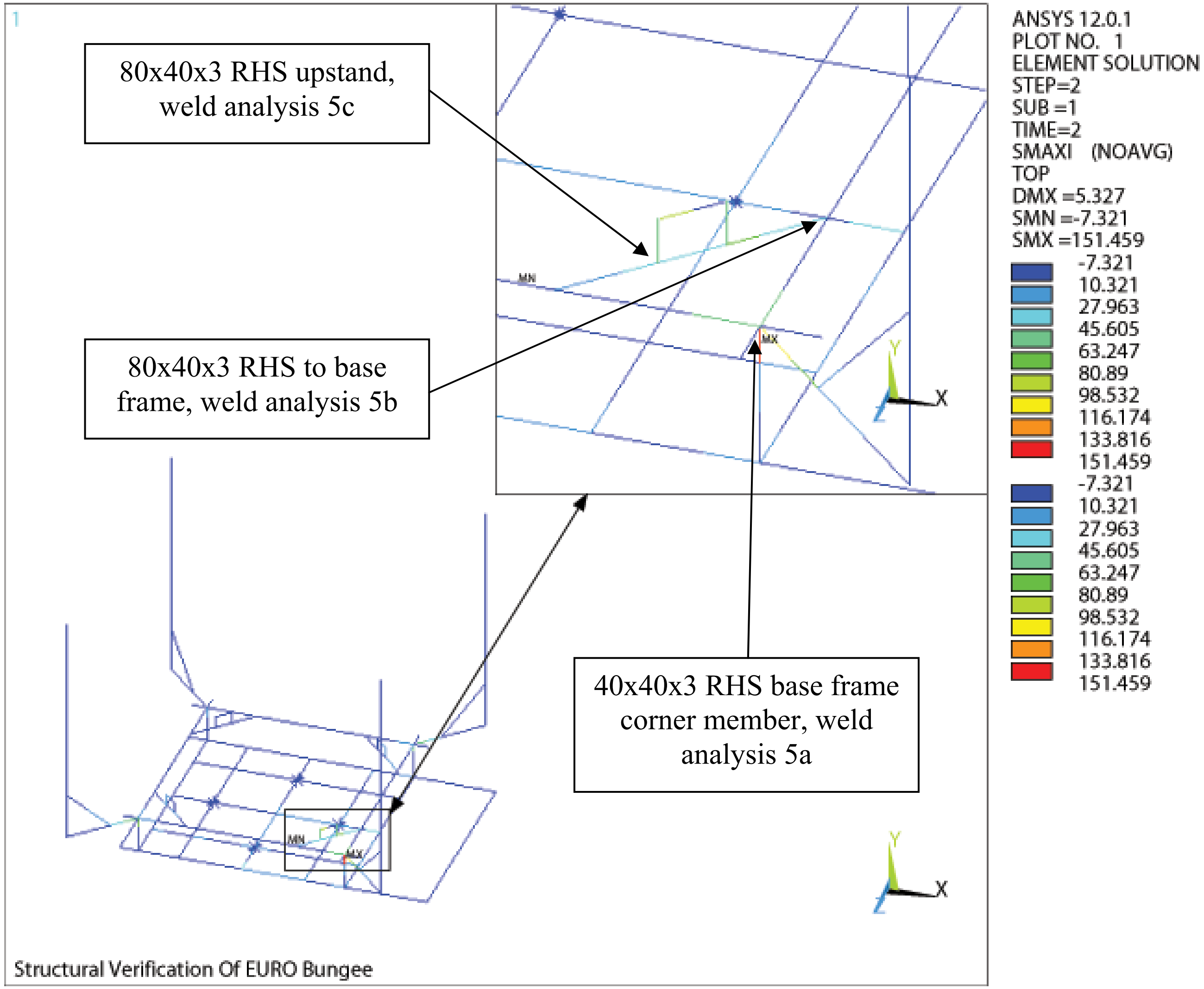


Figure 4.1 – Critical Welds

Appendix A – Certificate Of Conformity For Aluminium Support Poles

TEST CERTIFICATE - DIN 50049/3.1 B

DATE: | ISSUE No 2528 | CONTRACT No 40-50-1-06-0495

REEL SIZE No.

Trzcianka, 28-11-2006

sapa:

Deklaracja zgodności z zamówieniem 2.1

EN 10204:2004, IDT

Firma SAPA Aluminium Sp. z o.o. zaświadcza, że wyroby:

Nr profilu	**90082/5/6/D6600**
Nr zamówienia	**196796-1**
Nr faktury VAT	**227928**
Rodzaj stopu	**6005A**
Masa netto	**956,80 kg**

„BARTEK" S. C. P.P.H.
Ul. Franki 38
51 – 348 Wrocław

wyprodukowane zostały w Polsce z surowca, którego własności zgodne są z charakterystyką techniczną stopów używanych przez naszą firmę oraz zostały skontrolowane i odpowiadają wymaganiom określonym przez Zleceniodawcę oraz normom gwarantowanym przez firmę SAPA Aluminium Sp. z o.o. zgodnym z normami europejskimi:

- **Norma PN-EN 573-3-** Aluminium i stopy aluminium. Skład chemiczny i rodzaje wyrobów przerobionych plastycznie. Część 3: Skład chemiczny
- **Norma PN-EN 755-2:2001 -** Aluminium i stopy aluminium. Pręty, rury i kształtowniki wyciskane. Część 2: Własności mechaniczne
- **Norma PN-EN 755-9:2004 -** Aluminium i stopy aluminium. Pręty, rury i kształtowniki wyciskane. Część 9: Tolerancje wymiarów i kształtu kształtowników
- **Norma PN-EN 12020-2:2004 -** Aluminium i stopy aluminium. Kształtowniki wyciskane precyzyjne ze stopów EN AW-6060 i EN AW-6063. Część 2: Tolerancje wymiarów i kształtu
- **Norma PN-EN 22768-1:1999 -** Tolerancje ogólne. Tolerancje wymiarów liniowych i kątowych bez indywidualnych oznaczeń tolerancji
- **Norma PN-EN 22768-2:1999 -** Tolerancje ogólne. Tolerancje geometryczne elementów bez indywidualnych oznaczeń tolerancji
- **Norma EN 14024:2004 -** Kształtowniki metalowe z przekładką termiczną. Właściwości mechaniczne. Wymagania, sprawdzenie i badania dla oceny
- **QUALANOD:2004 –** Wymagania Znaku Jakości QUALANOD dla anodowania aluminium w roztworach kwasu siarkowego
- **QUALICOAT:2002 -** Wymagania Techniczne Znaku Jakości QUALICOAT dla farb, lakierów i powłok proszkowych na aluminium do celów architektonicznych

Dział Jakości Produkcji

10 May 07 19:35 SD LEISURE 0161 8399330 p.2

Figure A1 – Conformity Certificate For Aluminium Grade 6005A T5 Support Poles

Trzcianka 10-02-26

Świadectwo kontroli 3.1 Nr 66/02/2010

Inspection certificate 3.1 Abnahmeprüfzeugnis 3.1

(PN EN 10204:2004)

Zamawiający Ordered by – Besteller	EUROJUMPER S.C ul. Szkolna 10 55-093 Kiełczów Polska

Nr zamówienia klienta Customer order No – No und datum der Bestellung	Wykonano zgodnie ze zlecenia SAPA nr Manuf. Order No – Auftrag No	Wykonano zgodnie z normą Produced according to – Hergestellt nacht Norm	
-	240605-4 Loading Note No. 1371 / 10 Invoice No. 101830	PN-EN 573-3 – Aluminium alloy PN EN 755-2 – Mechanical properties PN EN 755-9 – Dimensional tollerances * PN EN 12020-2 - Dimensional tollerances *	
Postać wyrobu Item and specification – Gegenstand und Ausfuhrung	Nazwa towaru lub usługi Section No - Ware- oder Bedienungsbezeichnung	Rodzaj stopu Alloy – Legierung	Ilość Quantity – Menge
The profiles of aluminium	90076/ 5 / 6 / D 2850	6005A	62 szt.

1. SKŁAD CHEMICZNY – Chemical composition – Chemische zusammensetzung %

Oznaczenie stopu Alloy designation – Werkstoff Kurzzeichen		Wytop Heat – Abstich	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
Numeryczne Numerical - Nummer	Symb. Chem. Chemical – Chemische									
EN AW – 6005A	EN AW-Al SiMg(A)	K911327HO6005A	0,61	0,19	0,13	0,14	0,55	<0,001	0,002	0,016

2. BADANIA MECHANICZNE – Mechanical tests – Mechanische untersuchungen

Nr próby Tests No – Probe No	Stan obróbki cieplnej Heat treatment – Therm. Bearbeitung	HB	R_m MPa	R_p MPa	A_{50} %
2010 / 02 / 203	T6	98	303	278	10,6

3. BADANIA TECHNOLOGICZNE – NIE PRZEPROWADZONO

Jakość powierzchni oraz istotne wymiary zbadano na poszczególnych etapach obróbki w SAPA. Surface and dimensions tested by Dept. at 100% - Oberfläche und Abmessungen geprüft von Prod.-Abt. Zu	
Materiał oznaczono: Material marked – Das Material wurde bezeichnet:	Nr rysunku, nr zlecenia, gat. stopu, stan obr. termicznej, znak B Drawing no, Order no, Alloy, Heat treatment

Bazując na powyższych wynikach kontroli przeprowadzonych przez niezależne od produkcji laboratorium, Sapa Aluminium deklaruje, że wyroby wyciskane wyszczególnione w niniejszym ateście spełniają wymagania przywołanych Norm.

