MARSHALL-TUFFLEX STILLAGE PROJECT
DESIGN REPORT

DATE: 26/02/2020

COURSE / SECTION: BTEC HIGHER NATIONAL CERTIFICATE / DIPLOMA (ENGINEERING)

INSTRUCTOR: JULIAN KUPPER

TEAM MEMBERS: DANIEL MILLS

EXECUTIVE SUMMARY, DESIGN PROBLEM AND OBJECTIVES

Project

The aim of this project was to develop an alternative stillage design for UK engineering and manufacturing company Marshall-Tufflex, to be used for storage and transportation of their extruded form products. The new design was required to be cost-efficiently produced, easily and safely stackable, flat-packable, provide adequate mechanical protection for the transported products, easily handled, stored and transported, and finally trackable. These requirements were extracted from the Customer Design Brief and detailed as part of a Product Design Specification.

One of the primary problems that the customer was experiencing was regular purloining of their stillages. Due to using a fairly common design, their stillages unfortunately look like every other stillage so aren't very easy to distinguish from others, hence the requirement for the new design to be trackable and easy to identify.

An existing stillage design was provided in the form of a Technical Drawing, which was used as reference for the appropriate size and type of stillage. Two alternative designs were produced, tested and then evaluated against the specification, whereby the most appropriate one was proposed and a conclusion provided.

Proposed Design

This report presents the design of a Mild Steel stillage. This design makes use of 8 individual Stainless Steel folding corner brackets that provide flat-packability along with good structural rigidity. In this design, the overall objectives were met, as detailed above. The design was aimed to be stackable in both its open form, and flat-packable form (see figure 1.1 and 1.2) to ensure space in both storage and transportation was being efficiently utilised.

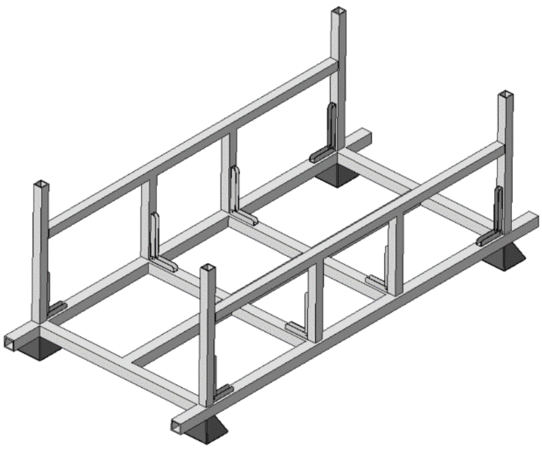


Figure 1.1

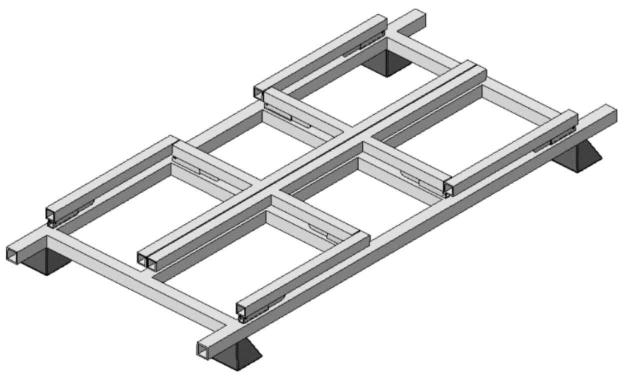


Figure 1.2

CONTENTS

DETAILED DESIGN DOCUMENTATION

Proposed Design

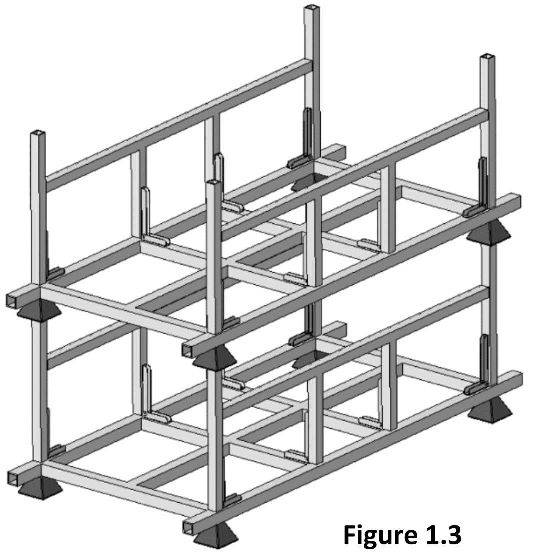


Figure 1.3

This stillage was designed to be very easily transported and easily flat-packable. It is constructed using Mild Steel extruded box section welded together, along with Stainless Steel folding corner brackets and Cast Steel feet.

