Advanced Computational Analysis

ACA

REPORT

REPORT NO: S1722-1

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

Client: Mr. J. Johnson (For Eurojumper) ul.

Author: R. Anderson BEng (Hons)

ADIPS Registration No.: 101244-1

Approved: Dr M Lacey BSc PhD CEng MIMechE

ADIPS Registration No.: 101244-0

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4A, Main Road, Gedling, Nottingham NG4 3HP
Tel (0115) 9533931
e-mail: info@aca-consultants.co.uk

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 in-house, closed-form calculations.

The analysis detailed below was carried out based on loadings form 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 the in-house, closed-form calculations, show that all structural and mechanical components have adequate load-carrying capacity, based on the loading prescribed above, providing the recommendations detailed below are adopted.

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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. 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 amount of bungee rope 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 feel 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 drawings provided by Eurojumper.

The analysis of the bungee-trampoline structure was performed with regard to the initial in-house, closed-form calculations (not reported here).

1) Structural Analysis

The finite element model of the device was generated using a combination of BEAM4, LINK10, LINK8, CONTACT52, COMBIN14 and MASS21 element types. The BEAM4, 3-dimensional prismatic beam elements were used to model the steel base frame of the device and the main arms. The cross-sectional properties of these elements were set to those of the frame 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 can sustain only tensile loads and is removed from the element formulation if the forces are equal to, or decrease below zero. The cross-sectional area of the element was set to that of the steel rope, as appropriate. In addition LINK10 elements were used to model the bungee cords and ropes. The bungee cords and ropes were given the same sectional and material properties as the steel guy ropes, since in the model their purpose is to distribute the loads from the participant to the main structure. The LINK8 compression/tension only elements where used to model the aluminium support poles. This element can sustain only compressive and tensile loads, no bending of this element was considered. The cross-sectional area of the element was set to that of the aluminium support pole, 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 COMBIN14 3-dimensional, torsional spring elements were used to simulate the friction in the pulleys at the top of the arms. The MASS21 elements, without rotational inertia, were used to simulate the mass of the winch motors.

The finite element model comprised a total of 772 elements (683 beam elements, 32 tension-only elements, 4 spar elements, 8 mass elements, 8 torsion elements and 37 contact elements and) and 733 nodes. The finite element model of the device is shown in figure 2.1.

As contact elements were used in the finite element model the analysis was a non-linear. The model reached convergence to within 0.1% of the overall load on the structure.

A total of 4 load cases were analysed for the structure. These are detailed as follows:

i) Load Case 1

For this load case the loads from 4 passengers were applied as equivalent point loads, balancing the forces resolved at the motor mounting and the top of the aluminium poles. The loading on each passenger was equivalent to 2g, based on a passenger mass of 90 kg and as a worst case, the included angle between the bungee ropes was taken as approximately 45º. This position would be concomitant with a passenger reaching these accelerations at the bottom of the bounce, in the absence of the trampoline. Further details of the individual resolved load components for passenger loading are shown in calculation sheet 1.

ii) Load Case 2

This load case was similar to load case 1 except that the loading on the structure was derived from only two passengers, positioned on opposite 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 opposite sides of the frame.

iii) Load Case 3

This load case was again similar to load case 1, but with passenger loading applied at only two adjacent passenger stations. This load cases represented the first of two out-of-balance load conditions for the complete frame.

iv) Load Case 4

This load case represented the second of the two out-of-balance load conditions. In this load case a single passenger loading was applied at one passenger station and represented the combined out-of-balance effect from load cases 2 and 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.

2) Material Properties And Component Capacities

a) The material properties for the aluminium sections used for the analysis were based on grade 6005A T5 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 (in the absence of material certificates), 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)

c) The worst case condition for alternating stress in a weld is 106.5 N/mm^2, as detailed in calculation sheet 4. This weld has been verified and given a fatigue life expectancy of 1.8 years.

d) The carabineers are 'Offset D Screw' type, manufactured to DIN 5299 D. The certificate of conformity for the carabineers is shown in Appendix B.

e) The current 5mm D-Shackles have a maximum loading capacity of 200 kg. These should be change to 8mm type to provide a maximum capacity of 600 kg. The certificate of conformity for the D-shackles is shown in Appendix C.

f) The eyebolts, manufactured to DIN 582 have been tested to a capacity of maximum 2720 kg. The certificate of conformity for the eyebolts is shown in Appendix D.

g) The steel ropes are a standard 6x19 configuration, with a fibre core, to DIN 3060. They have a maximum capacity of 1380 kg. The certificate of conformity for the steel rope is shown in Appendix C.

The results of the analysis are presented below.

Results

Load Case No.	Stresses In Steel Beams Structure (N/mm^2)	Stresses In Aluminium Beam Structure (N/mm^2)	Forces in Steel Ropes (N)	Overall Deflexion (mm)	Maximum Reaction Forces (N)		
					Fx	Fy	Fz
1	28.5 *(figure 3.1)*	-73.3 *(figure 3.2)*	4772	22.97 *(figure 3.3)*	575	1627	-575
2	22.5 *(figure 3.4)*	-69.6 *(figure 3.5)*	2873	53.66 *(figure 3.6)*	80	1052	118
3	42.0 *(figure 3.7)*	-82.8 *(figure 3.8)*	3136	46.87 *(figure 3.9)*	565	1739	565
4	22.3 *(figure 3.10)*	-62.7 *(figure 3.11)*	2164	63.25 *(figure 3.12)*	293	1149	385

Table 1 – Results For Stresses And Deflexions

Note:

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

ii) The deflexion quoted above represents the vector sum of the Cartesian deflexion components, at any point in the continuum.

iii) 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 7.

iv) The max reaction of 1627 N is equivalent to an average pressure on the ground of 40.7 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 closed-form verification report on this ride. The results of the substantiating analysis are based on a closed-form analysis of the structure, using similar loads and accelerations to those described in the present study.

The small discrepancies between the predictions from the closed-form analysis and the present study arise mainly from the method of analysis used in each case. The analysis carried out in the present study of the Bungee Trampoline device 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 a utilisation factor of approximately 83.3 % 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 beam members provide a minimum factor of safety of approximately 5 (for load case 3), based on a permissible equivalent strength of 213 N/mm^2.

The maximum deflexion in the structure represents approximately $^1/_{105}$ of the overall height of the device (for load case 4). Whilst this would be excessive for a static structure the deflexions result from dynamic loads and result from sway of the structure, rather than 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 60x40x3 RHS, forming the main arm connection spigot to the central column, shown in figure 4.1, were identified as the critical welds on the structure. They have been given a predicted fatigue life of approximately 1.8 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 1.8 years. Hence the 1.8 year fatigue life is presented as a minimum fatigue life condition.

The material certificates provided by the manufacturer and owner demonstrate that the aluminium sections have adequate load –carrying capacity for the proposed maximum loading.

The component certificates provided by the manufacturer and owner demonstrate that all component have adequate load –carrying capacity for the proposed maximum loading with exception of the D – shackles. To comply with the loading as described in this report the current 5mm D – shackles should be replaced with 8mm diameter types.

Where components certificates have not been provided (for the bungee cords, the winch ropes, it is the responsibility of the ride owner to ensure these proprietary items are adequate for the loading as detailed in this design review.

Note finally that this report does not cover the verification of the trampoline unit. Generally most proprietary units are suitable, providing the loading capacity is at least 1800 N (180 kgf) and the landing area is large enough to ensure that the passenger cannot land beyond the edge of the trampoline.

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.

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 40.7 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.

The 5 mm D-shackles used currently for the device must be replaced by 8 mm D-shackles as soon as possible, to ensure the full load-carrying capacity is achieved.

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.