On basis of special laboratory control we hereby confirm that the above mentioned material fulfil the requirements of the indicated specification.
Nach überprüfung o.g. Resultaten, unsere QS in SAPA Aluminium deklaliert, dass die gepresste Artikel, die Zeugnis ausgestellt sin, für o.g. Normen entsprechen.

Wystawca Świadectwa:

Sapa Aluminium Sp. z o.o.
Wiesław Kasperek

Figure A2 – Conformity Certificate For Aluminium Grade 6005A T5 Support Poles

Appendix B – Conformity Certificate For Steel Cables

10 May 07 19:37 SD LEISURE 0161 8399330 p.2

TEST CERTIFICATE - DIN 50049/3.1 B

DATE:	ISSUE No 2628	CONTRACT No 40-50-1-06-0495
REEL SIZE No. 5	SAMPLING No.	INVOICE No.

PRODUCT: Steel Rope	~~UNGALVANIZED~~/GALVANIZED
WIRE ROPE SPEC: DIN 3060	WIRE SPEC.: DIN 3051
CONSTRUCTION: 6x19St+FE	LAY: SZ
ROPE DIAM.: 5,0 mm	LUBRICATION: –
TENSILE STRENGTH: 1770 N/mm^2	ACTUAL BRAKING LOAD kN 18,4
ROPE LENGTH: 2000 M	

TEST RESULTS

ITEM	DIAMETER OF WIRE Mm		BREAKING LOAD N		TENSILE STRENGTH N/mm^2	
WIRE	SPEC	RESULT	SPEC	RESULT	SPEC	RESULT
d1	0,20	0,20	56	61	1770	1940
d2	0,22	0,22	67	69	1770	1820
d3						
d4						
d5						
d6						

ITEM	CBENDS		TORSIONS TURNS		COATING WEIGHT g/m^2	
WIRE	SPEC	RESULT	SPEC	RESULT	SPEC	RESULT
d1					15	22
d2					15	24
d3						
d4						
d5						
d6						

CHEMICAL ANALYSIS OF WIRE ROD

CHARGE No	Cx100	Si x 100	Mn x 100	P x 1000	S x 1000	
207434	72	26	55	17	31	

OTK

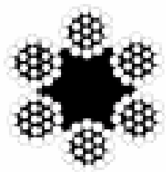
Figure B1 – Conformity Certificate For Steel Cables

TEST WYTRZYMAŁOŚCIOWY / RESISTANCE TEST

LINA STALOWA OCYNKOWANA DIN 3060 6x19+FC
HOT DIP GALV.STEEL WIRE ROPE DIN 3060 6x19+FC

DOSTAWCA / SUPPLIER

Przedsiębiorstwo "GÓRALMET" M. i J. Góral Sp. J.
Ul.Krakowska 68, 32-860 Czchów
Tel / fax: 014 6635260
www.goralmet.pl



TEST KONTROLNY NR
TEST CONTROL NO. **42/GM/2006**

ROZMIAR/SIZE ∅	Splot Strand				Masa/m. Weight/m. [kg]	Wytrzymałość na rozciąganie Tensile strenght [N/mm²] [Mpa]	Obciąż. zrywające Breaking load [kg]
5 mm	RHRL				0.0826	1770	1380
6 mm	RHRL				0.1104	1770	2000
8 mm	RHRL				0.213	1770	3550

MATERIAŁ / MATERIAL
C7 (Mn+Si)

POKRYCIE / COVERING
ocynk ogniowy / hot dip galv.

tolerancja pomiarów +/- 5%
measurement tolerance +/- 5%

badania wykonał / tested by :
Instytut Odlewnictwa
Ul. Zakopiańska 73, 30-418 Kraków
nr raportu / report no.: 146/TBM/2006

Przedsiębiorstwo „GÓRALMET"
M. i J. Góral Sp. J.
32-860 Czchów, ul. Krakowska 68
tel./fax 014 66 35 260, 66 35 265

PIECZĄTKA DOSTAWCY
SUPPLIER'S STAMP

DATA / DATE
12-07-2006

Figure B2 – Conformity Certificates For Steel Cables

Appendix C – Certificate Of Conformity For Carabiners.

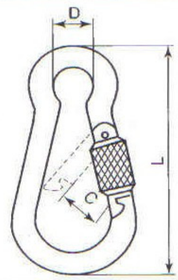
TEST WYTRZYMAŁOŚCIOWY / RESISTANCE TEST

KARABIŃCZYK DO LIN Z ZABEZPIECZENIEM DIN 5299 D

SNAP HOOK WITH SCREW DIN 5299 D

DOSTAWCA / SUPPLIER

Przedsiębiorstwo "GÓRALMET" M. i J. Góral Sp. J.
Ul.Krakowska 68, 32-860 Czchów
Tel / fax: 014 6635260
www.goralmet.pl



TEST KONTROLNY NR TEST CONTROL NO.	**11/GM/2006**

ROZMIAR/SIZE		L [mm]	D [mm]	C [mm]		**Masa/szt** Weight/pc [kg]	**Obciąż. znamion.** Working load [kg]	**Obciąż. zrywające** Breaking load [kg]
4 mm		40	6	5		0.009	70	100
5 mm		50	8	6		0.0164	100	150
6 mm		60	9	6		0.0284	120	180
7 mm		70	10	7		0.0434	180	270
8 mm		80	11	9		0.0648	230	345
10 mm		100	16	13		0.128	350	525
11 mm		120	18	17		0.1842	400	600
12 mm		140	20	20		0.2562	450	675
13 mm		160	25	25		0.3454	530	795
14 mm		180	25	30		0.4578	580	870
15 mm		200	25	35		0.5658	700	1 050

MATERIAŁ / MATERIAL	**POKRYCIE** / COVERING
C15	*ocynk / galv.*

tolerancja pomiarów +/- 5%
measurement tolerance +/- 5%

artykuł posiada sygnaturę dostawcy - "GM"
product with supplier's signature - "GM"

badania wykonał / tested by :
Instytut Odlewnictwa
Ul. Zakopiańska 73, 30-418 Kraków
nr raportu / report no.: **54/TBM/2006**

Przedsiębiorstwo „GÓRALMET"
M. i J. Góral Sp. J.
32-860 Czchów, ul. Krakowska 68
tel./fax 014 66 35 260, 66 35 265
NIP 869-[illegible]

PIECZĄTKA DOSTAWCY
SUPPLIER'S STAMP

DATA / DATE
28-06-2006

Figure C1 – Conformity Certificates For Carabiners

Appendix D – Certificate Of Conformity For Steel Sections.

FERROMORAVIA, s.r.o
Tovární 1688, 686 02, Staré Město

DIČ: CZ63480085 IČO: 63480085
OR: Krajský soud v Brně, spis.zn. C 20789 dne 29.9.1995

Inspekční certifikát
Werksprüfzeugniss
ČSN EN 10204/3.1

Číslo: /Nr.:
75860

PRZEDSIEBIORSTWO WIELOBRANZOWE
"CENTROSTAL - WROCLAW" S.A.
UL. PELCZYŃSKA 4
50-950 WROCLAW
POLAND

Předmět / Gegenstand	**KALTGEZOGENER RUNDSTAHL 018.00**	
Rozměr / Abmesuengen	**018.00 h9 3000+100-0**	
Jakost / Güte	**S235JRG2C**	
Dle norem / Maße nach DIN	**EN10278**	**EN 10277-2**
Objednávka / Auftragsbestätigung	**987206**	
Zakázka č. / Inner Auftrag Nr.	**4/T3E/617609**	
Dodací list č. / Aviso	**50092**	
Auto / LKW Nr.	**DW 45435/WI 836 AM**	
Množství / Menge	**0,000 T**	
Váha / Gewicht	**1,018 T**	

Mechanické vlastnosti / Mechanische Werte **(1MPa=1 N/mm²)**
Vzorek č. / Prüfung Nr. 2060851

		Hodnota / Wert
Rp02 (MPa)	Streckgrenze	**466,0000**
Rm (MPa)	Zugfestigkeit	**482,0000**
A(%)	Bruchdehnung	**20,0000**

Chemické složení / Chemische Zusammensetzung
Tavba č. / Schmelze Nr. 14547
(Tavbová analýza - Die Schmelze Analyse)

	Hodnota / Wert
C%	**0,0700**
P%	**0,0230**
S%	**0,0290**
Mn%	**0,6500**
Si%	**0,1800**
Cu%	**0,0700**
N%	**0,0040**
CEQ %	**0,2000**

Vyřízení zakázky vyhovuje stanoveným požadavkům.
Dodržena radioizotopická aktivita taveb. vzorku - max. 100 BQ/KG.
Die obengenannten erzeugnisse entsprechen den Bestellungsvorschrifte.
Radioisotopische Aktivität der Schmelzprobe ist eingehalten - max. 100 BQ/KG.