The main base frame is a singular item, made up of 60mm x 60mm x 5mm (wall thickness) Mild Steel box sections that together form a rigid and robust frame to support the transported items from underneath.

The folding gate pieces secured to the basic via the Stainless Steel corner brackets, are constructed by welding 50mm x 50mm x 5mm (wall thickness) Mild Steel extruded box section. The two gates (when in the open position) sit flush between the upward corner struts that are also 50mm x 50mm x 5mm (wall thickness). The design can be folded down as see in figure 1.4.

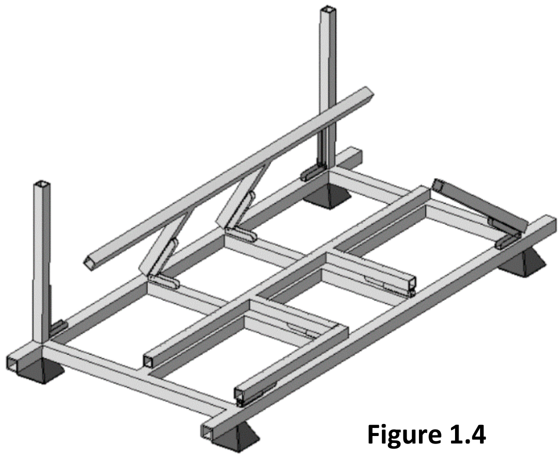


Figure 1.4

Mild Steel Box Section

Mild Steel box section was used due to its availability, low costs and desirable physical properties, including high toughness (impact force resistance), good rigidity and robustness and a relatively good strength to weight ratio (although not the best when compared to higher quality, more expensive materials such as Carbon Fibre). These box sections would be ordered from suppliers and cut to size.

Folding Corner Brackets

These would be bought in bulk during the production of this stillage.

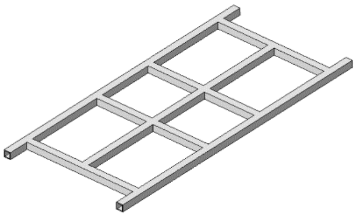
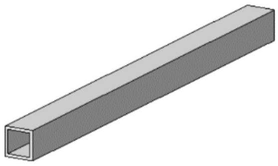
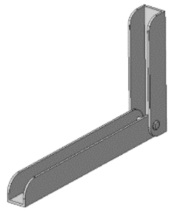
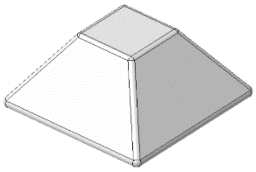
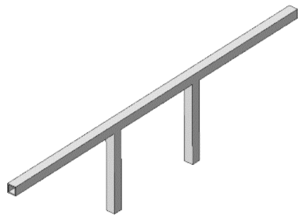
Figure 1.5

Adjustable Folding Bracket 400mm x 272mm - 2 Pack

"Heavy duty folding brackets with 3 x adjustable positions and push-button lock / release mechanism. Zinc-plated. Can be used in areas with limited space. 200kg load per bracket"

The benefit to using these pre-manufactured parts is they are Zinc plated which provides good wear and corrosion resistance, something that is important to think about as the stillages may be exposed to the elements over periods of time, therefore will be prone to rust and corrode, which will affect the stillages performance.

Stillage Design Breakdown

		
Main Frame Mild Steel Box Section 60mm x 60mm x 5mm Wall Thickness, welded	**Upwards Support Struts** Mild Steel Box Section 50mm x 50mm x 5mm Wall Thickness, fixed to Corner Brackets	**Folding Corner Brackets** Stainless Steel folding corner bracket 0 – 90 degree movement, clicks in place
		
Foot Piece Aluminium/Steel Block Piece interfaces with Upward Support Struts to allow stacking when at open position, provides space under base for forklift arms, welded to base frame	**Folding T-shaped Gates** Mild Steel Box Section 50mm x 50mm x 5mm Wall Thickness, fixed to Corner Brackets. Provides better damage protection and encloses items more.	

