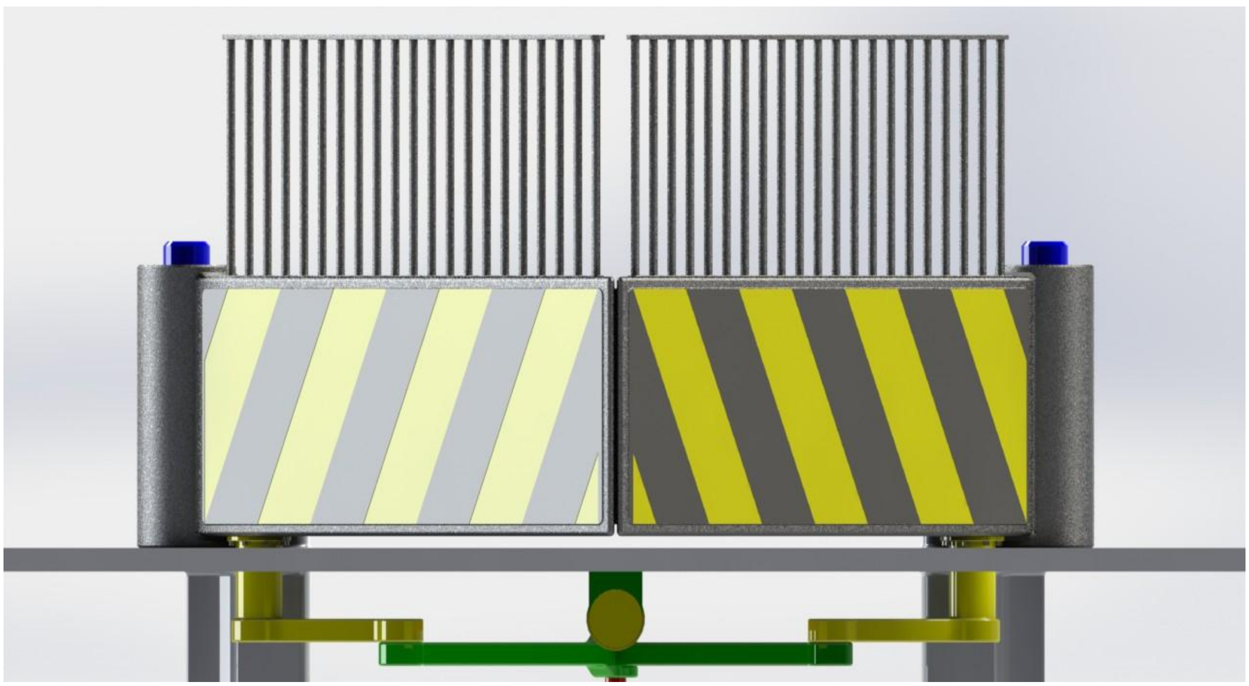
**College of Engineering**

**Department of Mechanical Engineering**

ASSE 4311: Learning Outcome Assessment III

# Design of Hydraulic Road Blocker

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## Acknowledgment

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In addition, sincere acknowledgements go to the faculty of mechanical engineering at PMU whose inspirational lectures and expertise have proven priceless throughout this project.

There are other people who have contributed directly or indirectly in developing our project whom we cannot recall their full names. Appreciations are also extended to them for their valuable participation and contributions.

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# 1. Introduction

## 1.1. Objective

The objective of this project is to generate an innovative design of a hydraulic road blocker that meets the highest impact ratings, specifically the United States Department of State’s K-12 impact rating, which requires a road blocker to withstand a hit from a truck that weighs 6180 kg (15000 lb) travelling at a speed of 80 kph (50 mph) and still remains operational after receiving the hit. The proposed road blocker must have an emergency closing time of 1.5 seconds or lees and must have a manual actuation mechanism in case of power failure. In addition, the proposed road blocker must be manufacturable in Saudi Arabia.

## 1.2. Literature review

### 1.2.1 Background

The hydraulic road blocker is the vehicle control device that can be either integrated with various parking systems or installed as single unit, designed as an effective means of controlling access to high security areas such as airports, ports, customs, governmental buildings, banks, penitentiaries, power stations, military sites, stores, embassies, warehouses, and the likes. The hydraulic road blocker is designed to guarantee the full level of security.