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

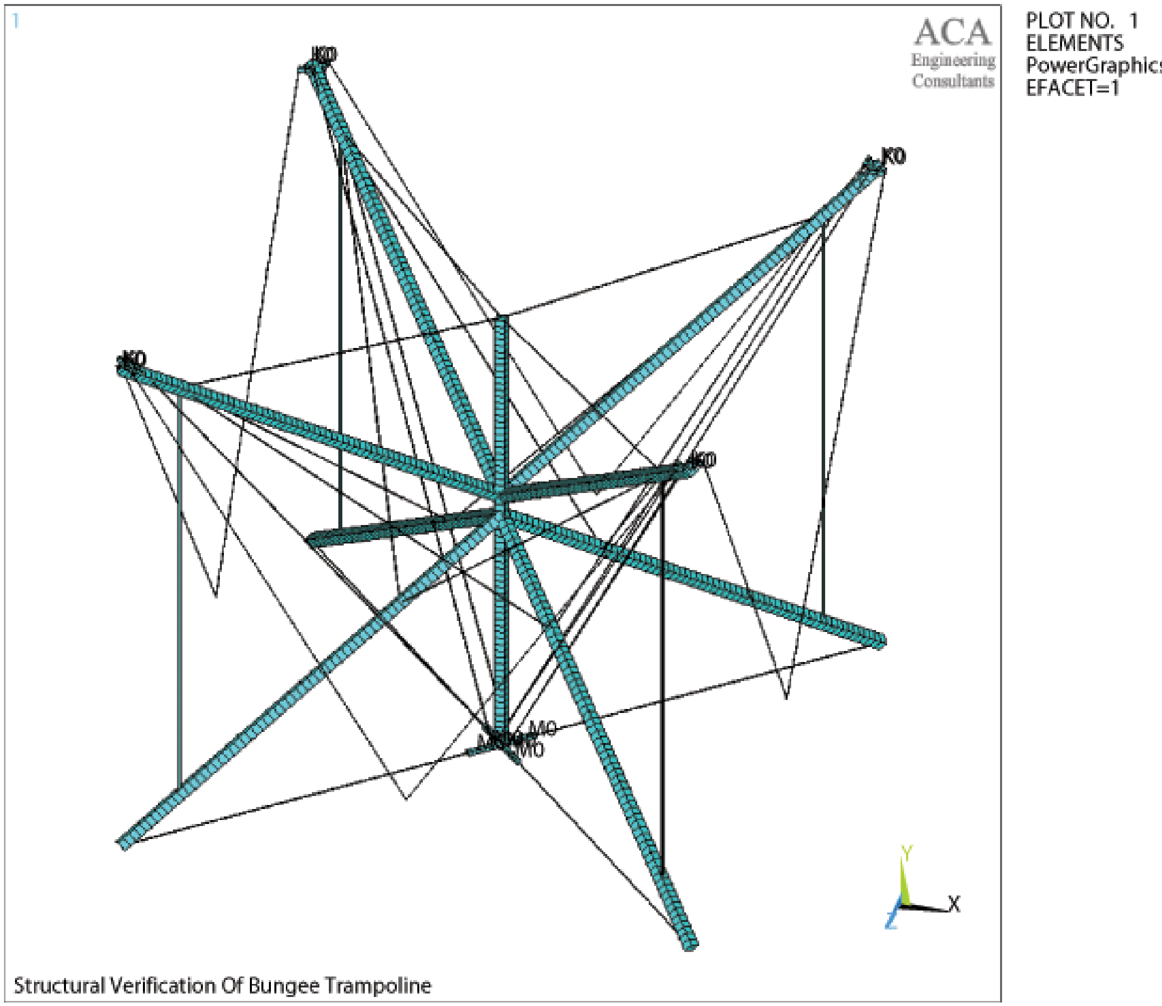


Figure 2.1 – Finite Element Model Of 4-Person Bungee Trampoline

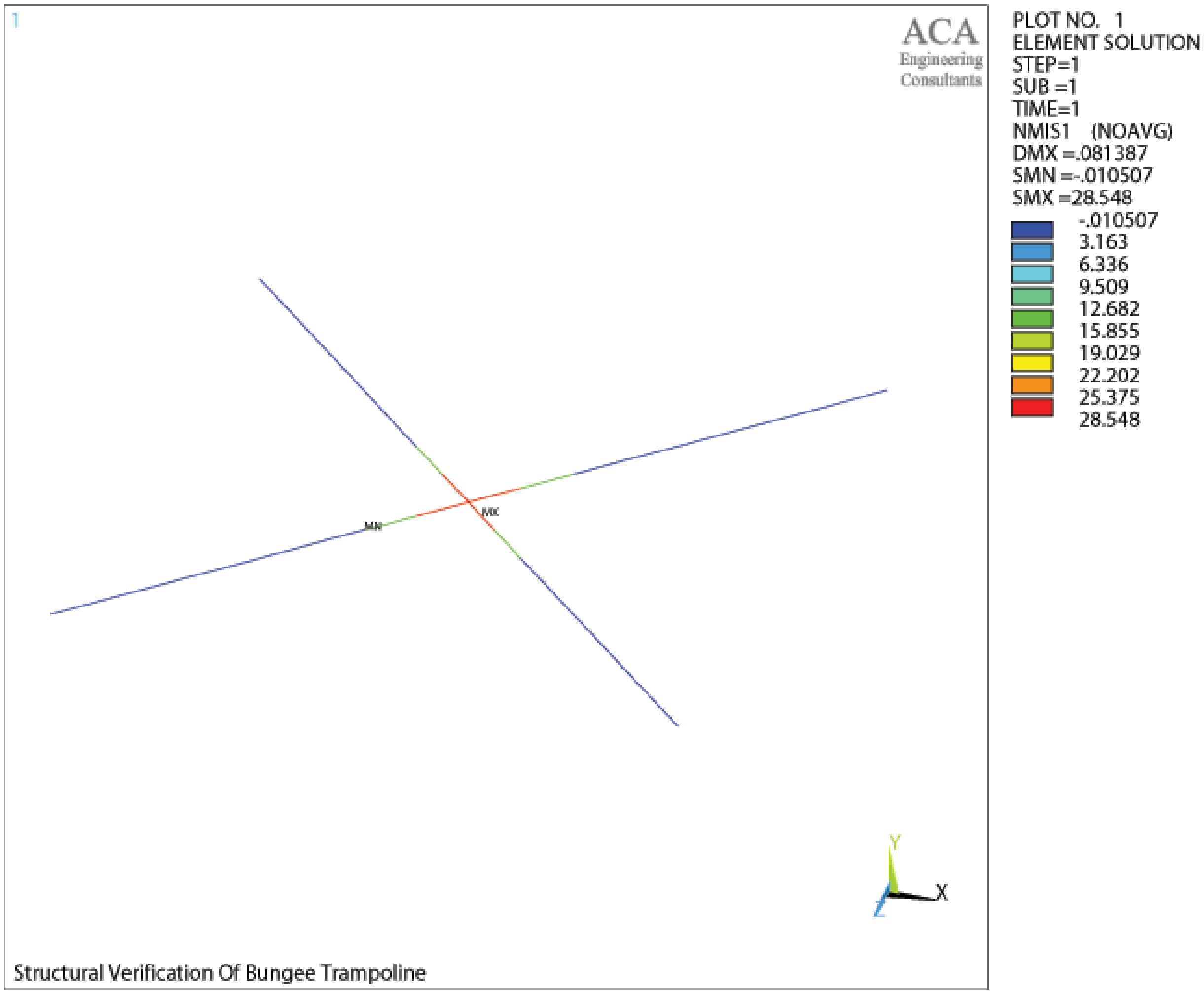


Figure 3.1 – Stresses In Steel Beam Structure, Due To Load Case 1

Maximum Stress = 28.5 N/mm^2

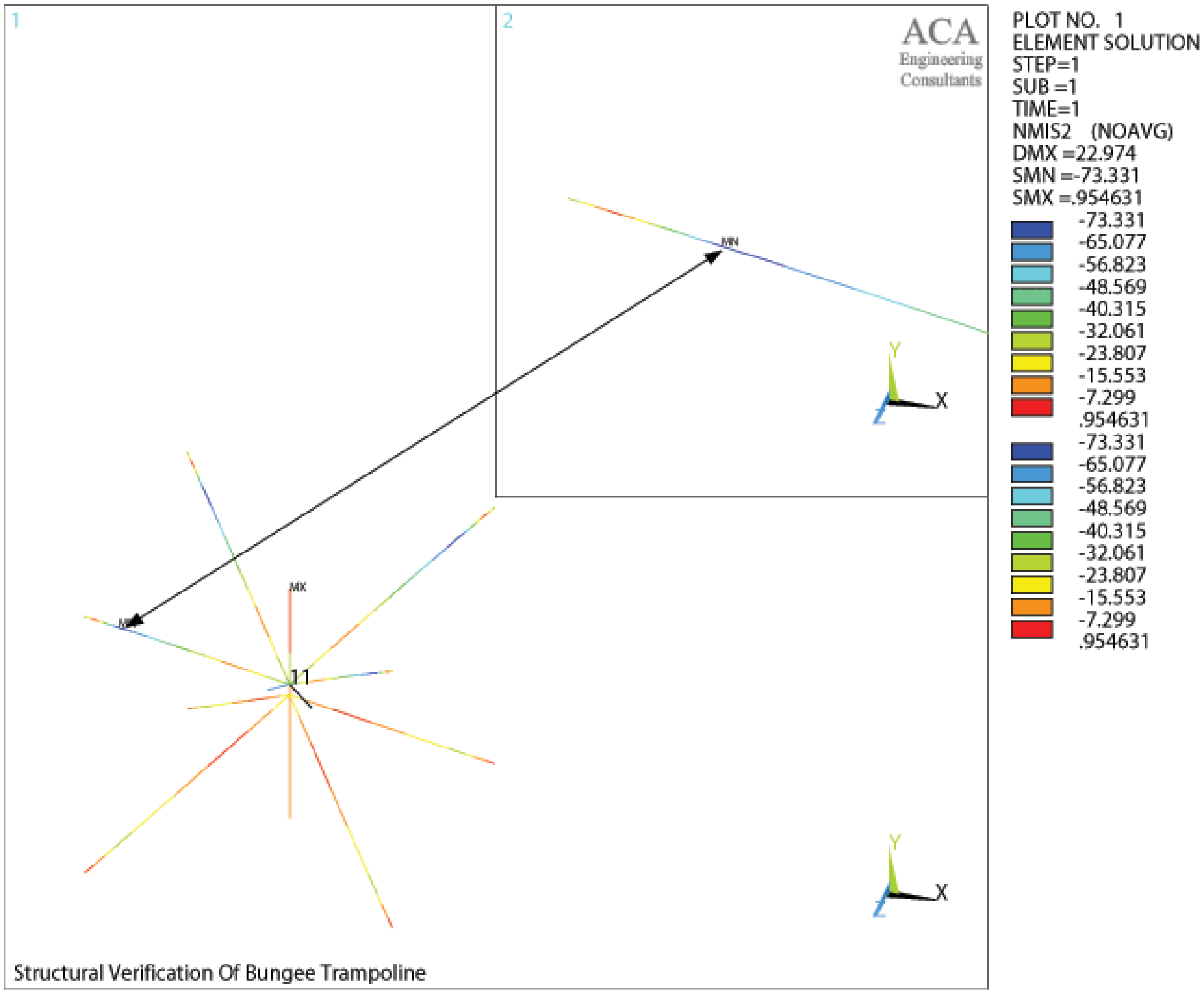


Figure 3.2 – Stresses In Aluminium Beam Structure, Due To Load Case 1

Maximum Stress = -73.3 N/mm^2

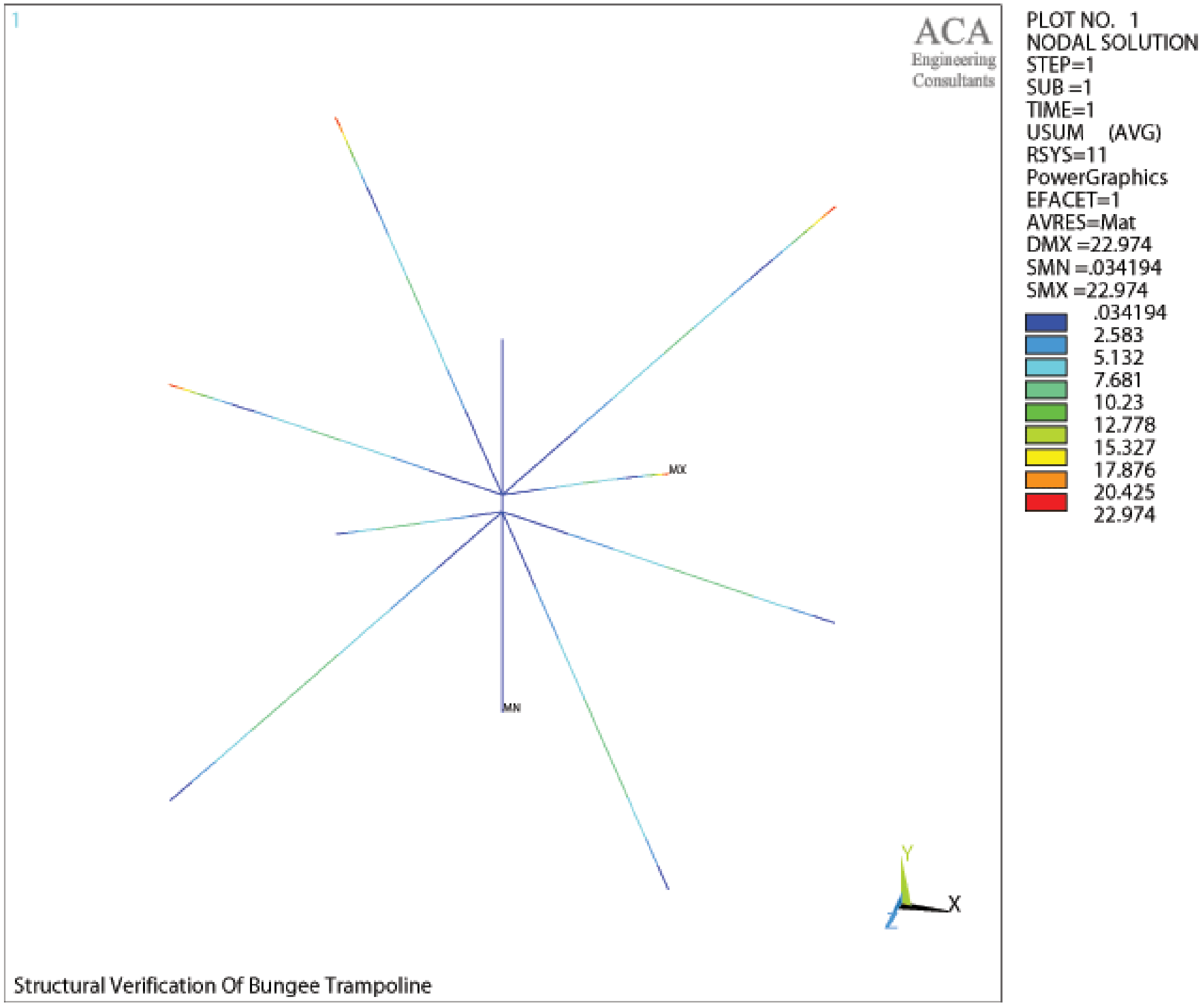


Figure 3.3 – Overall Deflexion In Structure, Due To Load Case 1

Maximum Deflexion = 22.97 mm

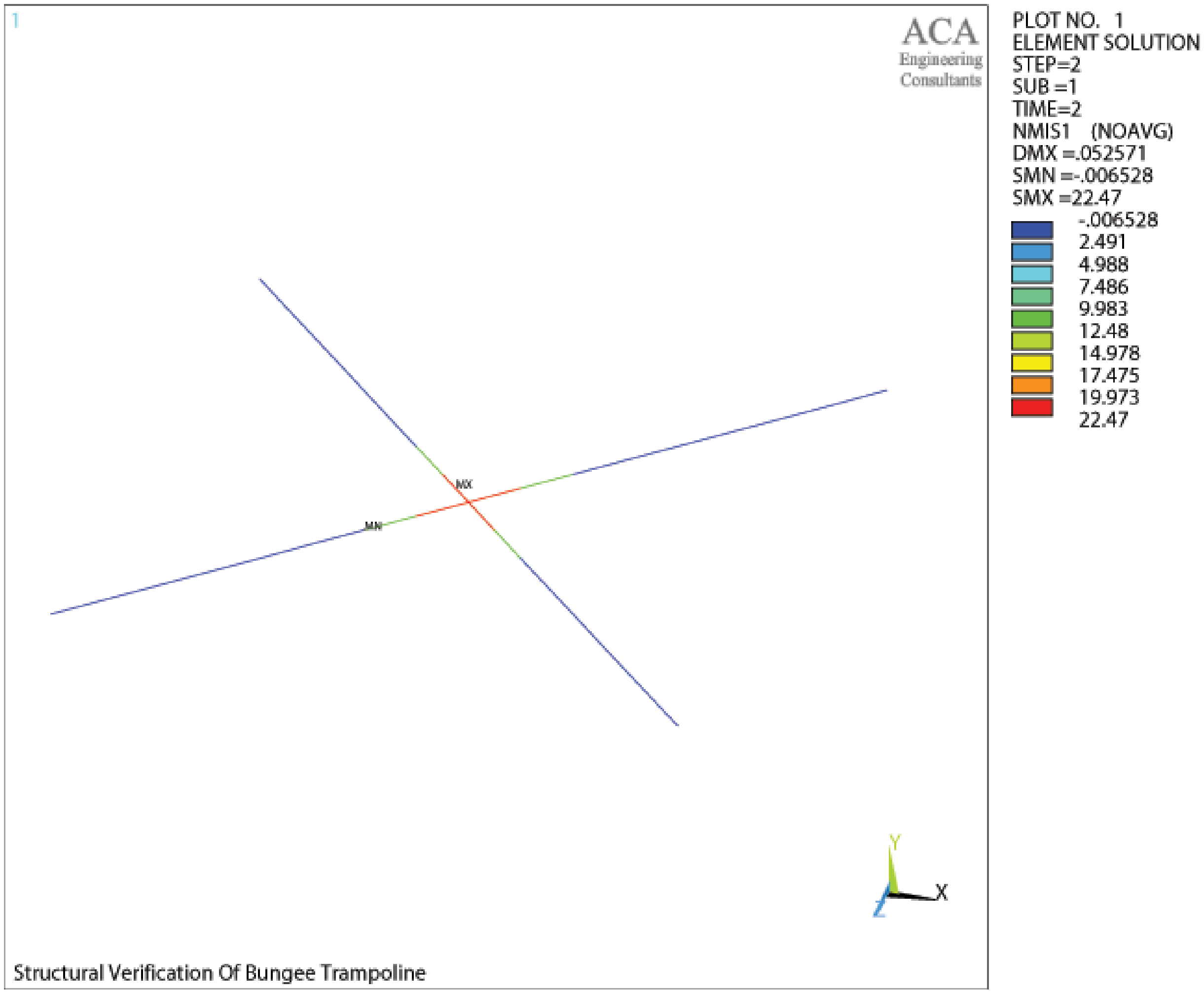


Figure 3.4 – Stresses In Steel Beam Structure, Due To Load Case 2

Maximum Stress = 22.5 N/mm^2

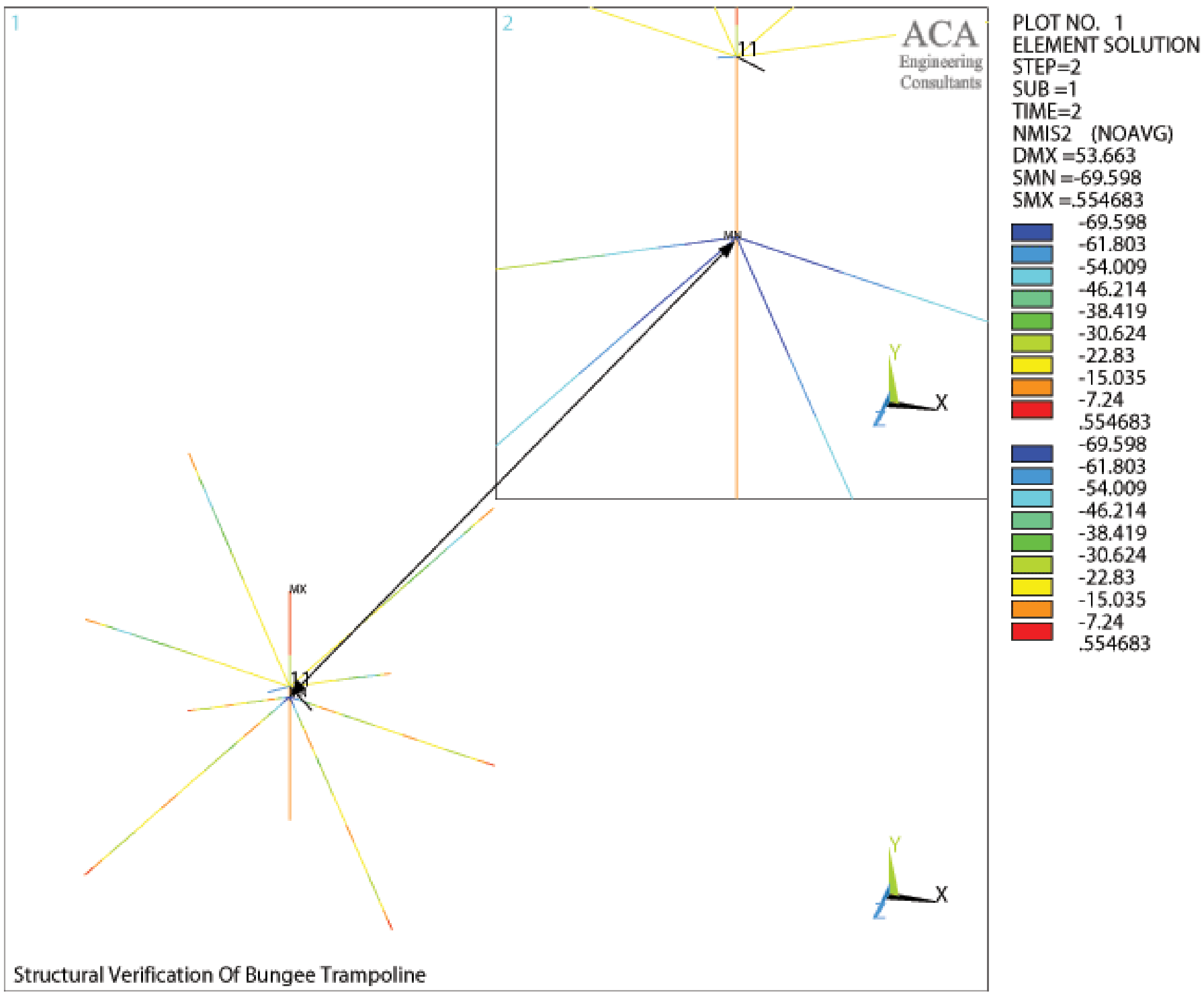


Figure 3.5 – Stresses In Aluminium Beam Structure, Due To Load Case 2

Maximum Stress = -69.6 N/mm^2

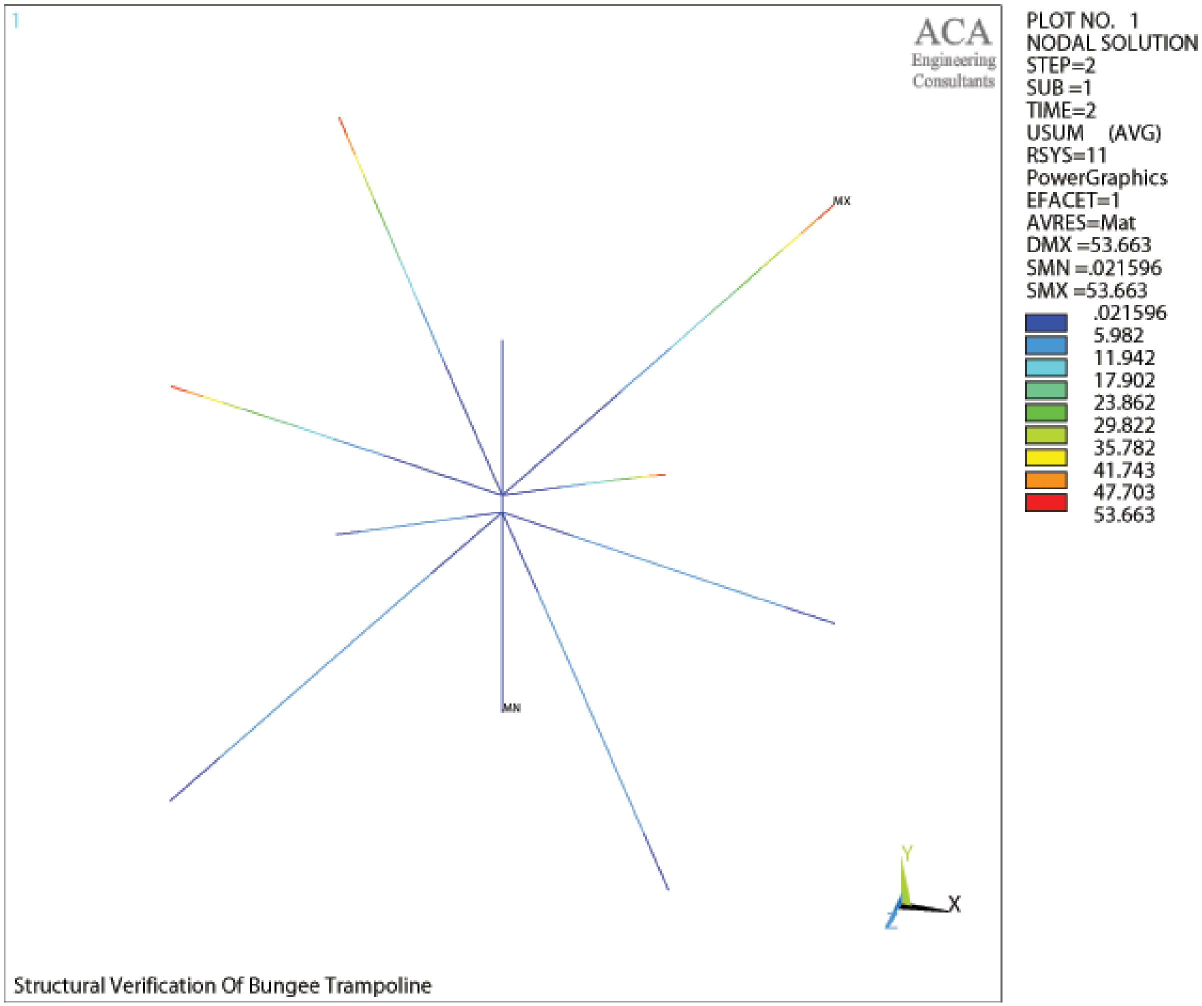


Figure 3.6 – Overall Deflexion In Structure, Due To Load Case 2

Maximum Deflexion = 53.66 mm

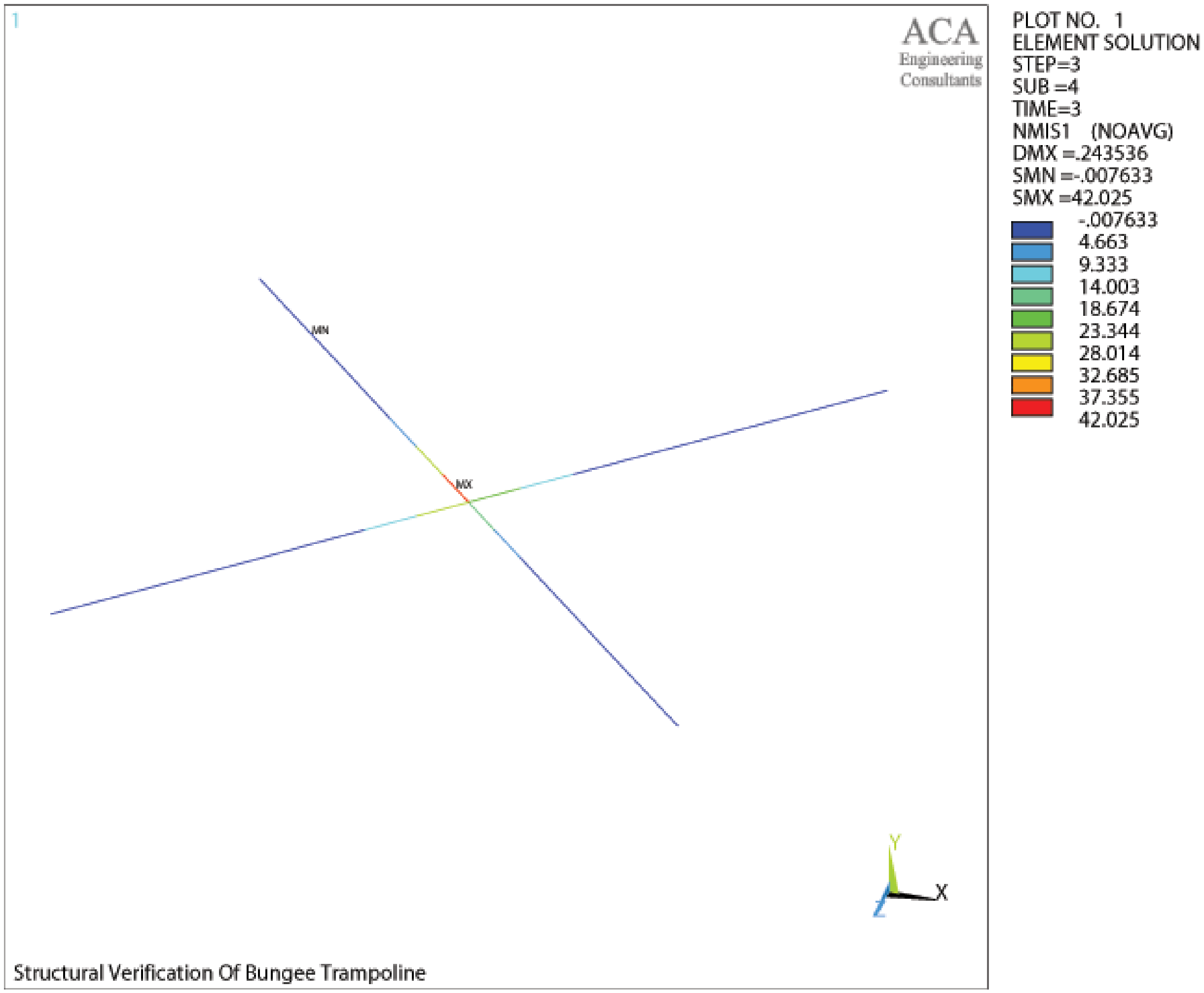