Staré Město 18.07.2006

FERROMORAVIA s. r. o.
Tovární 1688
686 02 Staré Město
tel.: 572 430 171
fax: 572 541 665
atestace

Typ dokumentu oceny jakości:
Do faktury nr: F-030749
Dla ilości: = 12,50kg
Słownie: = dwanaście i pół kg
P. W. „CENTROSTAL - WROCŁAW" S. A.
dnia 12.03.07 wydał Dudkowski

Strana :

Figure D1 – Conformity Certificate For Steel Sections.

Appendix E – Certificate Of Conformity For Bungee Harness

CE

EC DECLARATION OF CONFORMITY

Product : Bungee Trampoline harness

Product description : bungee trampoline harnesses have lateral attachment points and are designed primarily to be used for work with bungee elastics (connected with a carabiners). Max weight of jumping person is 85 kg.

Manufacturer : **EUROJUMPER s.c.**
Szkolna 10
55093 Kiełczów
Poland

The Directives covered by this Declaration :

EN 12277 - Mountaineering equipment. Harnesses. Safety requirements and test methods

Signed: ....

Authority: ....

Date: ....

EuroJumper

EUROJUMPER s.c. ul. Szkolna 10 - 55093 Kiełczów – PL - Tel : + 48 (0) 609 65 895
info@eurojumper.pl - www.eurojumper.pl

Bank : Kredyt Bank, I/Wo Wroclaw - ul. Poleska 9-15, SWIFT: KRDBPLPW - IBAN : PL49 1500 1793 1217 9005 5268 0000

Figure E1 – Conformity Certificate For Bungee Harness

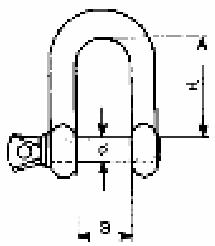
Appendix F – Certificate Of Conformity For D-Shackle

TEST WYTRZYMAŁOŚCIOWY / RESISTANCE TEST

SZEKLA ZWYKŁA
DEE SHACKLE

DOSTAWCA / SUPPLIER

Przedsiębiorstwo "GÓRALMET" M. i J. Góral Sp. J.
Ul.Krakowska 68, 32-860 Czchów
Tel / fax: 014 6635260
www.goralmet.pl



TEST KONTROLNY NR / TEST CONTROL NO.	12/GM/2006

ROZMIAR/SIZE		d [mm]	B [mm]	H [mm]		Masa/szt Weight/pc [kg]	Obciąż. znamion. Working load [kg]	Obciąż. zrywające Breaking load [kg]
3,5 mm		4	8	16		0.0082	50	150
5 mm		5	10	19		0.0146	80	240
6 mm		6	12	24		0.0248	100	300
8 mm		8	16	32		0.0510	200	600
10 mm		10	20	40		0.1086	320	960
12 mm		12	25	48		0.2056	520	1 560
14 mm		14	28	56		0.3248	650	1 950
16 mm		16	32	64		0.4874	800	2 400
18 mm		18	36	71		0.7076	1 000	3 000
20 mm		20	38	76		0.9122	1 100	3 300
22 mm		22	44	85		1.285	1 500	4 500
25 mm		25	50	95		1.8496	2 100	6 300
28 mm		28	56	106		2.5068	3 000	9 000
32 mm		32	64	120		3.1668	3 500	10 500
38 mm		41	76	145		6.2002	5 000	15 000
45 mm		45	80	155		10.810	7 000	21 000

MATERIAŁ / MATERIAL	POKRYCIE / COVERING
C15	*ocynk / galv.*

tolerancja pomiarów +/- 5%
measurement tolerance +/- 5%

artykuł posiada sygnaturę dostawcy - "GM"
product with supplier's signature - "GM"

badania wykonał / tested by :
Instytut Odlewnictwa
Ul. Zakopiańska 73, 30-418 Kraków
nr raportu / report no.: **55/TBM/2006**

Przedsiębiorstwo „GÓRALMET"
M. i J. Góral Sp. J.
32-860 Czchów, ul. Krakowska 68
tel./fax 014 66 35 260, 66 35 265

PIECZĄTKA DOSTAWCY
SUPPLIER'S STAMP

DATA / DATE
28-06-2006

Figure F1 – Conformity Certificate For D-Shackle

Appendix G – Certificate Of Conformity For Eye-Nut

TEST WYTRZYMAŁOŚCIOWY / RESISTANCE TEST

NAKRĘTKA Z UCHEM DIN 582

EYE NUT DIN 582

DOSTAWCA / SUPPLIER

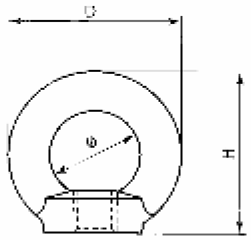
Przedsiębiorstwo "GÓRALMET" M. i J. Góral Sp. J.

Ul.Krakowska 68, 32-860 Czchów

Tel / fax: 014 6635260

www.goralmet.pl

TEST KONTROLNY NR / TEST CONTROL NO. **6/GM/2006**



ROZMIAR/SIZE		D [mm]	Ø [mm]	H [mm]		Masa/szt Weight/pc [kg]	Obciąż. znamion. Working load [kg]	Obciąż. zrywające Breaking load [kg]
6 mm		36	20	36		0.045	70	560
8 mm		36	20	36		0.0422	140	1 120
10 mm		45	25	45		0.078	230	1 840
12 mm		54	30	53		0.164	340	2 720
14 mm		63	35	62		0.2302	490	3 920
16 mm		63	35	62		0.2192	700	5 600
18 mm		72	40	71		0.3266	900	7 200
20 mm		72	40	71		0.3436	1 200	9 600
22 mm		90	50	90		0.699	1 500	12 000
24 mm		90	50	90		0.6638	1 800	14 400
27 mm		96	53	97		0.8724	2 500	15 000
30 mm		108	60	109		1.4326	3 600	21 600

MATERIAŁ / MATERIAL	**POKRYCIE** / COVERING
C15	*ocynk / galv.*

tolerancja pomiarów +/- 5%
measurement tolerance +/- 5%

artykuł posiada sygnaturę dostawcy - "GM"
product with supplier's signature - "GM"

badania wykonał / tested by :
Instytut Odlewnictwa
Ul. Zakopiańska 73, 30-418 Kraków
nr raportu / report no.: **49/TBM/2006**

Przedsiębiorstwo „GÓRALMET"
M. i J. Góral Sp. J.
32-860 Czchów, ul. Krakowska 68
tel./fax 014 66 35 260, 66 35 265

PIECZĄTKA DOSTAWCY
SUPPLIER'S STAMP

DATA / DATE
28-06-2006

Figure G1 – Conformity Certificate For Eye-Nut

Appendix H – Certificate Of Conformity For Rope Clip

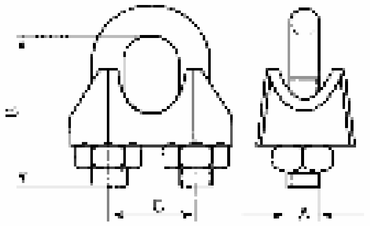
PARAMETRY TECHNICZNE / TECHNICAL PARAMETERS

ZACISK LINOWY DIN 741

WIRE ROPE CLIP DIN 741

DOSTAWCA / SUPPLIER

Przedsiębiorstwo "GÓRALMET" M. I J. Góral Sp. J.
Ul.Krakowska 68, 32-860 Czchów
Tel / fax: 014 6635260
www.goralmet.pl



TEST KONTROLNY NR / TEST CONTROL NO.	27/GM/2006

ROZMIAR/SIZE do liny/for wire	A [mm]	B [mm]	C [mm]					Masa/szt Weight/pc [kg]
3 mm	4	16	9					0.0084
5 mm	5	19	11					0.0142
6 mm	5	23	13					0.0158
8 mm	6	28	16					0.0276
10 mm	8	35	19					0.0595
11 mm	8	37	20					0.0662
12/13 mm	10	45	24					0.1120
14 mm	10	46	25					0.1234
16 mm	12	51	27					0.1838
19/20 mm	12	62	32					0.2316
22 mm	14	72	37					0.3458
26 mm	14	76	41					0.3850
30 mm	16	95	48					0.6356
34 mm	16	105	54					0.7410
40 mm	16	125	60					0.9340