These devices are usually hidden, buried or embedded in the ground at the entrance of the security gateway of a protected site and are erected automatically under alarm conditions, such as when entrance of a suspected vehicle is to be prevented. Under normal conditions, road blockers remain buried under the ground allowing vehicular traffic flow to the site. Erection and retraction of road blockers are usually made by hydraulic or pneumatic actuating element.

Upon reviewing road blockers technologies, research has shown pluralities of patent applications are present in the field in relation to hidden road blockers and to their inner configurations. As an example, blocking elements of the known road blockers have flat or generally convex (cylindrical) impact surfaces. However, these configurations cause the vehicle’s front driving over the blocking element, since the impact results in forces being upwardly exerted on the colliding vehicle’s chassis. In the present invention; by the use of a concave impact surface, the colliding vehicle’s front is prevented from taking an upward movement and tires of a colliding vehicle’s are localized. The geometry of the impact surface of the road blocker is designed to impede upward movement of the colliding vehicle’s front, thus preventing the vehicle’s at least partial entry in the

protected site in a cheap, safe and easily accessible way without any need .of an additional element.
According to another aspect of the invention, damage assessments relating to the present hidden road blocker systems reveal that problems encountered after an impact are generally determined at the actuating systems of the blockers. Main reason of this general problem is the weakness of the actuating systems against large forces occurring during an impact.
But our design is a total new innovation to the road blockers arsenal, our road blocker depends on hydraulic mechanism to open and close our truss geometry gate that will be explained thoroughly in this report.

### 1.2.2. The need of road blockers in Saudi Arabia:

According to the ministry of internal affairs From 2003 to 2012 there had been more than 75 terrorist attack in various places in Saudi Arabia, most of the attacks occurred in sensitive places like the oil refineries and the compounds where the foreigners live. Starting 2003 the government starts to heavily secure the compounds and oil refineries with more security measures like armed security personnel, high security fences, and blocks. One of the most needed things was road blockers to secure the gate of entrance and exit of the secured place, fully secure road blockers was needed to prevent terrorists from entering the secure place, and the need of Saudi manufactured road blockers raised and there were only one Saudi manufacturer of road blockers in Saudi Arabia and the rest were imported.

### 1.2.3. Hydraulic Road blocker:

The hydraulic road blocker is a perfect type of road blocker that is commonly used for electro hydraulic purposes. With this type of road block, no car can be able to access the blocked route. It helps in maintaining the motorist speed in order to prevent accidents. This type of road block is also used for the purpose of controlling gangways together with parking lots perhaps in a home or industrial setting. The Hydraulic road block is normally designed with some rising kerbs that are sharp-pointed in order to perfectly prevent any vehicle from accessing that particular route that has been blocked. In America the anti ram road block is normally used for controlling traffic. The block looks like a long string that is laid across the road to prevent cars from accessing a certain blocked route.

# 2. Theory and Governing Equations:

## 2.1. Introduction:

The strength is a property or characteristic of a mechanical element. This property results from the material identity, the treatment and processing incidental to creating its geometry, and the loading, and it is at the controlling or critical location.
In addition to considering the strength of a single part, we must be cognizant that the strengths of the mass-produced parts will all be somewhat different from the others in the collection or ensemble because of variations in dimensions, machining, forming, and composition. Descriptors of strength are necessarily statistical in nature, involving parameters such as mean, standard deviations, and distributional identification.
A static load is a stationary force or couple applied to a member. To be stationary, the force or couple must be unchanging in magnitude, point or points of application, and direction. A static load can produce axial tension or compression, a shear load, a bending load, a torsional load, or any combination of these. To be considered static, the load cannot change in any manner.
We must consider the relations between strength and static loading in order to make the decisions concerning material and its treatment, fabrication, and geometry for satisfying the requirements of functionality, safety, reliability, competitiveness, usability, manufacturability, and marketability. How far we go down this list is related to the scope of the examples.
Failure can mean a part has separated into two or more pieces; has become permanently distorted, thus ruining its geometry; has had its reliability downgraded; or has had its function compromised, whatever the reason. A designer speaking of failure can mean any or all of these possibilities.
In strength-sensitive situations the designer must separate mean stress and mean strength at the critical location sufficiently to accomplish his purposes. (Shigley's Mechanical Engineering Design, 2006)