Stacking the Stillages

The stillage was designed to be stackable in both forms, as already explained in the Executive Summary. Figures 1.6 and 1.7 show how the stillages stack. A limit of two high when open and 8 high when closed was set for safety reasons.

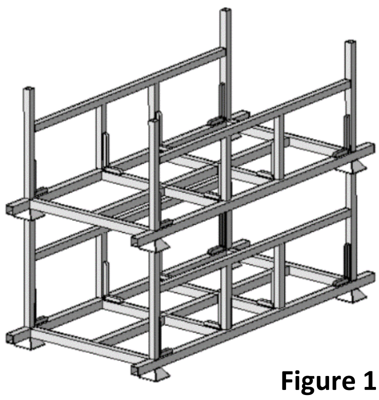


Figure 1.6

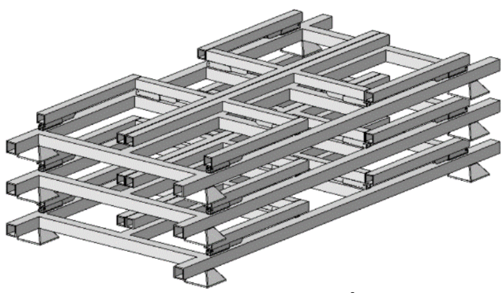


Figure 1.7

Activity Based Costing (ABC)

PROJECT ACTIVITIES	TIME (Hours)	COSTS			TOTAL COSTS
		Labour	Materials and Consumables	Overheads	
Project Planning	5	£20.00 per hour x 5 hours = **£100.00**	-	**£0.50**	**£100.50**
Research	5	£12.00 per hour x 5 hours = **£60.00**	-	**£0.50**	**£60.50**
Design	25	£12.00 per hour x 25 hours = **£300.00**	-	**£2.50**	**£302.50**
Analysis	10	£12.00 per hour x 10 hours = **£120.00**	-	**£1.00**	**£121.00**
Documentation	10	£12.00 per hour x 10 hours = **£120.00**	-	**£0.50**	**£120.50**
Ordering and Storage	2	£10.00 per hour x 2 hours = **£20.00**	Bill of Materials = **£614.38**	**£0.20**	**£634.58**
Preperation	3	£10.00 per hour x 3 hours = **£30.00**	-	-	**£30.00**
Manufacture and Assembly	20	£10.00 per hour x 3 hours = **£30.00**	Welding Materials = **£20.00**	**£5.00**	**£55.00**
Quality Assurance	2	£10.00 per hour x 3 hours = **£30.00**	-	-	**£30.00**
Testing	5	£15.00 per hour x 5 hours = **£75.00**	-	-	**£75.00**
Delivery	1	£15.00 per hour x 1 hour = **£15.00**	Transport Costs = **£5.00**	-	**£20.00**
		Total = £885.00	**Total = £639.38**	**Total = £10.20**	**£1,549.58**

From the Activity Based Costing (ABC) performed above, it shows the total costs for each individual project activity (listed in the left column) which are divided between labour costs (paying the workforce), materials and consumable costs (cost of ordering materials including the additional welding materials and cost of transporting materials in the form of fuel costs) and finally overhead costs which are the cost of running the facilities including lighting, water and machinery.

From performing this analysis, we were able to identify that the total cost of producing a single “one-off” stillage with all the included costs came to a total of **£1549.58.** When the start-up costs are removed (costs associated with activities from Project Planning to Documentation) the total cost is then **£844.58** which equates to the total cost of producing one single stillage / unit once production has been setup.

To achieve a 20% from each stillage, the unit selling price would be **£844.58 x 1.20 = £1013.50**

Cutting Costs of Production

The cost of producing a single stillage I believe could be considerably reduced by further refinement of the design to streamline, cutting material where possible, and also further research to identify more affordable material suppliers.

Due to the timescales of this project, the total unit costs have ended up being higher than anticipated.

TESTS AND RESULTS

As part of the testing of the stillage design, I performed representative stress and displacement analysis tests to simulate the performance of the stillage under particular specified load cases.

I gathered results on how the structure reacts top these dynamics in terms of Maximum Induced Stress and Maximum Induced Displacement. The results gathered from performing FEA (Finite Element Analysis) allow us to predict how the stillage will perform in real life when in function, and helps to identify areas of improvement such as structural weakness.

During the analyses, it is assumed there is infinite friction between the surfaces of the feet contacting the floor and the floor itself, allowing for absolutely no movement in the horizontal axes. The stillage feet have been locked from sliding in the X and Z axes, as shown in the figure 1.8.