MATERIAŁ / MATERIAL	POKRYCIE / COVERING
C15	*ocynk / galv.*

tolerancja pomiarów +/- 5%
measurement tolerance +/- 5%

badania wykonal / tested by :
Instytut Odlewnictwa
Ul. Zakopiańcka 73, 30-418 Kraków
nr raportu / report no.: 288/TBM/2006

Przedsiębiorstwo „GÓRALMET"
M. i J. Góral Sp. J.
32-860 Czchów, ul. Krakowska 68
tel./fax 014 68 35 260, 68 35 265
NIP 869-[illegible]

PIECZĄTKA DOSTAWCY
SUPPLIER'S STAMP

DATA / DATE
14-07-2006

Figure H1 – Conformity Certificate For Rope Clip

Appendix I – Certificate Of Conformity For Turnbuckle

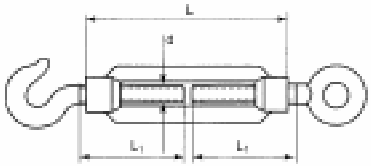
TEST WYTRZYMAŁOŚCIOWY / RESISTANCE TEST

ŚRUBA RZYMSKA UCHO + HAK DIN 1480
TURNBUCKLE WITH EYE / HOOK DIN 1480

DOSTAWCA / SUPPLIER

Przedsiębiorstwo "GÓRALMET" M. i J. Góral Sp. J.
Ul.Krakowska 68, 32-860 Czchów
Tel / fax: 014 6635260
www.goralmet.pl

TEST KONTROLNY NR / TEST CONTROL NO.: 3/GM/2006



ROZMIAR/SIZE		L [mm]	L1 [mm]	d		Masa/szt Weight/pc [kg]	Obciąż. znamion. Working load [kg]	Obciąż. zrywające Breaking load [kg]
5 mm		70	35	M5		0.0498	50	125
6 mm		110	55	M6		0.0912	70	175
8 mm		110	57	M8		0.1552	140	350
10 mm		125	68	M10		0.2808	220	550
12 mm		125	70	M12		0.4222	310	770
14 mm		140	75	M14		0.603	450	1 120
16 mm		170	88	M16		0.9080	600	1 500
18 mm		200	98	M18		1.3216	750	1 875
20 mm		200	105	M20		1.6264	910	2 270
22 mm		220	118	M22		2.1972	1 100	2 750
24 mm		255	135	M24		3.0572	1 300	3 250
28 mm		255	135	M27		4.3588	1 900	4 750
32 mm		295	148	M33		5.9846	2 200	5 500

MATERIAŁ / MATERIAL	POKRYCIE / COVERING
C15	ocynk / galv.

tolerancja pomiarów +/- 5%
measurement tolerance +/- 5%

artykuł posiada sygnaturę dostawcy - "GM"
product with supplier's signature - "GM"

badania wykonał / tested by :
Instytut Odlewnictwa
Ul. Zakopiańska 73, 30-418 Kraków
nr raportu / report no.: **48/TBM/2006**

Przedsiębiorstwo „GÓRALMET”
M. i J. Góral Sp. J.
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DATA / DATE
28-06-2006

Figure I1 – Conformity Certificate For Turnbuckle

Appendix J – Test Certificate For Bungee Cords

TÜV
THÜRINGEN

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TÜV Thüringen e.V.

Testing centre for firmness and flying structures

P r o j e c t
No. 1557 - 2004

Tensile test of rubber cords of **bungee- trampoline structures**

Jena, 23.03.2004

Dipl.-Ing. (graduate engineer) S. Schubert

Figure J1 – Front Page Of Test Certificate For Bungee Cords

3.3. Damage to the rubber cords

During the visual control of the rubber cords that was performed while recording strain curves at regular intervals, no faults or dilapidations of the rubber cords or on the end connections could be observed.

Changes of the length of the rubber cords were only observed after the strain of up to the 2,5-fold length.

4. Summary and conclusions

For the rubber cord red / black, a minimal collapse load of 700 N and for the black / red rubber cord – a minimal collapse load of 1060 N was determined.

Strains over the 2,5-fold initial length must be avoided, i.e. the rubber cords in the structure may reach a maximal length of 6,0 m (carabiner hook to carabiner hook).

This report is valid for the rubber cords of the same construction type (certificate) of a producer and only for application in bungee-trampoline structures.

Figure J2 – Conclusion Page Of Test Certificate For Bungee Cords

Likelihood						
	5	L	M	H	H	H
	4	L	M	M	H	H
	3	L	M	M	M	H
	2	L	L	M	M	M
	1	L	L	L	L	L
		1	2	3	4	5
		Severity				

Risk Assessment Criteria

Severity
1 - None or Trivial injury / illness / loss - 1 person at risk.
2 - Minor injury. Minor first aid required only - Up to 5 persons at risk.
3 - Injury (reportable). Moderate loss - Up to 10 persons at risk.
4 - Major injury / severe incapacity. Serious loss. Up to 25 persons at risk.
5 - Fatality / incapacity. Widespread loss. - 25 or more persons involved.

Likelihood
1 - Improbable
2 - Remote
3 - Possible
4 - Likely
5 - Almost Certain

When calculating the risk the number of persons exposed and the frequency of exposure to the risk must be taken into account.
Risks that calculate as high MUST have further control measures put into place that reduce the risk BEFORE the activity is carried out.
Medium risk factors should have more control measures introduced where possible to reduce the risk to the lowest possible risk.

Risk	Area							
Hazard	Risk & Identity of Persons Affected	Risk Severity			Control Measures	Remaining Risk Severity		
		S	L	RR		S	L	RR
Uneven ground	Ride may be unlevel. Risk of becoming unstable and overturning on packing blocks. Serious injury or death to participants, operators and nearby public	5	4	H	All work force to be trained and supervisor to have appropriate experience. Ground should be assessed prior to build up Always try to assemble on most level ground Use adequate and sufficient packing blocks Regular visual checks on packing areas by trained personnel, re-pack if and when necessary. To be assembled as per manufacturers operating manual.	5	2	L
Soft ground	Risk of ride leveling/packing points sinking into ground. Ride may become unstable and risk of overturning Serious injury or death to participants, operators and nearby public	5	3	M	All work force to be trained and supervisor to have appropriate experience. Ground should be assessed prior to build up Always try to build up on most stable ground possible Use adequate and sufficient packing blocks Regular visual checks on packing areas by trained personnel, re-pack if and when necessary To be assembled as per manufacturers operating manual.	5	2	L

Risk	Structural failure								
Hazard	**Risk & Identity of Persons Affected**	**Risk Severity**			**Control Measures**	**Remaining Risk Severity**		
		S	**L**	**RR**		**S**	**L**	**RR**
Failure of welds on base frame	Ride could become unstable and collapse Serious injury or death to participants, operators and nearby public	5	3	M	Daily and periodic checks and maintenance by adequately trained workforce Adequately trained workforce in operation and evacuation of the ride Repair as and when necessary by qualified/competent person Device not to be opened until repairs etc carried out Annual inspection and NDT by RIB **Refer to manufacturers instruction**	5	2	L
Failure of pins/brackets supporting & connecting main aluminum arms	Main arm could collapse Serious injury or death to participants, operators and nearby public	5	3	M	Daily and periodic checks and maintenance by adequately trained workforce Adequately trained workforce in operation and evacuation of the ride Repair as and when necessary by qualified/competent person Device not to be opened until repairs etc carried out Annual inspection and NDT by RIB **Refer to manufacturers instruction**	5	1	L
Failure of aluminum arms	Main arm could collapse Serious injury or death to participants, operators and nearby public	5	3	M	Daily and periodic checks and maintenance by adequately trained workforce Adequately trained workforce in operation and evacuation of the ride Repair as and when necessary by qualified/competent person Device not to be opened until repairs etc carried out Annual inspection and NDT by RIB **Refer to manufacturers instruction**	5	1	L

Risk	Structural failure								
Hazard	**Risk & Identity of Persons Affected**	**Risk Severity**			**Control Measures**	**Remaining Risk Severity**			
		S	**L**	**RR**		**S**	**L**	**RR**	
Failure of eye bolts securing bungee to aluminum arms	Failure of eye bolts/eye bolts not assembled correctly. Participant would not be supported by bungee. Risk of falling from height/being thrown from ride. Serious injury to participants	4	3	M	Daily and periodic checks and maintenance by adequately trained workforce Device only to be assembled by competent person in accordance with the manufacturers operating manual. Adequately trained workforce in operation and evacuation of the ride Repair as and when necessary by qualified/competent person Device not to be opened until repairs etc carried out Annual inspection and NDT by RIB **Refer to manufacturers instruction**	4	2	L	
Failure of bungee cord	Participant would not be supported by bungee. Risk of falling from height/being thrown from ride. Serious injury to participants	4	3	M	Daily and periodic checks and maintenance by adequately trained workforce Adequately trained workforce in operation and evacuation of the ride Bungee to meet loading requirements as specified by operating manual and this design review Replace bungee as and when necessary by qualified/competent person Device not to be opened until repairs etc carried out Annual inspection and NDT by RIB **Refer to manufacturers instruction**	4	1	L	