## 2.2. Static strength:

Ideally, in designing any machine element, the engineer should have available the results of a great many strength tests of the particular material chosen. These tests should be made on specimens having the same heat treatment, surface finish, and size as the element the engineer proposes to design; and the tests should be made under exactly the same loading conditions as the part will experience in service. This means that if the part is to experience a bending load, it should be tested with a bending load. If it is to be subjected to combined bending and torsion, it should be tested under combined bending

and torsion. If it is made of heat-treated AISI 1040 steel drawn at 500◦C with a ground finish, the specimens tested should be of the same material prepared in the same manner.
Such tests will provide very useful and precise information. Whenever such data are available for design purposes, the engineer can be assured of doing the best possible job of engineering.
The cost of gathering such extensive data prior to design is justified if failure of the part may endanger human life or if the part is manufactured in sufficiently large quantities. But unfortunately for time and budget constrains we only could do our testing by using the computer aided design program Solid Work and it provided us with the information we need.
And if you would ask why testing is so important the answer would be that Failure of the part would endanger human life, or the part is made in extremely large quantities; consequently, an elaborate testing program is justified during design. (Shigley's Mechanical Engineering Design, 2006)

## 2.3. Failure Theories:

Events such as distortion, permanent set, cracking, and rupturing are among the ways that a machine element fails. Testing machines appeared in the 1700s, and specimens were pulled, bent, and twisted in simple loading processes.
If the failure mechanism is simple, then simple tests can give clues. Just what is simple? The tension test is uniaxial (that's simple) and elongations are largest in the axial direction, so strains can be measured and stresses inferred up to "failure."
Unfortunately, there is no universal theory of failure for the general case of material properties and stress state. Instead, over the years several hypotheses have been formulated and tested, leading to today's accepted practices. Being accepted, we will characterize these "practices" as *theories* as most designers do.
Structural metal behavior is typically classified as being ductile or brittle, although under special situations, a material normally considered ductile can fail in a brittle manner. Ductile materials are normally classified such that $\varepsilon_f \geq 0.05$ and have an identifiable yield strength that is often the same in compression as in tension
($S_{yt} = S_{yc} = S_y$ ). Brittle materials, $\varepsilon_f < 0.05$, do not exhibit an identifiable yield strength, and are typically classified by ultimate tensile and compressive strengths, $S_{ut}$ and $S_{uc}$, respectively (where $S_{uc}$ is given as a positive quantity).
It would be inviting if we had one universally accepted theory for each material type, but for one reason or another, they are all used. Later, we will provide rationales for selecting a particular theory. First, we will describe the bases of these theories and apply them to some examples. (Shigley's Mechanical Engineering Design, 2006)

2.4. Stochastic Analysis:

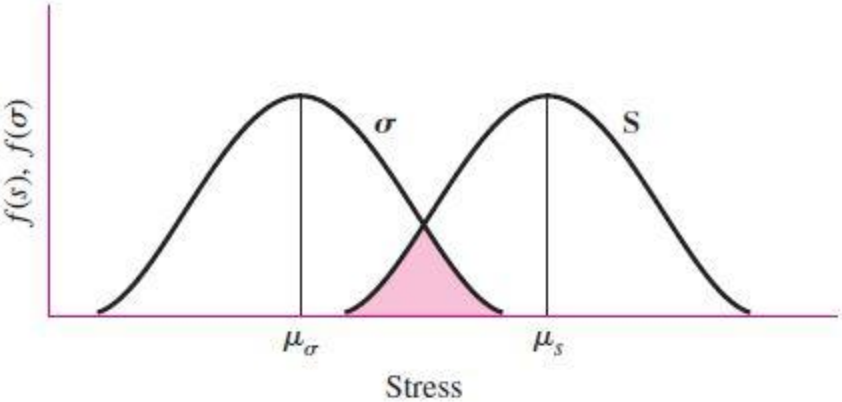
Reliability is the probability that machine systems and components will perform their intended function satisfactorily without failure. Determining relations between static stress, strength, and the design factor. Stress and strength, however, are statistical in nature and very much tied to the reliability of the stressed component. Consider the probability density functions for stress and strength. The mean values of stress and strength are $\mu\sigma$ and $\mu S$ , respectively. Here, the "average" factor of safety is