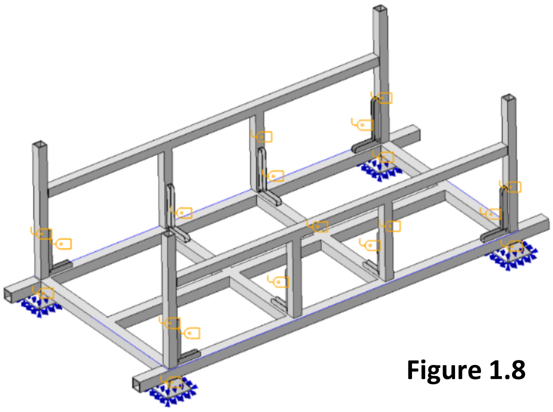


Figure 1.8

Analysis 1: After applying a load of 1000kg to the required surface region on the model, the results showed a Maximum Induced Stress of 14.3MPa and a Maximum Induced Displacement of 0.98mm. These figures have shown that the structure is much more capable of greater loads, given the Yield Strength of Steel is 400MPa and 0.98mm Maximum Displacement is negligible over such a distance.

Analysis 2: A second analysis, with an applied load of 2000kg showed a Maximum Induced Stress of 28MPa and a Maximum Induced Displacement of 1.98mm which is still well within the structures safety margins. The figure below clearly illustrates the areas of maximum displacement (red) and minimum displacement (blue). It is expected for the maximum to be in the centre as this is where the least amount of support as provided to the box sections running across the stillage.

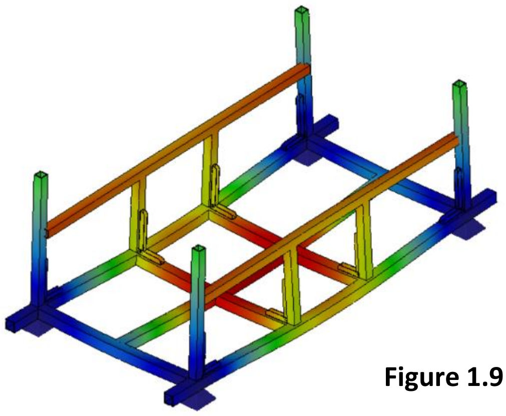


Figure 1.9

Analysis 3: A further third analysis on this stillage, with a combined load of 2179kg to the top surfaces of the upright struts and the original surface region (simulating a 2000kg + mass of stacked stillage), showed a Maximum Induced Stress of 43MPa and a Maximum Induced Displacement of 2.10mm which were exceptionally good for the amount of material that could be stored in these stillages.

Analysis 4: One final test applying 3000kg to the top and bottom stacked stillages was performed to identify if the results were acceptable in the worst case scenario. The results showed a Maximum Induced Stress of 50MPa with a Maximum Induced Displacement of 3mm. With these results I can say I have calculated a factor of safety 1.5.

Analyses Conclusions:

- Maximum Load of Stillage = 2000kg (3000kg with 1.5 Safety Factor)
- Stillages should be stacked 2 high

BILL OF MATERIALS

Unit Costing Calculations *(1 Unit = 1 Stillage)*

Derived from CAD Model Properties:

Total Mass w/ Aluminium Feet = 168kg
Total Mass w/ Mild Steel Feet = 179kg
Change in Mass = 11kg > 5% (Negligible)

Calculations – Main Frame:

Total Derived Volume of "Main Frame" = 12 x 10^6 mm^3
Cross Sectional Area of Box Section = (60 x 60) – (50 x 50) = 1100 mm^2

$$\frac{Volume}{Cross\ Sectional\ Area} = Length$$

$$\frac{12 \times 10^6}{1100} = 10909.09\ mm$$

Max Length of Box Section = 6000 mm
Required Box Section for 1 x Unit = 5500 x 2 = 11000 mm
Cost of 1 x 5500 mm Box Section = £143.45 inc VAT
Cost of 2 x 5500 mm Box Section = £143.45 x 2 = £286.90
Total Estimated Cost (Main Frame) Per Unit = £286.90