Figure 3.7 – Stresses In Steel Beam Structure, Due To Load Case 3

Maximum Stress = 42.0 N/mm^2

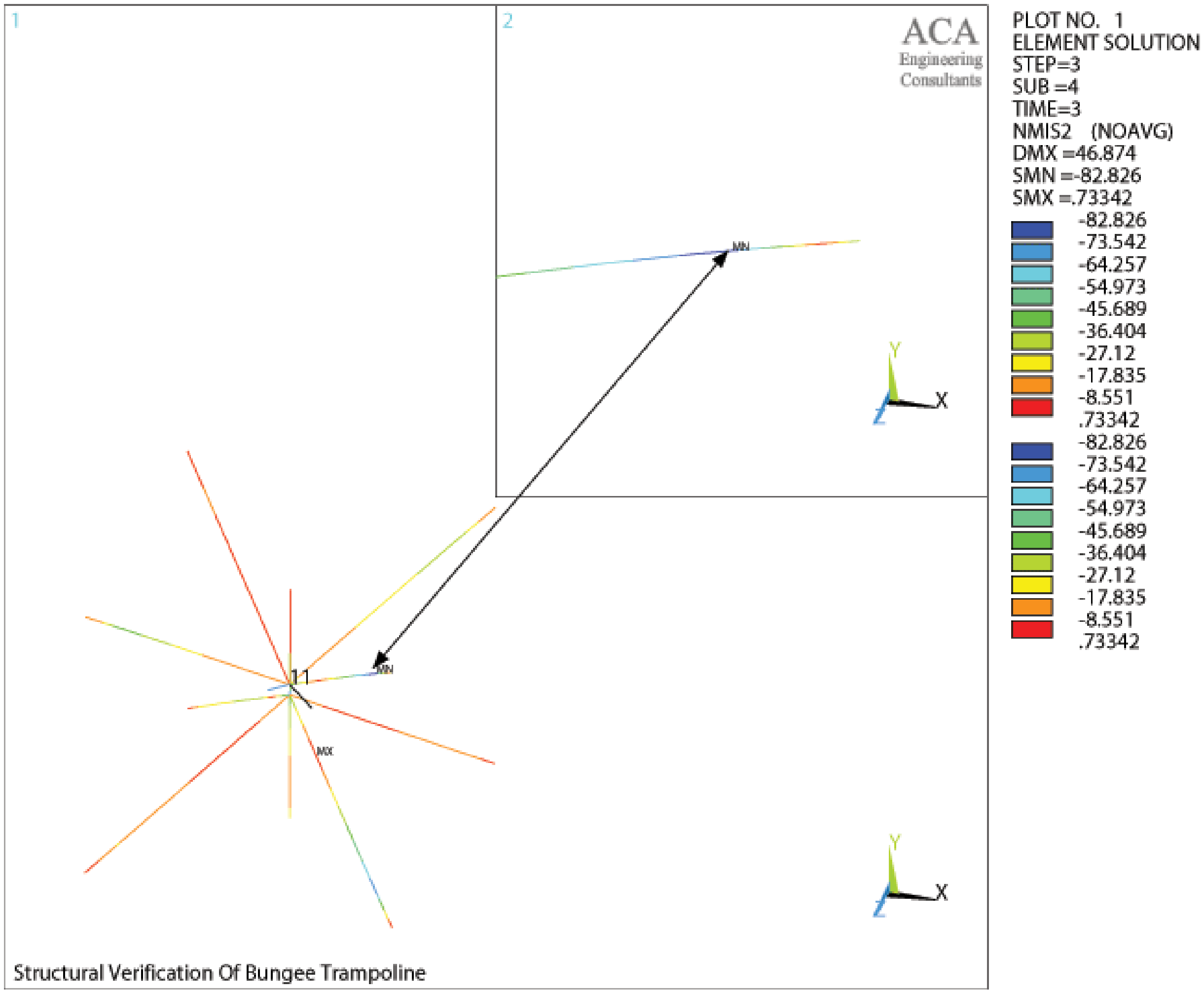


Figure 3.8 – Stresses In Aluminium Beam Structure, Due To Load Case 3

Maximum Stress = -82.8 N/mm^2

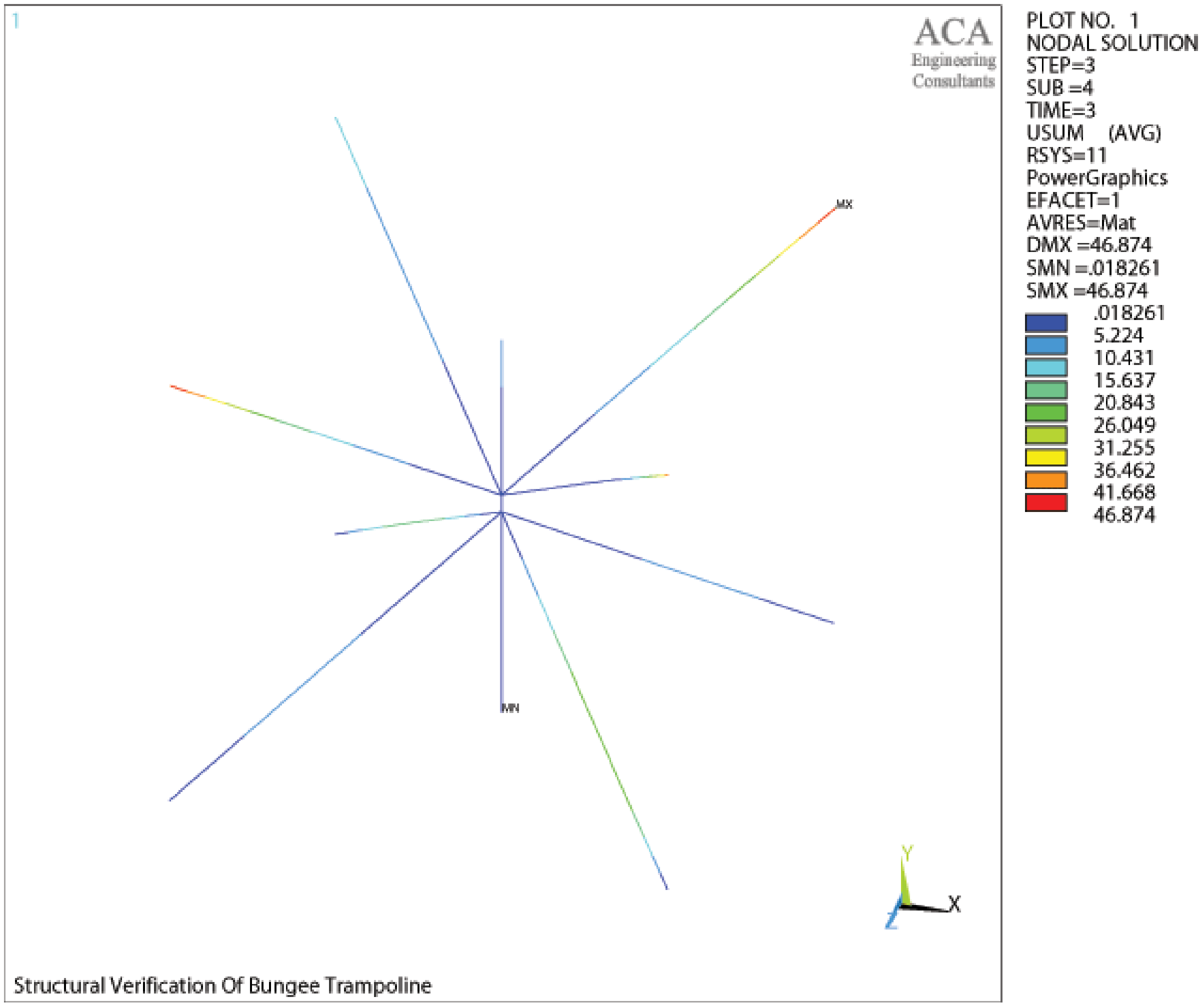


Figure 3.9 – Overall Deflexion In Structure, Due To Load Case 3

Maximum Deflexion = 46.87 mm

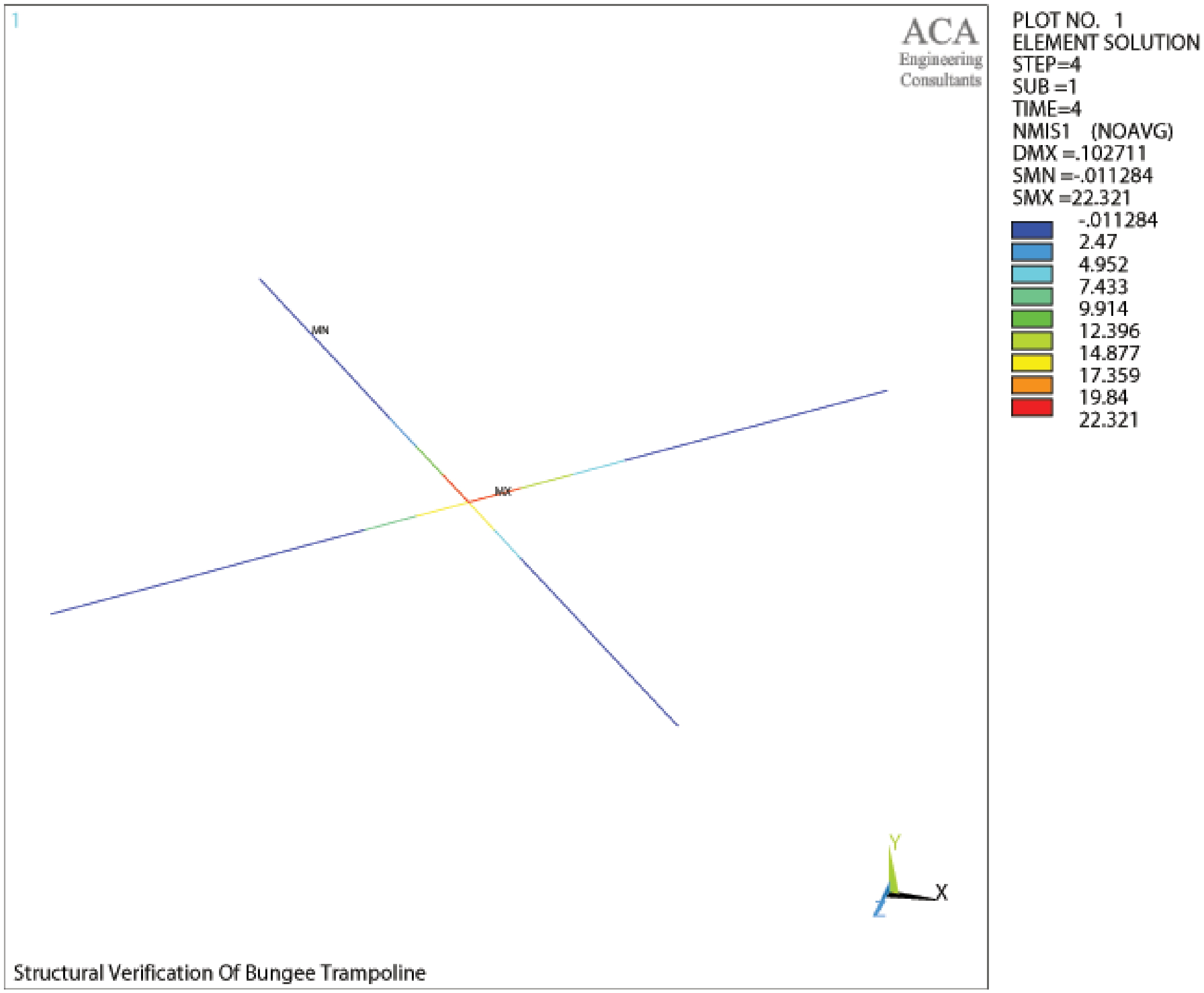


Figure 3.10 – Stresses In Steel Beam Structure, Due To Load Case 4

Maximum Stress = 22.3 N/mm^2

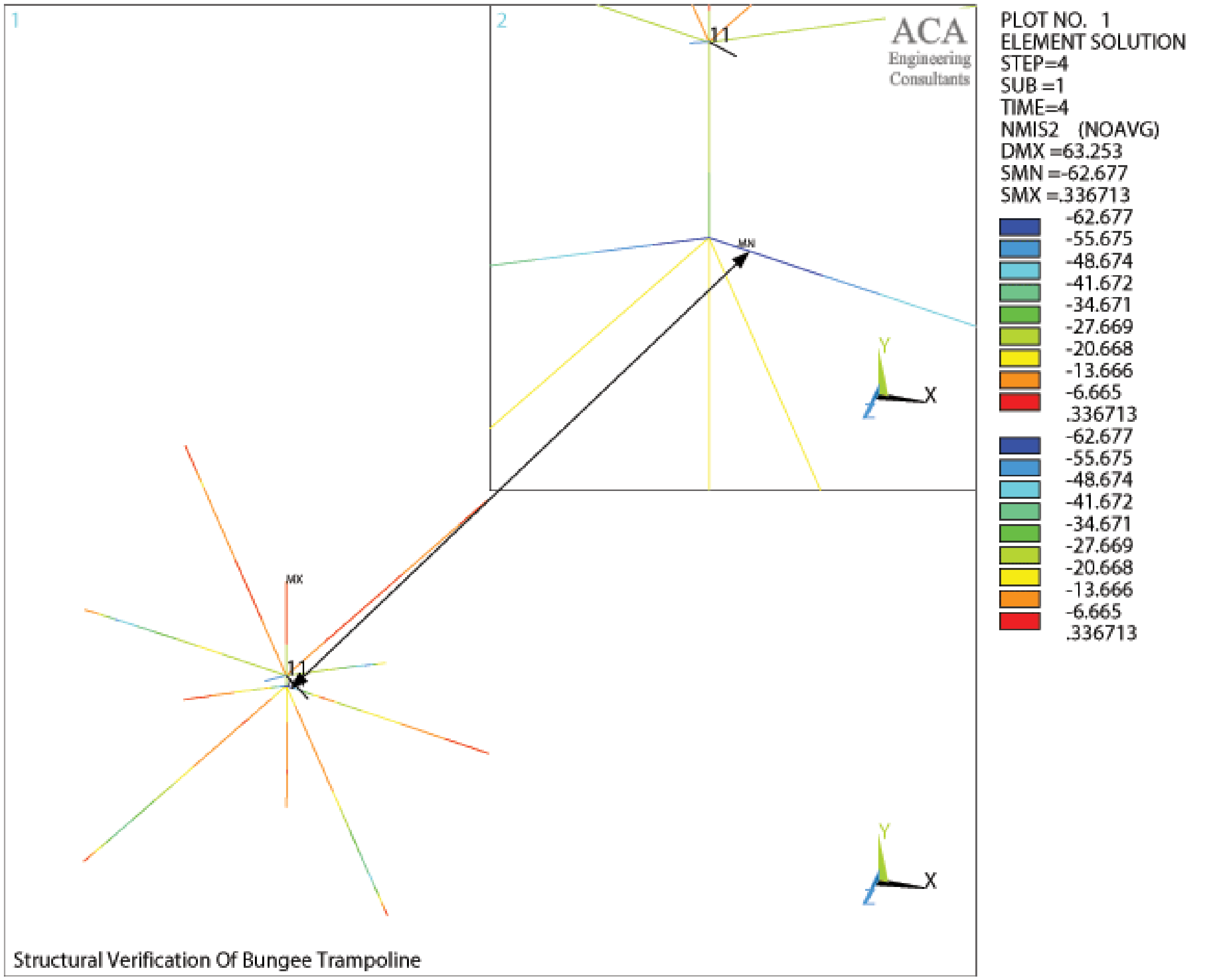


Figure 3.11 – Stresses In Aluminium Plate Structure, Due To Load Case 4

Maximum Stress = -62.7 N/mm^2

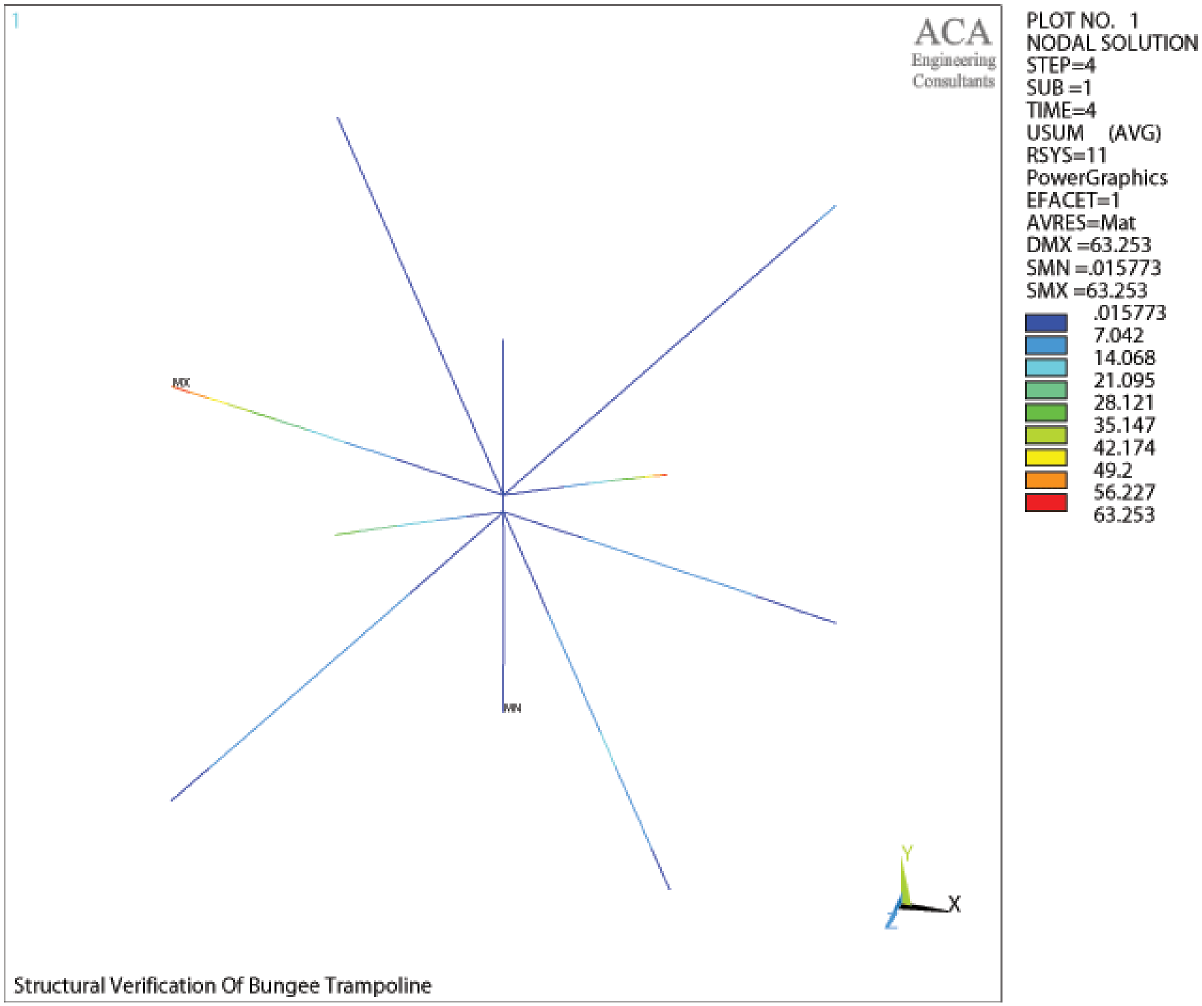


Figure 3.12 – Overall Deflexion In Structure, Due To Load Case 4

Overall Deflexion = 63.25 mm

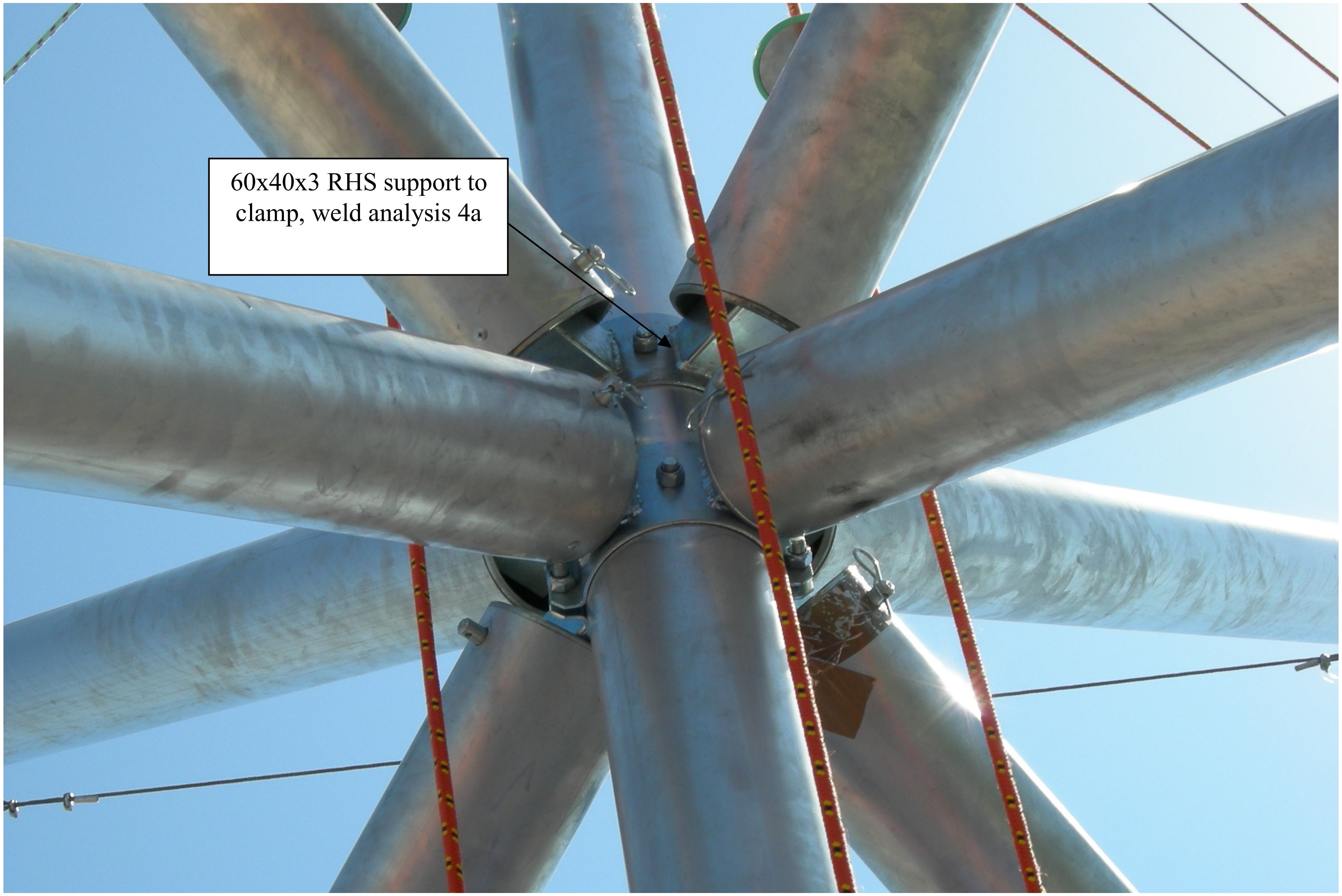


Figure 4.1 – Critical Welds

Appendix A – Certificate Of Conformity For Aluminium Sections

Trzcianka 10-02-26

Świadectwo kontroli 3.1 Nr 67/02/2010

sapa:

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	