$$\bar{n} = \frac{\mu_S}{\mu_\sigma}$$

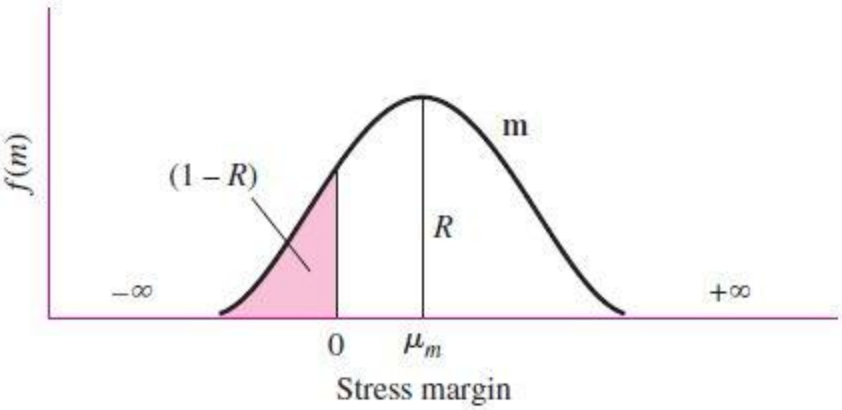
*(a)* The margin of safety for any value of stress σ and strength *S* is defined as
$m = S - \sigma$

*(b)* The average part will have a margin of safety of $m = \mu S - \mu\sigma$ . However, for the overlap of the distributions shown by the shaded area in the figure below the stress exceeds the strength, the margin of safety is negative, and these parts are expected to fail. This shaded area is called the *interference* of _ and S.

The second figure shows the distribution of *m*, which obviously depends on the distributions of stress and strength. The reliability that a part will perform without failure, *R*, is the area of the margin of safety distribution for $m > 0$. The interference is the area




(a)




(b)

2.5. Beam Deflection:

$$\frac{q}{EI} = \frac{d^4 y}{dx^4}$$

$$\frac{V}{EI} = \frac{d^3 y}{dx^3}$$

$$\frac{M}{EI} = \frac{d^2 y}{dx^2}$$

$$\theta = \frac{dy}{dx}$$

$$y = f(x)$$

Equations shown above are the basis for relating the intensity of loading *q*, vertical shear *V*, bending moment *M*, slope of the neutral surface θ, and the transverse deflection *y*. Beams have intensities of loading that range from *q* = constant (uniform loading), variable intensity *q*(*x*), to Dirac delta functions (concentrated loads).
The intensity of loading usually consists of piecewise contiguous zones, the expressions for which are integrated through Equations Shown above with varying degrees of difficulty. Another approach is to represent the deflection *y*(*x*) as a Fourier series, which is capable of representing single-valued functions with a finite number of finite discontinuities, then differentiating through Equations above, and stopping at some level where the Fourier coefficients can be evaluated. A complication is the piecewise continuous nature of some beams (shafts) that are stepped-diameter bodies.
All of the above constitute, in one form or another, formal integration methods, which, with properly selected problems, result in solutions for *q*, *V*, *M*, θ, and *y*. These solutions may be:

1. Closed-form, or
2. Represented by infinite series, which amount to closed form if the series are rapidly convergent, or
3. Approximations obtained by evaluating the first or the first and second terms.

The series solutions can be made equivalent to the closed-form solution by the use of a computer. Roark's1 formulas are committed to commercial software and can be used on a personal computer.
There are many techniques employed to solve the integration problem for beam deflection. Some of the popular methods include:

• Superposition
• The moment-area method2
• Singularity functions
• Numerical integration3

The two methods described in this chapter are easy to implement and can handle a large array of problems.
There are methods that do not deal with these equations directly. An energy method, based on Castigliano's theorem, is quite powerful for problems not suitable for the methods mentioned earlier. Finite element programs are also quite useful for determining beam deflections. (Shigley's Mechanical Engineering Design, 2006)

## 2.6. Welding:

A weldment is fabricated by welding together a collection of metal shapes, cut to particular configurations. During welding, the several parts are held securely together, often by clamping or jigging. The welds must be precisely specified on working drawings, and this is done by using the welding symbol, shown in Fig. 1, as standardized by the American Welding Society (AWS). The arrow of this symbol points to the joint to be welded. The body of the symbol contains as many of the following elements as are deemed necessary:

- Reference line
- Arrow
- Basic weld symbols as in Fig. 9–2
- Dimensions and other data
- Supplementary symbols
- Finish symbols
- Tail
- Specification or process

The *arrow side* of a joint is the line, side, area, or near member to which the arrow points. The side opposite the arrow side is the *other side*.

Figures 9–3 to 9–6 illustrate the types of welds used most frequently by designers.