Calculations – Upwards Support Struts

Total Derived Volume of 1 x "Support Strut" = 0.69 x 10^6 mm^3
Cross Sectional Area of Box Section = (50 x 50) – (40 x 40) = 900 mm^2

$$\frac{Volume}{Cross\ Sectional\ Area} = Length$$

$$\frac{0.69 \times 10^6}{900} = 766.67\ mm$$

Required Box Section for 1 x "Support Strut" = 800 mm
Cost of 1 x 800mm Box Section = £17.03 inc VAT
No. of Required Struts Per Unit = 4
Total Estimated Cost (Support Struts) Per Unit = 4 x £17.03 = £68.12

Calculations – Folding Corner Brackets

No. of Required Folding Corner Brackets Per Unit = 8
Total Cost for 8 x Folding Corner Brackets = £115.16
Total Estimated Cost (Folding Corner Brackets) Per Unit = £115.16

Calculations – Foot Piece

Estimated Cost of 1 x Foot Piece (Steel Casted) = £4.65
No. of Required Feet Per Unit = 4

Total Estimated Cost (Foot Piece) Per Unit = 4 x £4.65 = £18.60

Calculations – Folding T-Shaped Gates

Total Derived Volume of 1 x "Folding T-Shaped Gate" = 2.62 x 10^6 mm^3
Cross Sectional Area of Box Section = (50 x 50) – (40 x 40) = 900 mm^2

$$\frac{Volume}{Cross\ Sectional\ Area} = Length$$

$$\frac{2.62 \text{ x } 10^6}{900} = 2911.11\ mm$$

No. of "T-Shaped Gates" Per Unit = 2
Required Box Section for 1 x Unit = 2950 mm x 2 = 5900 mm
Cost of 1 x 2950 mm Box Section = £62.80
Cost of 2 x 2950 mm Box Section = £62.80 x 2 = £125.60
Total Estimated Cost (T-Shaped Gates) Per Unit = £125.60

Calculations – Total Costing

Total Estimated Costs Per Unit

Main Frame	£286.90
Upwards Support Struts	£68.12
Folding Corner Brackets	£115.16
Feet	£18.60
Folding T-Shaped Gates	£125.60
TOTAL COST PER UNIT	**£614.38**

GANTT CHART

	TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
PLANNING	CUSTOMER REQUIREMENTS MEETING	■																											
	IDENTIFY TECHNICAL REQUIREMENTS - REVIEW DESIGN BRIEF	■	■																										
	DEVELOPMENT OF DESIGN SPECIFICATION			■	■																								
DESIGN	CREATION OF DESIGN CONCEPTS					■	■	■																					
	REVIEW CONCEPTS AGAINST SPECIFICATION								■	■																			
	REFINE / DEVELOP CHOSEN CONCEPT								■	■																			
	DEVELOPMENT OF 3D CAD MODEL/S										■	■																	
	FEA / STRESS ANALYSIS												■																
	STRENGTH OF DESIGN DOCUMENTATION												■	■															
	DEVELOPMENT OF TECHNICAL DRAWING														■														
	CHECKING AND APPROVAL OF DRAWING AGAINST STANDARDS															■													
	DOCUMENT RELEASE - SENT FOR MANUFACTURE																■												
PREP	COLLECTING TOOLS, EQUIPMENT, MATERIALS AND MACHINERY																	■	■										
	RISK ASSESSMENTS - WORKPLACE INSPECTIONS																	■	■										
	ORGANISING WORKFORCE AND WORKLOADS																	■	■										
PROD	MANUFACTURE																			■	■	■	■	■					
	QUALITY CONTROL AND ASSURANCE CHECKS																			■	■	■	■	■					
ANALYSIS	PRODUCT TESTING - FUNCTION AND PERFORMANCE																								■	■	■		
	REVIEW AGAINST DESIGN SPECIFICATION																								■	■			
	CUSTOMER REQUIREMENTS REVIEW MEETING																											■	
	DELIVERY TO CUSTOMER																											■	■

SAFETY:

Factor of Safety

As stated in the Test and Results section, there has been a calculated Factor of Safety of 1.5 for the stillage. This means that the stillage is safely capable of 1.5 times the recommended carrying mass but has also been engineering to withstand 2 times this mass for further safety security (that is not noted to the customer for their own safety).

The results and analyses were as follows. Analyses Conclusions:

- Maximum Load of Stillage = 2000kg (3000kg with 1.5 Safety Factor)
- Stillages should be stacked 2 high

Recommended Actions

From the analysis conclusions, the geometry of the stillage, its mass and the nature of its function, it is recommended that there is a limit of two high when open and 8 high when closed to ensure safe use and practice.