-	240605-8 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	90082/ 5 / 6 / D 6600	6005A	32 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)	K912252HO6005A	0,62	0,19	0,14	0,15	0,56	0,001	0,011	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 / 190	T6	93	284	260	8,5

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% - Oberflache 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 A1 – Conformity Certificate For Aluminium Grade 6005A T5 Support Poles

Appendix B - Certificate Of Conformity For Carabineers

TEST WYTRZYMAŁOŚCIOWY / RESISTANCE TEST

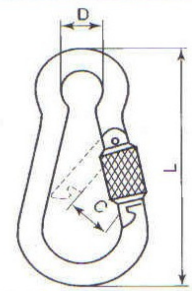
KARABIŃCZYK DO LIN Z ZABEZPIECZENIEM DIN 5299 D

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: *C15*

POKRYCIE / COVERING: *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

PIECZĄTKA DOSTAWCY
SUPPLIER'S STAMP

DATA / DATE
28-06-2006

Figure B1 – Conformity Certificate For 10mm Carabineers

Appendix C - Certificate Of Conformity For D – Shackles

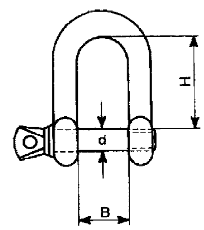
TEST WYTRZYMAŁOŚCIOWY / RESISTANCE TEST

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