For general machine elements most welds are fillet welds, though butt welds are used a great deal in designing pressure vessels. Of course, the parts to be joined must be arranged so that there is sufficient clearance for the welding operation. If unusual joints are required because of insufficient clearance or because of the section shape, the design may be a poor one and the designer should begin again and endeavor to synthesize another solution.

Since heat is used in the welding operation, there are metallurgical changes in the parent metal in the vicinity of the weld. Also, residual stresses may be introduced because of clamping or holding or, sometimes, because of the order of welding. Usually these residual stresses are not severe enough to cause concern; in some cases a light heat treatment after welding has been found helpful in relieving them. When the parts to be welded are thick, a preheating will also be of benefit. If the reliability of the component is to be quite high, a testing program should be established to learn what changes or additions to the operations are necessary to ensure the best quality. (Shigley's Mechanical Engineering Design, 2006)

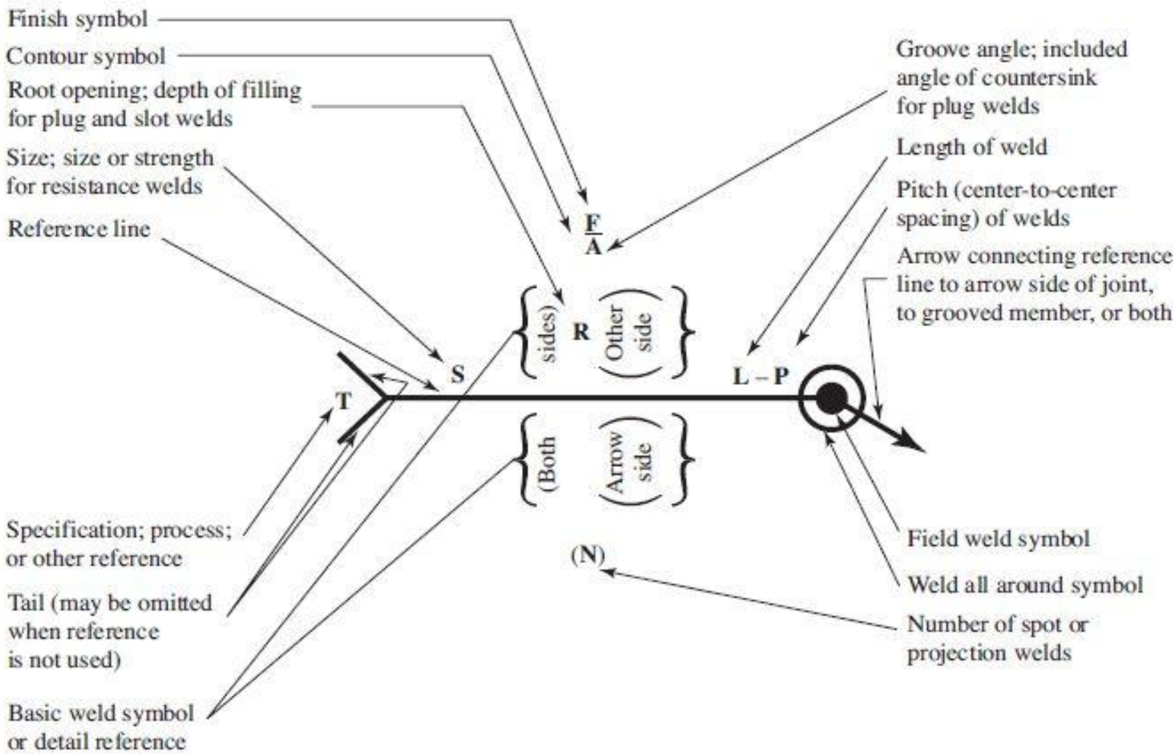
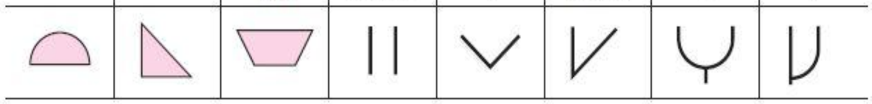

Finish symbol
Contour symbol
Root opening; depth of filling for plug and slot welds
Size; size or strength for resistance welds
Reference line
Groove angle; included angle of countersink for plug welds
Length of weld
Pitch (center-to-center spacing) of welds
Arrow connecting reference line to arrow side of joint, to grooved member, or both
F
A
R
S
T
L – P
(Both sides)
(Other side)
(Arrow side)
(N)
Specification; process; or other reference
Tail (may be omitted when reference is not used)
Basic weld symbol or detail reference
Field weld symbol
Weld all around symbol
Number of spot or projection welds