Risk	**Structural failure**								
Hazard	**Risk & Identity of Persons Affected**	**Risk Severity**			**Control Measures**	**Remaining Risk Severity**			
		S	**L**	**RR**		**S**	**L**	**RR**	
Failure of winch rope	Participant would not be supported by bungee. Risk of falling from height/being thrown from ride. Serious injury to participants	4	3	M	Daily and periodic checks and maintenance by adequately trained workforce Adequately trained workforce in operation and evacuation of the ride Winch to meet loading requirements as specified by operating manual and this design review Replace bungee as and when necessary by qualified/competent person Device not to be opened until repairs etc carried out Annual inspection and NDT by RIB **Refer to manufacturers instruction**	4	1	L	
Failure of harness	Main arm could collapse Serious injury or death to participants, operators and nearby public	5	3	M	Daily and periodic checks and maintenance by adequately trained workforce Adequately trained workforce in operation and evacuation of the ride Harness to meet loading requirements as specified by operating manual and this design review Replace as and when necessary by qualified/competent person Ensure harness is correct size for participant. Adequately trained operators to ensure harnesses are fitted correctly Device not to be opened until repairs etc carried out Annual inspection and NDT by RIB **Refer to manufacturers instruction**	5	1	L	

Risk	Structural failure							
Hazard	**Risk & Identity of Persons Affected**	**Risk Severity**			**Control Measures**	**Remaining Risk Severity**		
		S	**L**	**RR**		**S**	**L**	**RR**
Failure of electric winch	Participant would not be supported by bungee. Risk of falling from height/being thrown from ride. Serious injury to participants	4	3	M	Daily and periodic checks and maintenance on electrics and power source, and generator for- water-oil-diesel, by adequately trained workforce Adequately trained workforce in operation and evacuation of the ride Repair as and when necessary by qualified/competent person Device not to be opened until repairs etc carried out Annual inspection, and Electrical test by RIB **Refer to manufacturers instruction**	4	1	L
Electric shock	Risk of major injury or death to operators, participants and nearby public	5	3	M	All required MCB's and RCD's in place Daily and periodic checks and maintenance on electrics by adequately trained workforce Adequately trained workforce in operation and evacuation of the ride Repair as and when necessary by qualified/competent person Device not to be opened until repairs etc carried out Annual Electrical test by RIB **Refer to manufacturers instruction**	5	1	L

Risk	Structural failure							
Hazard	**Risk & Identity of Persons Affected**	**Risk Severity**			**Control Measures**	**Remaining Risk Severity**		
		S	**L**	**RR**		**S**	**L**	**RR**
High winds	Risk of major injury or death from participant being blown off normal trajectory to overturn of ride	5	3	M	Adequately trained workforce in operation and evacuation of the ride Sufficient checks and maintenance throughout operation by adequately trained persons Device to be operated only in wind speeds as specified by the manufacturer and in the design review. Device to be disassembled in wind speeds greater than 8 m/s. Device to be guy roped down if excessive movement results when not in use	5	1	L
Age of passengers	This type of ride may cause distress to young participants. Young riders may lack the ability to understand the dangers associated with misbehaving on this ride	2	2	L	Adequately trained workforce in operation and evacuation of the ride Injuries etc are not always visible to operator/attendants therefore safety and instructional signage should be clearly visible Operator to give verbal instruction if necessary **Refer to manufacturers instruction**	2	1	L

This risk assessment report covers the operation of the attraction when used as an amusement device. It is based on an overview of the risks associated with the device. It does not cover detailed component failure. The assessment is based on engineering and operational aspects of the device and does not take into account personal or legislative risks. Each hazard/risk has been reviewed individually to ensure that all required actions have been taken to reduce the risk, so far as reasonably practicable and in line with the manufacturer's recommendation. As there is no statistical data available this risk assessment is based on the experience, judgement and knowledge of the device by the manufacturer Eurojumper and various Owner/Operators. There is a manufacturers operation manual in place for owner/controller reference.

NB;

Operation and maintenance should only be carried out by an adequately trained adult after instruction and training from the manufacturer.
When the 'Bungee Trampoline' is owned/controlled by anyone other than the manufacturer if there is any part of the assessment or operations manual that they do not understand they should consult the manufacturer as soon as possible.
All maintenance and training should be documented.
The manufacturer's instruction should be followed at all times

Appendix L – Non-Destructive Test Schedule

BUNGEE TRAMPOLINE RIDE NDT SCHEDULE FOR ROUTINE TESTING OF CRITICAL PARTS

Item	Description/Location	Test Method	Frequency Of Test
Trailer chassis	Welds on trailer chassis at points where out riggers connect to chassis. Weld connecting arm support to chassis	MPI	Annually
Arm pins	All pins in the ends of the arms connecting arms to trailer chassis	UTS/MPI	Annually
Arm joints	All joint brackets	Visual	Annually
Winch rope	Winch ropes	Visual	Annually
Bungee cords	Bungee cords	Visual	Annually

- 100% of all items listed must be visually examined unless stated.
- Any and all defects found must be reported to the AIB.
- Any previous weld repairs must be recorded.
- Any areas outside the scope of the schedule must be examined by the NDT engineer if deemed relevant , and reported to the AIB
- Eddy Current may be used as an alternative or in combination with other listed Test Methods where appropriate.
- All items to be sufficiently dismantled for proper and adequate NDE
- Remove any flaky paint, corrosion and de-grease. Remaining paint layers to be no more than the maximum thickness to allow proper and adequate NDE

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Client :*Eurojumper* Contract No : *S1778*

Date : *4th October 2010*

Description : *Structural Verification Of Trailer Mounted 4-Person Bungee Trampoline*

1) *Loading Verification*

i) Self weight
Self weight loading was included automatically by the FE program,
based on material densities an acceleration due to gravity of $9.81\ m/s^2$
ii) Passenger loading
$Passenger\ mass = 90\ kg$
$Equivalent\ acceleration = 2x9.81 = 19.62\ m/s^2$
$Equivalent\ force = 19.62x90 = 1765.8N$

Prepared By: *R. Anderson* | Checked By: *Dr M. Lacey*

Sheet: 1 of: 16

iii) Trampoline frame loading verification

Assuming linear variation of spring forces from middle to end of each side of mat

length of short side of mat $= 2a$, *length of long side* $= 2b$

$k =$ *spring stiffness*

number of springs on short side $a = m$ $(m\ odd)$ $\left(one\ spring\ on\ centreline\right)$

number of springs on long side $b = n$ $(n\ even)$ $\left(one\ spring\ on\ centreline\right)\cdot$

let $F_1 =$ *maximum force at middle of long side* $2b$, $F_2 =$ *maximum force at middle of short side* $2a$

ratio of forces $\dfrac{F_1}{F_2} = \dfrac{k\left(l_1 - a\right)}{k\left(l_2 - b\right)} = \dfrac{l_1 - a}{l_2 - b}$

where l_1 *and* l_2 *are the extended lengths under load of sides a and b respectively*

$$l_1 = \sqrt{a^2 + \delta^2}\ ;\ l_2 = \sqrt{b^2 + \delta^2}$$

$$\frac{F_1}{F_2} = \frac{\sqrt{a^2 + \delta^2} - a}{\sqrt{b^2 + \delta^2} - b} = \frac{a}{b}\,\frac{\left(\sqrt{1 + \left(\frac{\delta}{a}\right)^2} - 1\right)}{\left(\sqrt{1 + \left(\frac{\delta}{b}\right)^2} - 1\right)}$$

let $\delta = \gamma a; b = \phi a$

$$\frac{F_1}{F_2} = \frac{1}{\phi}\,\frac{\left(\sqrt{1 + \gamma^2} - 1\right)}{\left(\sqrt{1 + \cdot\left(\frac{\gamma}{\phi}\right)^2} - 1\right)}$$