NIP 869-[illegible] REGON [illegible]

PIECZĄTKA DOSTAWCY
SUPPLIER'S STAMP

DATA / DATE
28-06-2006

Figure C1 – Conformity Certificate For 8mm D – Shackles

Appendix D - Certificate Of Conformity For Eyebolts

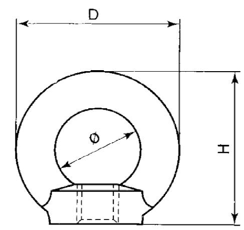
TEST WYTRZYMAŁOŚCIOWY / RESISTANCE TEST

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
NIP 869-10-46-648 REGON 850427217

PIECZĄTKA DOSTAWCY
SUPPLIER'S STAMP

DATA / DATE
28-06-2006

Figure D1 – Conformity Certificate For 12mm Eyebolt

Appendix E - Certificate Of Conformity For Steel Rope

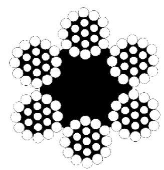
TEST WYTRZYMAŁOŚCIOWY / RESISTANCE TEST

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 Ø	**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	**POKRYCIE** / COVERING
C7 (Mn+Si)	*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
NIP 869-10-46-848 REGON 850427217

PIECZĄTKA DOSTAWCY
SUPPLIER'S STAMP

DATA / DATE
12-07-2006

Figure E1 – Conformity Certificate For 5mm Steel Rope

Appendix F - Certificate Of Conformity For Turnbuckle

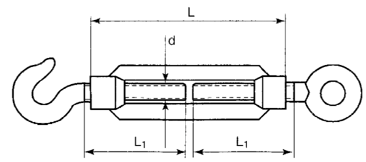