Figure 1

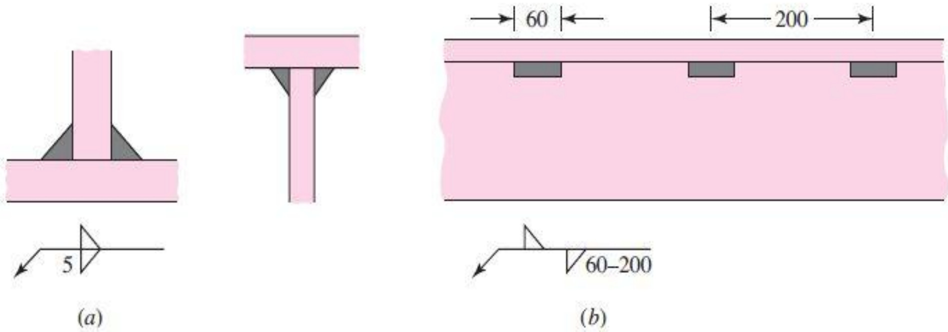
## Figure 9–2

Arc- and gas-weld symbols.

| Type of weld | | | | | | | |
|---|---|---|---|---|---|---|---|
| Bead | Fillet | Plug or slot | Groove | | | | |
| | | | Square | V | Bevel | U | J |

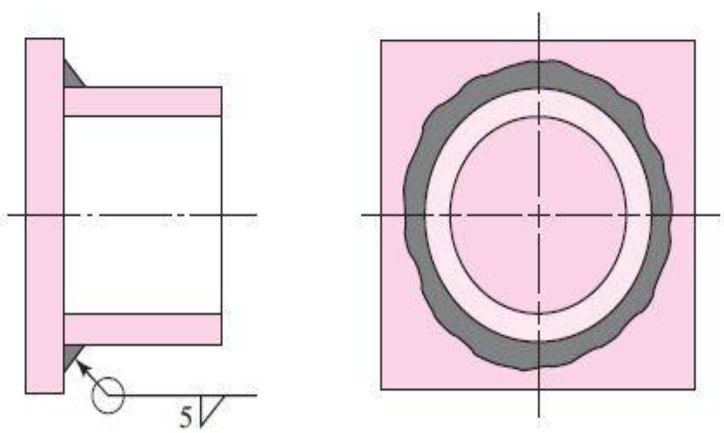


## Figure 9–3




Fillet welds. (*a*) The number indicates the leg size; the arrow should point only to one weld when both sides are the same. (*b*) The symbol indicates that the welds are intermittent and staggered 60 mm along on 200-mm centers.

## Figure 9–4




The circle on the weld symbol indicates that the welding is to go all around.

**Figure 9–5**

Butt or groove welds: (*a*) square butt-welded on both sides; (*b*) single V with 60° bevel and root opening of 2 mm; (*c*) double V; (*d*) single bevel.

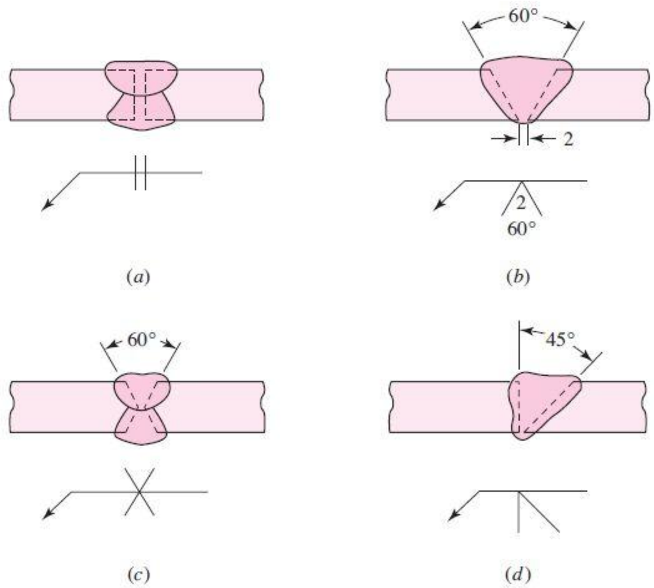
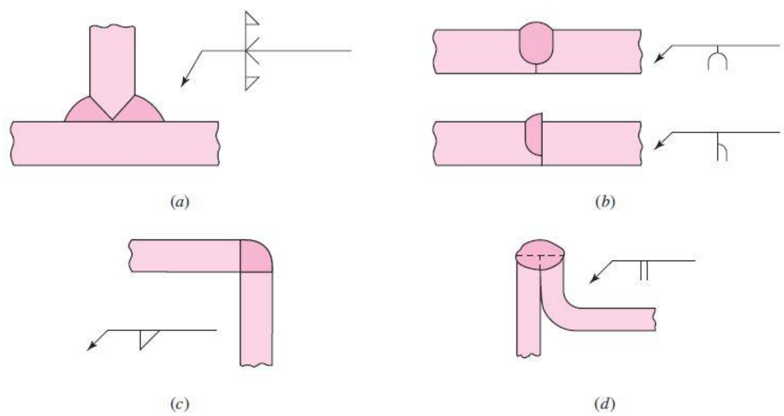