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total force along side 2b assuming linear variation

$$F_b = 2\left(\frac{F_1}{n} + \frac{2F_1}{n} + \frac{3F_1}{n} + \dots\right) + F_1 = F_1 + \frac{2F_1}{m}\sum_1^p i \qquad p = n-1$$

$$F_b = F_1\left(1 + \frac{p}{n}(1+p)\right) = F_1\left(1 + \frac{(n-1)\,n}{n}\right) = F_1\,n$$

total force along side 2a, assuming linear variation

$$F_a = 2\left(\frac{F_2}{m} + \frac{2F_2}{m} + \frac{3F_2}{m} + \dots\right) + F_2 = F_2 + \frac{2F_2}{m}\sum_1^p i \qquad p = m-1$$

$$F_a = F_2\left(1 + \frac{p}{m}(1+p)\right) = F_2\left(1 + \frac{(m-1)\,m}{m}\right) = F_2\,m$$

hence total vertical force

$$F_{total} = 2F_1\,n + 2F_2\,m$$

$$F_{total} = 2F_1\left[n + m\phi\,\frac{\left(\sqrt{1+\left(\frac{\gamma}{\phi}\right)^2} - 1\right)}{\left(\sqrt{1+\gamma^2} - 1\right)}\right]$$

$$F_{1_v} = \frac{F_{total}}{2\left[n + m\phi\,\frac{\left(\sqrt{1+\cdot\left(\frac{\gamma}{\phi}\right)^2} - 1\right)}{\left(\sqrt{1+\gamma^2} - 1\right)}\right]} \qquad (1)$$

$$F_{2_v} = F_1\,\phi\,\frac{\left(\sqrt{1+\cdot\left(\frac{\gamma}{\phi}\right)^2} - 1\right)}{\left(\sqrt{1+\gamma^2} - 1\right)} \qquad (2)$$

$$\Delta F_{1_v} = \frac{F_1}{n} \qquad (3)$$

$$\Delta F_{2_v} = \frac{F_2}{m} \qquad (4)$$

above are vertical forces, derived from vertical equilibrium *for horizontal force*

$$F_{1_h} = F_{1_v}\frac{a}{\delta}\ ;\ \Delta F_{1_h} = F_{1_h}\frac{a}{\delta} \quad (5)$$

$$F_{2_h} = F_{2_v}\frac{b}{\delta}\ ;\ \Delta F_{2_h} = F_{2_h}\frac{b}{\delta} \quad (6)$$

hence equations 1 *to* 6 *can be used to determine force distribution on frame side members*
to determine total force
assume one passenger of maximum mass 90 *kg generates an inertia force due to bouncing equivalent to* $2g$ max

$$F_{total} = 90x9.81x2 = 1765.8\,N$$

$$a = 840mm,\ b = 1638mm,\ assume\ \delta = 200mm,\ n = 10,\ m = 5$$

from equation (1)

$$F_{1_v} = \frac{1765.8}{2\left[11 + 5x1.95\,\dfrac{\left(\sqrt{1+\left(\frac{0.24}{1.95}\right)^2} - 1\right)}{\left(\sqrt{1+0.24^2} - 1\right)}\right]} = 65\,N$$

from equation (2)

$$F_{2_V} = 65x1.95x\,\frac{\left(\sqrt{1+\left(\frac{0.24}{1.95}\right)^2} - 1\right)}{\left(\sqrt{1+0.24^2} - 1\right)} = 33.7\,N$$

from equations (3) *and* (4)

$$\Delta F_{1_v} = \frac{65}{10} = 6.5\,N \quad ; \quad \Delta F_{2_v} = \frac{33.7}{5} = 6.7\,N$$

from equations (5) *and* (6)

$$F_{1_h} = 65x\,\frac{840}{200} = 273\,N \quad ; \quad \Delta F_{i_h} = \frac{273}{10} = 27.3\,N$$

$$F_{2_h} = 33.7x\,\frac{1638}{200} = 276\,N \quad ; \quad \Delta F_{i_h} = \frac{276}{5} = 55.2\,N$$

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2) *Section Verification*

i) *Load Case* 1

Steel Plate Section

$\sigma_{vm} = 22.5\, N/mm^2 < 213\, N/mm^2$

$Factor\ of\ Safety\ on\ Permissible\ Strength = \frac{213}{22.5} = 9.4$ ***Satisfactory***

$Deflexion = \frac{217}{6845} \geq \frac{1}{200}$ ***Satisfactory Based On Dynamic Deflexion***

ii) *Load Case* 2

Steel Plate Section

$\sigma_{vm} = 22.0\, N/mm^2 < 213\, N/mm^2$

$Factor\ of\ Safety\ on\ Permissible\ Strength = \frac{213}{22.0} = 9.6$ *Satisfactory*

$Deflexion = \frac{76}{6845} \geq \frac{1}{200}$ ***Satisfactory Based On Dynamic Deflexion***

iii) *Load Case* 3

Steel Plate Section

$\sigma_{vm} = 21.4\, N/mm^2 < 213\, N/mm^2$

$Factor\ of\ Safety\ on\ Permissible\ Strength = \frac{213}{21.4} = 9.9$ ***Satisfactory***

$Deflexion = \frac{271}{6845} \geq \frac{1}{200}$ ***Satisfactory Based On Dynamic Deflexion***

iv) *Load Case* 4

Steel Plate Section

$\sigma_{vm} = 17.7\, N/mm^2 < 213\, N/mm^2$

$Factor\ of\ Safety\ on\ Permissible\ Strength = \frac{213}{17.7} = 12.0$ ***Satisfactory***

$Deflexion = \frac{67}{6845} \geq \frac{1}{200}$ ***Satisfactory Based On Dynamic Deflexion***

$3\ )\ \textit{Beam section verification} - \textit{Section Capacities}$

$i\ )\ \textit{Main Structure Real Constant}\ 1 - 80x40x3\ RHS$

$$\frac{l}{r} = \frac{1690x0.85}{16.3} = 88.1$$

$$P_{cf} = (83\ x\ 674)\,x10^{-3} = 55.9\ kN$$

$$P_{tf} = (145\ x\ 674)\,x10^{-3} = 97.7\ kN$$

$$P_{bc_{tzz}} = (154\ x\ 13600)\,x10^{-6} = 2.09\ kNm$$

$$P_{bc_{tyy}} = (154\ x\ 9000)\,x10^{-6} = 1.39\ kNm$$

$\textit{Real Constant}\ 2 - 60x60x3\ SHS$

$$\frac{l}{r} = \frac{1565}{23.2} = 67.5$$

$$P_{cf} = (107\ x\ 674)\,x10^{-3} = 72.1\ kN$$

$$P_{tf} = (145\ x\ 674)\,x10^{-3} = 97.7\ kN$$

$$P_{bc_{tzz}} = (154\ x\ 12100)\,x10^{-6} = 1.86\ kNm$$

$$P_{bc_{tyy}} = (154\ x\ 12100)\,x10^{-6} = 1.86\ kNm$$

$\textit{Real Constant}\ 6 - 30x30x3\ SHS$

$$\frac{l}{r} = \frac{95}{10.9} = 8.7$$

$$P_{cf} = (141\ x\ 314)\,x10^{-3} = 44.3\ N$$

$$P_{tf} = (145\ x\ 314)\,x10^{-3} = 45.5\ kN$$

$$P_{bc_{tzz}} = (154\ x\ 2500)\,x10^{-6} = 0.39\ kNm$$

$$P_{bc_{tyy}} = (154\ x\ 2500)\,x10^{-6} = 0.39\ kNm$$

$\textit{Real Constant}\ 14 - 80x40x3\ RHS$

$$\frac{l}{r} = \frac{1690x0.85}{16.3} = 88.1$$

$$P_{cf} = (83\ x\ 674)\,x10^{-3} = 55.9\ kN$$

$$P_{tf} = (145\ x\ 674)\,x10^{-3} = 97.7\ kN$$

$$P_{bc_{tzz}} = (154\ x\ 9000)\,x10^{-6} = 1.39\ kNm$$

$$P_{bc_{tyy}} = (154\ x\ 13600)\,x10^{-6} = 2.09\ kNm$$

3) *Beam section verification – Section Capacities*

Real Constant 19 – 50*x*30*x*3 *RHS*

$$\frac{l}{r} = \frac{95}{19.1} = 5$$

$$P_{cf} = (142\,x\,434)\,x10^{-3} = 61.6\,kN$$

$$P_{tf} = (145\,x\,434)\,x10^{-3} = 62.9\,kN$$

$$P_{bc_{tzz}} = (154\,x\,5430)\,x10^{-6} = 0.84\,kNm$$

$$P_{bc_{tyy}} = (154\,x\,3960)\,x10^{-6} = 0.61\,kNm$$

ii) *Trampoline Structure Real Constant* 1 – 50*x*30*x*3 *RHS*

$$\frac{l}{r} = \frac{1725x0.85}{11.8} = 124$$

$$P_{cf} = (49\,x\,434)\,x10^{-3} = 21.3\,kN$$

$$P_{tf} = (145\,x\,434)\,x10^{-3} = 62.9\,kN$$

$$P_{bc_{tzz}} = (154\,x\,5430)\,x10^{-6} = 0.84\,kNm$$

$$P_{bc_{tyy}} = (154\,x\,3960)\,x10^{-6} = 0.61\,kNm$$

Real Constant 3 – 40*x*40*x*3 *SHS*

$$\frac{l}{r} = \frac{682}{15} = 45$$

$$P_{cf} = (123\,x\,434)\,x10^{-3} = 53.4\,kN$$

$$P_{tf} = (145\,x\,434)\,x10^{-3} = 62.9\,kN$$

$$P_{bc_{tzz}} = (154\,x\,4890)\,x10^{-6} = 0.75\,kNm$$

$$P_{bc_{tyy}} = (154\,x\,4890)\,x10^{-6} = 0.75\,kNm$$

3b) Summary of Utilisation factors in accordance with BS449 for Main Structure

Load Case	Real Constant Utilisation Factors				
	1	2	6	14	19
1	0.75	0.2	0.9	0.27	0.46
2	0.74	0.08	1	0.35	0.65
3	0.74	0.23	0.81	0.38	0.47
4	0.57	0.07	0.79	0.27	0.52