TEST WYTRZYMAŁOŚCIOWY / RESISTANCE TEST

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.: **46/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 869-10-46-048 REGON 850427217

PIECZĄTKA DOSTAWCY
SUPPLIER'S STAMP

DATA / DATE
28-06-2006

Figure F1 – Conformity Certificate For 12mm Turnbuckle

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 - Non 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 Ride may be unlevel	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 of 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 of 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 of 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 aluminum arms	Main arm could collapse Serious injury of 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 ne 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 ne 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 of 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 of 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 of 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 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

Appendix H – Non-Destructive Test Schedule

BUNGEE TRAMPOLINE RIDE NDT SCHEDULE FOR ROUTINE TESTING OF CRITICAL PARTS

Item	Description/Location	Test Method	Frequency Of Test
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
Connections	All carabineers, eyebolts, D-shackles, turnbuckles etc	Visual	Annually
Steel rope	All steel rope	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 not more than the maximum thickness to allow proper and adequate NDE

Advanced Computational Analysis
4a, Main Road, Gedling, Nottingham. NG4 3HP
Telephone 0115 9533931 e-mail:m.lacey@aca-consultants.co.uk

ACA
Engineering Consultants

Client :*Mr Jeffrey Johnson* Contract No : *S1722*

Date : *15th June 2010*

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

1) Loading

a) Self weight
Self weight loading was included automatically by the FE program, based on material densities and an acceleration due to gravity of 9.81 m/s^2
b) Passenger loading
Passenger mass = 90 kg
Equivalent acceleration = 2x9.81=19.62 m/s^2
Equivalent force = 19.62x90=1965.8N