Further Safety considerations were more specifically during the Design of the Stillage, when thinking about how the unit would be carried and transported. The stillage should be carried by multiple people, preferably 4 (1 at each corner) although could be shared between 2 workers. All sharp edges are removed in manufacture to prevent injury when carrying and the design being simple mild steel box section provides plenty of places to grip and handle.

In larger workplaces where multiple stillages are in use and are being moved about, it is highly recommended that a forklift truck is used to manoeuvre them, especially when moving them to lorries for transporting. This is to prevent fatigue in carrying which could possibly lead to dropping them and causing injury. The stillage would have to have the applied forklift package as mentioned in the previous design conclusion (Assignment 2).

CONCLUSIONS:

When evaluating the proposed stillage design against the original design specification, you can see that the design adequately meets all the technical requirements of the customer and is a very well-refined product. The simplistic design allows foe easier, less intricate manufacturing methods, good transportability whilst also providing good mechanical protection.

It showed very good results during the simulation analysis whereby we successfully tested for a factor of safety of 1.5, showing a Maximum Induced Stress of 50MPa and a Maximum Induced Displacement of 3mm which are acceptable for its functional requirements.

Upon further design refinement, the materials could be cut down whilst still maintain very good test results, which would cut down on the overall mass of the stillage and also reduce material costs and manufacturing costs therefore resulting in a lower cost per unit. This would provide more flexibility when design the additional forklift package that would come in use in many workshop environment where multiple units would be in use.

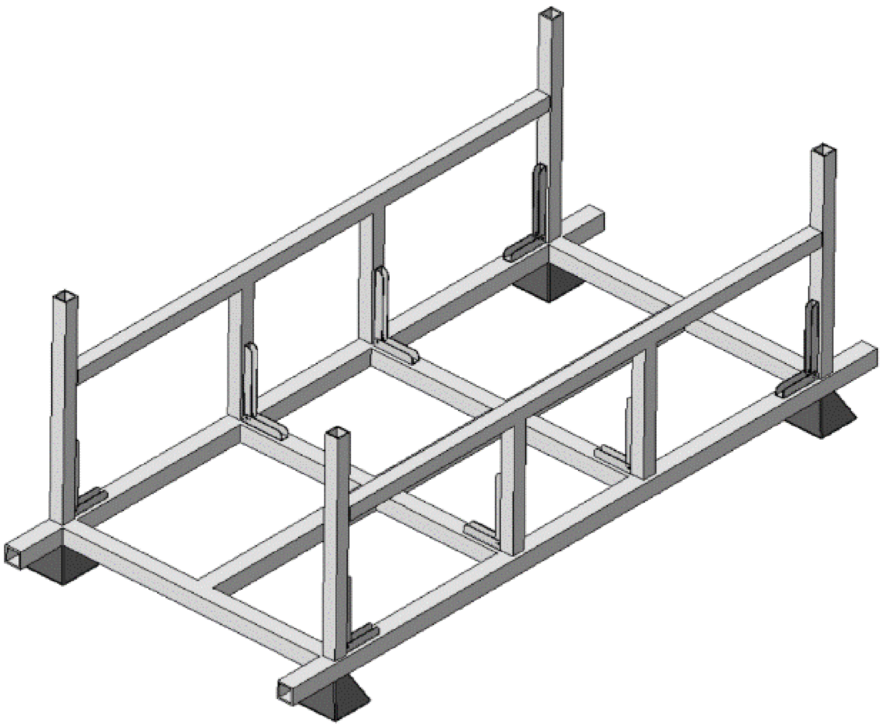


Figure 1.10

ACKNOWLEDGEMENTS AND REFERENCES:

Mild Steel Box Section

https://www.austenknapman.co.uk/mild-steel/mild-steel-box-section/?gclid=EAIaIQobChMIkfLZwJzJ5wIVRrTtCh1xTwl0EAQYAiABEgJ4mPD_BwE

Folding Bracket

https://www.screwfix.com/p/adjustable-folding-bracket-silver-400-x-272mm-2-pack/56422?kpid=56422&ds_kid=92700048793315984&ds_rl=1244072&gclid=EAIaIQobChMIobDy8ZLJ5wIVxbTtCh2uYw42EAQYAiABEgK8yPD_BwE&gclsrc=aw.ds

Steel Casting Calculator http://www.iron-foundry.com/cast-steel-price-calculator.html