Table 3 – Utilisation Factors For Steel Beam Elements

3c) Summary of Utilisation factors in accordance with BS449 for Trampoline Structure

Load Case	Real Constant Utilisation Factors	
	1	3
1	0.55	0.44

Table 4 – Utilisation Factors For Steel Beam Elements

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$3c\ )\ Aluminium\ section\ verification - Section\ Capacities$

$i\ )\ 80x3\ CHS\ grade\ 6005A\ T5$

$Factored\ Axial\ Force\ P = F_{Ax}\gamma_f\ 1x\gamma_f\ 2 = (7911x1.33x1)\,x10^{-3} = 10.52\ kN$

$Resultant\ Moment\ \overrightarrow{M} = \sqrt{M_{yy}^2 + M_{zz}^2} = \sqrt{0.1^2 + 0.16^2} = 0.19\ kNm$

$Factored\ Moment\ M = M\,x\gamma_{f_1}\,x\gamma_{f_2} = 0.19x1.33x1 = 0.25\ kNm$

$$Slenderness\ parameter\ \lambda = \frac{kl}{r} = 1.25\ x\ \frac{2855}{29} = 123$$

$Buckling\ Stress\ p_s = 39.6\ N/mm^2$

$$Factored\ axial\ resistance\ to\ buckling\ P_R = \frac{p_{sxA}}{\gamma_m} = \left(39.6x\ \frac{726}{1.2}\right)x10^{-3} = 23.96\ kN$$

$$Factored\ moment\ resistance\ M_{RS} = p_1\frac{S}{\gamma}\ m = \left(240x\ \frac{20497}{1.2}\right)x10^{-6} = 4.1\ kNm$$

$$\frac{P}{P_R} + \frac{M}{M_{RS}} + \frac{PM_{RS}}{2P_R\,M_{RS}} \le 1$$

$$= \frac{10.52}{23.96} + \frac{0.25}{4.1} + \frac{3.36x0.25}{2x23.96x4.1} = 0.5 \le 1\ \textbf{\textit{Satisfactory}}$$

$ii\ )\ 90x3\ CHS\ grade\ 6005A\ T5$

$Factored\ Axial\ Force\ P = F_{Ax}\gamma_f\ 1x\gamma_f\ 2 = (7952x1.33x1)\,x10^{-3} = 10.6\ kN$

$Resultant\ Moment\ \overrightarrow{M} = \sqrt{M_{yy}^2 + M_{zz}^2} = \sqrt{0.216^2 + 0.187^2} = 0.29\ kNm$

$Factored\ Moment\ M = M\,x\gamma_{f_1}\,x\gamma_{f_2} = 0.29x1.33x1 = 0.39\ kNm$

$$Slenderness\ parameter\ \lambda = \frac{kl}{r} = 1.25\ x\ \frac{4000}{30.6} = 163$$

$Buckling\ Stress\ p_s = 24\ N/mm^2$

$$Factored\ axial\ resitance\ to\ buckling\ P_R = \frac{p_{sxA}}{\gamma_m} = \left(24x\ \frac{951}{1.2}\right)x10^{-3} = 19.02\ kN$$

$$Factored\ moment\ resistance\ M_{RS} = p_1\frac{S}{\gamma}\ m = \left(240x\ \frac{26202}{1.2}\right)x10^{-6} = 5.24\ kNm$$

$$\frac{P}{P_R} + \frac{M}{M_{RS}} + \frac{PM_{RS}}{2P_R\,M_{RS}} \le 1$$

$$= \frac{10.6}{19.02} + \frac{0.29}{5.24} + \frac{10.6x0.29}{2x19.02x5.24} = 0.63 \le 1\ \textbf{\textit{Satisfactory}}$$

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Contract No. S1778-1

4 *a*) *Weld Analysis*
Weld connecting 40*x*40*x*3 *SHS support at corner of base frame, detailed in figure* 4.1,
due to load case 2 · *Assuming* 3*mm continuous fillet weld*

$SF_x = 3634\,N$

$F_y = -9862\,N$

$SF_z = 3687\,N$

$M_{xx} = 317540\,Nmm$

$SM_{yy} = 1727\,Nmm$

$M_{zz} = -315290\,Nmm$

Force on weld due to tension

$$F_{maxM_{xx}} = \frac{M_{xx}}{bd + 2\frac{b^2}{3}} = \frac{317540}{40x40 + 2\left(\frac{40^2}{3}\right)} = 119\,N/mm$$

$$F_{maxM_{zz}} = \frac{M_{zz}}{bd + 2\frac{d^2}{3}} = \frac{315290}{40x40 + 2\left(\frac{40^2}{3}\right)} = 118\,N/mm$$

$$F_{maxF_y} = \frac{F_y}{2\,(b+d)} = \frac{-9862}{2\,(40+40)} = -62\,N/mm$$

$F_T = 119 + 118 - 62 = 175\,N/mm$

Force on weld due to shear

$$SF_{Fx} = \frac{SF_x}{2\,(b+d)} = \frac{3634}{2\,(40+40)} = 28\,N/mm$$

$$SF_{Fz} = \frac{SF_z}{2\,(b+d)} = \frac{3687}{2\,(40+40)} = 23\,N/mm$$

$$SF_{M_y} = \frac{M_y\,x\,r}{bd\,(b+d) + \frac{d^3+b^3}{3}} = \frac{1727\,x\,28}{40\,x\,40\,(40+40) + \frac{40^3+40^3}{3}} = 0.28\,N/mm$$

$\alpha = 45^\circ$

$$SF_T = \sqrt{\left(SF_{F_x} + SF_{M_y}\sin\alpha\right)^2 + \left(SF_{F_z} + SF_{M_y}\cos\alpha\right)^2}$$

$$= \sqrt{(28 + 0.28\sin 45)^2 + (23 + 0.28\cos 45)^2} = 37\,N/mm$$

Resultant force on weld

$$F_r = \sqrt{F_T^2 + SF_T^2} = \sqrt{175^2 + 37^2} = 179\,N/mm$$

Resultant stress on weld

$$\sigma_{max} = \frac{F_r}{3}\,x\,\sqrt{2} = \frac{179}{3}\,x\,\sqrt{2} = 84\,N/mm^2 \leq 125\,N/mm^2$$ ***Satisfactory***

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4 *b*) *Weld Analysis continued*

Weld connecting 80*x*40*x*3 *RHS connecting main arm support to frame, detailed in figure* 4.1, *due to load case* 2 · *Assuming* 3*mm continuous fillet weld*

$F_x = 148\ N$

$SF_y = 3518\ N$

$SF_z = 816\ N$

$SM_{xx} = -\ 8629\ Nmm$

$M_{yy} = -\ 13965\ Nmm$

$M_{zz} = 226440\ Nmm$

Force on weld due to tension

$$F_{maxM_{yy}} = \frac{M_{yy}}{bd + 2\frac{b^2}{3}} = \frac{13965}{80x40 + 2\left(\frac{80^2}{3}\right)} = 1.9\ N/mm$$

$$F_{maxM_{zz}} = \frac{M_{zz}}{bd + 2\frac{d^2}{3}} = \frac{226440}{80x40 + 2\left(\frac{40^2}{3}\right)} = 53\ N/mm$$

$$F_{maxF_x} = \frac{F_x}{2(b+d)} = \frac{148}{2(80+40)} = 0.6\ N/mm$$

$F_T = 1.9 + 53 + 0.6 = 55.5\ N/mm$

Force on weld due to shear

$$SF_{Fy} = \frac{SF_y}{2(b+d)} = \frac{3518}{2(80+40)} = 14.7\ N/mm$$

$$SF_{Fz} = \frac{SF_z}{2(b+d)} = \frac{816}{2(80+40)} = 3.4\ N/mm$$

$$SF_{M_x} = \frac{M_x\, x\, r}{bd(b+d) + \frac{d^3+b^3}{3}} = \frac{8629\, x\, 44.7}{80\, x\, 40\,(80+40) + \frac{40^3+80^3}{3}} = 0.67\ N/mm$$

$\alpha = 26.6^\circ$

$$SF_T = \sqrt{\left(SF_{F_y} + SF_{M_x}\sin\alpha\right)^2 + \left(SF_{F_z} + SF_{M_x}\cos\alpha\right)^2}$$

$$= \sqrt{(14.7 + 0.66\sin 26.6)^2 + (3.4 + 0.66\cos 26.6)^2} = 15.5\ N/mm$$

Resultant force on weld

$$F_r = \sqrt{F_T^2 + SF_T^2} = \sqrt{55.5^2 + 15.5^2} = 57.6 N/mm$$

Resultant stress on weld

$$\sigma_{max} = \frac{F_r}{3}\, x\, \sqrt{2} = \frac{57.6}{3}\, x\, \sqrt{2} = 27.2\ N/mm^2 \leq 125\ N/mm^2$$ ***Satisfactory***