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

 Sheet: 1 of: 6

Advanced Computational Analysis
4a, Main Road, Gedling, Nottingham. NG4 3HP.
Telephone 0115 9533931 e-mail:m.lacey@aca-consultants.co.uk

Contract No. *S1722*

ACA
Engineering Consultants

2 *Section Verification*

i Load Case 1

Steel Beam Section

$\sigma_B = 28.5\ N/mm^2 < 213\ N/mm^2$

$Factor\ of\ Safety\ on\ Permissible\ Strength = \frac{213}{28.5} = 7.4$ ***Satisfactory***

$Deflection = \frac{10}{5500} \leq \frac{1}{200}$ ***Satisfactory***

ii Load Case 2

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***

$Deflection = \frac{53}{6600} \geq \frac{1}{200}$ ***Satisfactory Based On Dynamic Deflexion***

iii Load Case 3

Steel Plate Section

$\sigma_{vm} = 42.0\ N/mm^2 < 213\ N/mm^2$

$Factor\ of\ Safety\ on\ Permissible\ Strength = \frac{213}{42.0} = 5$ ***Satisfactory***

$Deflection = \frac{46}{6600} \geq \frac{1}{200}$ ***Satisfactory Based On Dynamic Deflexion***

iv Load Case 4

Steel Plate Section

$\sigma_{vm} = 22.3\ N/mm^2 < 213\ N/mm^2$

$Factor\ of\ Safety\ on\ Permissible\ Strength = \frac{213}{22.3} = 9.5$ ***Satisfactory***

$Deflection = \frac{63}{6600} \geq \frac{1}{200}$ ***Satisfactory Based On Dynamic Deflexion***

Prepared By: R. Anderson

Checked By: Dr. M. Lacey

Advanced Computational Analysis
4a, Main Road, Gedling, Nottingham. NG4 3HP.
Telephone 0115 9533931 e-mail:m.lacey@aca-consultants.co.uk

Contract No. *S1722*

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3 *Alluminium section verification* *Section Capacities*

i 139.7*x*2.5 *CHS grade* 6005*A T5, central column, load case* 1

$Factored\ Axial\ Force\ P = F_A\,\gamma_{f1}\,\gamma_{f2} = 15185x1.33x1\ \ x10^{3} = 20.2\ kN$

$Resultant\ Moment\quad M = M_{yy}^2 + M_{zz}^2 = 0.0001^2 + 0.0001^2 = 0.0001\ Nmm\ Negligible$

$Slenderness\ parameter\ for\ buckling\ \lambda = \frac{kl}{r} = 1.25\ x\ \frac{300}{48.6} = 7.7$

$Buckling\ Stress\ p_s = 240\ N/mm^2$

$Factored\ axial\ resistance\ to\ buckling\ P_R = \frac{p_s A}{\gamma_m} = 240x\frac{1014}{1.2}\ x10^{3} = 202.8\ kN$

$Factored\ moment\ of\ resistance\ M_{RS} = \frac{p_1 S}{\gamma_m} = 240x\frac{43425}{1.2}\ x10^{6} = 8.68\ kNm$

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

$$= \frac{20.2}{202.8} + \frac{20.2}{2x202.8x8.68} = 0.1 \le 1\ \textbf{\textit{Satisfactory}}$$

ii 139.7*x*2.5 *CHS grade* 6005*A T5, main arm, load case* 3

$Factored\ Axial\ Force\ P = F_A\,\gamma_{f1}\,\gamma_{f2} = 6396x1.33x1\ \ x10^{3} = 8.5\ kN$

$Resultant\ Moment\quad M = M_{yy}^2 + M_{zz}^2 = 0.917^2 + 1.717^2 = 1.94\ kNm$

$Factored\ Moment\ M = M\gamma_{f1}\,\gamma_{f2} = 1.94x1.33x1 = 2.58\ kNm$

$Slenderness\ parameter\ \lambda = \frac{kl}{r} = 1.25\ x\ \frac{6607}{48} = 172$

$Buckling\ Stress\ p_s = 21.6\ N/mm^2$

$Factored\ axial\ resistance\ to\ buckling\ P_R = \frac{p_s A}{\gamma_m} = 21.6x\frac{1014}{1.2}\ x10^{3} = 18.3\ kN$

$Factored\ moment\ of\ resistance\ M_{RS} = \frac{p_1 S}{\gamma_m} = 240x\frac{43425}{1.2}\ x10^{6} = 8.68\ kNm$

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

$$= \frac{8.5}{18.25} + \frac{2.58}{8.68} + \frac{8.5x2.58}{2x18.25x8.68} = 0.83 \le 1\ \textbf{\textit{Satisfactory}}$$

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4 a Weld Analysis continued

Weld connecting 60x40x3 RHS support to clamp, detailed in figure 4.1, due to load case 3 Assuming 3mm continuous fillet weld

$F_x = 5627\ N$

$SF_y = 3073\ N$

$SF_z = 0.02\ N$

$SM_{xx} = 10\ Nmm$

$M_{yy} = 6\ Nmm$

$M_{zz} = 880130\ Nmm$

Force on weld due to tension

$$F_{maxM_{yy}} = \frac{M_{yy}}{bd + 2\frac{b^2}{3}} = \frac{6}{40x60 + 2\frac{60^2}{3}} = 0.005\ N/mm\ Negligible$$

$$F_{maxM_{zz}} = \frac{M_{zz}}{bd + 2\frac{d^2}{3}} = \frac{880130}{40x60 + 2\frac{40^2}{3}} = 254\ N/mm$$

$$F_{maxF_y} = \frac{F_y}{2\ b + d} = \frac{5627}{2\ 60 + 40} = 28\ N/mm$$

$F_T = 1254 \quad 28 = 226\ N/mm$

Force on weld due to shear

$$SF_{Fy} = \frac{SF_y}{2\ b + d} = \frac{3073}{2\ 60 + 40} = 15\ N/mm$$

$$SF_{Fz} = \frac{SF_z}{2\ b + d} = \frac{0.02}{2\ 60 + 40} = 0.0001\ N/mm\ Negligible$$

$$SF_{M_x} = \frac{6\,x\,M_x\,x\,r}{3bd\ \ b + d\ + 2\ \ d^3 + b^3} = \frac{6\,x\,10\,x\,36}{3\,x\,40\,x\,60\ \ 40 + 60\ + 2\ \ 60^3 + 40^3} = 0.002\ N/mm\ Negligible$$

$SF_T = SF_{Fy} = 15\ N/mm$

Resultant force on weld

$$F_r = \ F_T^2 + SF_T^2 = \ 226^2 + 15^2 = 226\ N/mm$$

Resultant stress on weld

$$\sigma_{max} = \frac{F_r}{3}\ x\ \ 2 = \frac{226}{3}\ x\ \ 2 = 106.5\ N/mm^2 \leq 125\ N/mm^2$$ ***Satisfactory***

4a, Main Road, Gedling, Nottingham. NG4 3HP.
Telephone 0115 9533931 e-mail:m.lacey@aca-consultants.co.uk

5 *Fatigue analysis*

Maximum change in weld resultant stesses

Weld identified in 5*a*

$\sigma_{R_1} = 106.5 N/mm^2$

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

$\Delta\sigma_p = 106.5\ N/mm^2$

Note: *The fatigue life of the aluminium poles have not been considered as the stress range goes from near* 0 *to compressive Failure through fatigue is more likely to occur at the welded steel joints which experience tensile loads*

4a, Main Road, Gedling, Nottingham. NG4 3HP.
Telephone 0115 9533931 e-mail:m.lacey@aca-consultants.co.uk

6 *Fatigue analysis*

$\Delta\sigma_p = 106.5\, N/mm^2$ *for* 90 *kg passenger load*

$\Delta\sigma_p = 106.5x\, \frac{3}{4} = 79.9\, N/mm^2$ *for* 67.5*kg passenger load*

$\Delta\sigma_p = 106.5x\, \frac{1}{2} = 53.3\, N/mm^2$ *for* 45*kg passenger load*

*For weld class F*2

with $\Delta\sigma = 106.5\, N/mm^2$, *predicted fatigue life* $= 3.57\, x10^5$ *cycles*

with $\Delta\sigma = 79.9\, N/mm^2$, *predicted fatigue life* $= 8.45\, x10^5$ *cycles*

with $\Delta\sigma = 53.3\, N/mm^2$, *predicted fatigue life* $= 28.5\, x10^5$ *cycles*

number of cycles per year with 90*kg passenger loading or balanced* $= 0.10x720000 = 72000$

number of cycles per year with 67.5*kg passenger loading* $= 0.20x720000 = 144000$

number of cycles per year with 42*kg passenger loading* $= 0.7x720000 = 504000$

from Miner s summation $\Sigma = \frac{0.72}{3.57} + \frac{1.44}{8.45} + \frac{5.04}{28.5} = 0.55$

predicted weld fatigue life $= \frac{1}{0.55} = 1.8$ *years Satisfactory*

Note:

i Above analysis based on an operational life of 30 *cycles* / min, 2*mins* / *ride,* 10 *rides* / *hour,* 5 *hours* / *day*
240 *days* / *year* = 720000 *cycles*

ii Assumed loading spectrum is 70% *of life half loaded* 42*kg participant* , 20% *of life with*
67.5 *kg particpant of load and* 10% *of life with* 90 *kg particpant Hence analysis based on*
*Miner s summation using BS*7608:1993

Prepared By: R. Anderson

Checked By: Dr. M. Lacey