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4 *c*) *Weld Analysis continued*

Weld connecting 80*x*40*x*3 *RHS connecting main arm pin to frame, detailed in figure* 4.1, *due to load case* 2 · *Assuming* 3*mm continuous fillet weld*

$SF_x = 4279\ N$

$SF_y = 2735\ N$

$F_z = -2758\ N$

$M_{xx} = -165710\ Nmm$

$M_{yy} = 386430\ Nmm$

$SM_{zz} = 126070\ Nmm$

Force on weld due to tension

$$F_{maxM_{xx}} = \frac{M_{xx}}{bd + 2\frac{b^2}{3}} = \frac{165710}{80x40 + 2\left(\frac{80^2}{3}\right)} = 22\ N/mm$$

$$F_{maxM_{yy}} = \frac{M_{yy}}{bd + 2\frac{d^2}{3}} = \frac{386430}{80x40 + 2\left(\frac{40^2}{3}\right)} = 90.6\ N/mm$$

$$F_{maxF_z} = \frac{F_z}{2(b+d)} = \frac{2758}{2(80+40)} = 11.5\ N/mm$$

$F_T = 22 + 90.6 + 11.5 = 124.1\ N/mm$

Force on weld due to shear

$$SF_{Fx} = \frac{SF_x}{2(b+d)} = \frac{4279}{2(80+40)} = 18\ N/mm$$

$$SF_{Fy} = \frac{SF_y}{2(b+d)} = \frac{2735}{2(80+40)} = 11.4\ N/mm$$

$$SF_{M_z} = \frac{M_z\ x\ r}{bd(b+d) + \frac{d^3+b^3}{3}} = \frac{126070\ x\ 44.7}{80\ x\ 40\ (80+40) + \frac{40^3+80^3}{3}} = 9.8\ N/mm$$

$\alpha = 26.6^\circ$

$$SF_T = \sqrt{\left(SF_{F_x} + SF_{M_z}\sin\alpha\right)^2 + \left(SF_{F_z} + SF_{M_z}\cos\alpha\right)^2}$$

$$= \sqrt{(18 + 9.8\sin 26.6)^2 + (11.4 + 9.8\cos 26.6)^2} = 30.1\ N/mm$$

Resultant force on weld

$$F_r = \sqrt{F_T^2 + SF_T^2} = \sqrt{124.1^2 + 30.1^2} = 127.7\ N/mm$$

Resultant stress on weld

$$\sigma_{max} = \frac{F_r}{3}\ x\ \sqrt{2} = \frac{127.7}{3}\ x\ \sqrt{2} = 60.2\ N/mm^2 \leq 125\ N/mm^2$$ ***Satisfactory***

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4 *d) Weld Analysis continued*

Weld connecting 40*x*40*x*3 *SHS on trampoline support structure, detailed in figure* 3.18, *due to load case* 1 · *Assuming* 3*mm continuous fillet weld*

$SF_x = -11\,N$

$SF_y = 849\,N$

$F_z = 1280\,N$

$M_{xx} = -2326\,Nmm$

$M_{yy} = 3958\,Nmm$

$SM_{zz} = -5967\,Nmm$

Force on weld due to tension

$$F_{maxM_{xx}} = \frac{M_{xx}}{bd + 2\frac{b^2}{3}} = \frac{2326}{40x40 + 2\left(\frac{40^2}{3}\right)} = 0.87\,N/mm$$

$$F_{maxM_{yy}} = \frac{M_{yy}}{bd + 2\frac{d^2}{3}} = \frac{3958}{40x40 + 2\left(\frac{40^2}{3}\right)} = 1.5\,N/mm$$

$$F_{maxF_z} = \frac{F_z}{2(b+d)} = \frac{1280}{2(40+40)} = 8\,N/mm$$

$$F_T = 0.9 + 1.5 + 8 = 10.4\,N/mm$$

Force on weld due to shear

$$SF_{Fx} = \frac{SF_x}{2(b+d)} = \frac{11}{2(40+40)} = 0.1\,N/mm$$

$$SF_{Fy} = \frac{SF_y}{2(b+d)} = \frac{849}{2(40+40)} = 5.3\,N/mm$$

$$SF_{M_z} = \frac{M_z\,x\,r}{bd(b+d) + \frac{d^3+b^3}{3}} = \frac{5967\,x\,28.3}{40\,x\,40\,(40+40) + \frac{40^3+40^3}{3}} = 1\,N/mm$$

$$\alpha = 45^\circ$$

$$SF_T = \sqrt{\left(SF_{F_x} + SF_{M_z}\sin\alpha\right)^2 + \left(SF_{F_z} + SF_{M_z}\cos\alpha\right)^2}$$

$$= \sqrt{(0.1 + 1\sin 45)^2 + (5.3 + 1\cos 45)^2} = 6.1\,N/mm$$

Resultant force on weld

$$F_r = \sqrt{F_T^2 + SF_T^2} = \sqrt{10.4^2 + 6.1^2} = 12.1\,N/mm$$

Resultant stress on weld

$$\sigma_{max} = \frac{F_r}{3}\,x\,\sqrt{2} = \frac{12.1}{3}\,x\,\sqrt{2} = 5.7\,N/mm^2 \le 125\,N/mm^2$$ ***Satisfactory***

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5) *Fatigue analysis*

Maximum change in weld resultant stresses

Weld identified in 4a

$\sigma_{R_1} = 84\, N/mm^2$

Assuming stress falls to 0 *N when participant is at top of bounce*

$\Delta\sigma_p = 84\, N/mm^2$

Weld identified in 4b

$\sigma_{R_1} = 27.2 N/mm^2$

Assuming stress falls to 0 *N when participant is at top of bounce*

$\Delta\sigma_p = 27.2\, N/mm^2$

Weld identified in 4c

$\sigma_{R_1} = 63.4\, N/mm^2$

Assuming stress falls to 0 *N when participant is at top of bounce*

$\Delta\sigma_p = 63.4\, N/mm^2$

Weld identified in 4d

$\sigma_{R_1} = 5.7\, N/mm^2$

Assuming stress falls to 0 *N when participant is at top of bounce*

$\Delta\sigma_p = 5.7\, N/mm^2$

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5) *Fatigue analysis*

$\Delta\sigma_p = 84\ N/mm^2\ for\ 90\ kg\ passenger\ load$

$\Delta\sigma_p = 84x\ \frac{3}{4} = 63\ N/mm^2\ for\ 67.5kg\ passenger\ load$

$\Delta\sigma_p = 85x\ \frac{1}{2} = 42\ N/mm^2\ for\ 45kg\ passenger\ load$

$For\ weld\ class\ F2$

$with\ \Delta\sigma = 84\ N/mm^2,\ predicted\ fatigue\ life = 7.27\ x10^5\ cycles$

$with\ \Delta\sigma = 63\ N/mm^2,\ predicted\ fatigue\ life = 1.72\ x10^6\ cycles$

$with\ \Delta\sigma = 42\ N/mm^2,\ predicted\ fatigue\ life = 5.82\ x10^6\ cycles$

$number\ of\ cycles\ per\ year\ with\ 90kg\ passenger\ loading\ (or\ balanced) = 0.25x864000 = 216000$

$number\ of\ cycles\ per\ year\ with\ 67.5kg\ passenger\ loading = 0.25x864000 = 216000$

$number\ of\ cycles\ per\ year\ with\ 42kg\ passenger\ loading = 0.5x864000 = 432000$

$from\ Miner's\ summation\ \Sigma = \frac{2.16}{7.27} + \frac{2.16}{17.2} + \frac{4.32}{58.2} = 0.50$

$predicted\ weld\ fatigue\ life = \frac{1}{0.5} = 2\ years$ ***Satisfactory***

Note:
i) *Above analysis based on an operational life of* 30 *cycles* / min, 2*mins* / *ride,* 12 *rides* / *hour,* 5 *hours* / *day*
240 *days* / *year* = 864000 *cycles*

ii) *Assumed loading spectrum is* 50% *of life half loaded* (42*kg participant*), 25% *of life with*
67.5 *kg particpant of load and* 25% *of life with* 90 *kg particpant* · *Hence analysis based on*
*Miner's summation using BS*7608:1993

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Sheet: 15 *of:* 16

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6) *Connection Verification*

a) 14 *dia pin connection main arms to support frame, load case* 2

$F_y = 2775\ N$

$F_z = 2779\ N$

Resultant shear force

$$F_{RS} = \sqrt{F_y^2 + F_z^2} = \sqrt{2775^2 + 2779^2} = 3927\ N$$

Maximum shear stress

$$\tau_{max} = \frac{4}{3} \times \frac{3927}{154} = 34.0\ N/mm^2 \le 80\ N/mm^2\ \textbf{\textit{Satisfactory}}$$