**Figure 9–6**

Special groove welds: (*a*) T joint for thick plates; (*b*) U and J welds for thick plates; (*c*) corner weld (may also have a bead weld on inside for greater strength but should not be used for heavy loads); (*d*) edge weld for sheet metal and light loads.




## 2.7. Truss:

In architecture a truss is a structure comprising one or more triangular units constructed with straight members whose ends are connected at joints referred to as nodes. External forces and reactions to those forces are considered to act only at the nodes and result in forces in the members which are either tensile or compressive forces. Moments (torques) are explicitly excluded because, and only because, all the joints in a truss are treated as revolutes.

A planar truss is one where all the members and nodes lie within a two dimensional plane, while a space truss has members and nodes extending into three dimensions. The top beams in a truss are called top chords and are generally in compression, the bottom beams are called bottom chords and are generally in tension, the interior beams are called webs and the area inside the webs are called panels.

Because the forces in each of its two main girders are essentially planar, a truss is usually modeled as a two-dimensional plane frame. If there are significant out-of-plane forces, the structure must be modeled as a three-dimensional space.

The analysis of trusses often assumes that loads are applied to joints only and not at intermediate points along the members. The weight of the members is often insignificant compared to the applied loads and so is often omitted. If required, half of the weight of each member may be applied to its two end joints. Provided the members are long and slender, the moments transmitted through the joints are negligible and they can be treated as "hinges" or 'pin-joints'. Every member of the truss is then in pure compression or pure tension – shear, bending moment, and other more complex stresses are all practically zero. This makes trusses easier to analyze. This also makes trusses physically stronger than other ways of arranging material – because nearly every material can hold a much larger load in tension and compression than in shear, bending, torsion, or other kinds of force.

Structural analysis of trusses of any type can readily be carried out using a matrix method such as the direct stiffness method, the flexibility method or the finite element method.

### 2.7.1 Design of members

A truss can be thought of as a beam where the web consists of a series of separate members instead of a continuous plate. In the truss, the lower horizontal member (the bottom chord) and the upper horizontal member (the top chord) carry tension and compression, fulfilling the same function as the flanges of an I-beam. Which chord carries tension and which carries compression depends on the overall direction of bending. In the truss pictured above right, the bottom chord is in tension, and the top chord in compression.

The diagonal and vertical members form the truss web, and carry the shear force. Individually, they are also in tension and compression, the exact arrangement of forces is depending on the type of truss and again on the direction of bending. In the truss shown above right, the vertical members are in tension, and the diagonals are in compression.

In addition to carrying the static forces, the members serve additional functions of stabilizing each other, preventing buckling. In the picture to the right, the top chord is prevented from buckling by the presence of bracing and by the stiffness of the web members.

The inclusion of the elements shown is largely an engineering decision based upon economics, being a balance between the costs of raw materials, off-site fabrication, component transportation, on-site erection, the availability of machinery and the cost of labor. In other cases the appearance of the structure may take on greater importance and so influence the design decisions beyond mere matters of economics. Modern materials such as prestressed concrete and fabrication methods, such as automated welding, have significantly influenced the design of modern bridges.

Once the force on each member is known, the next step is to determine the cross section of the individual truss members. For members under tension the cross-sectional area $A$ can be found using $A = F \times \gamma / \sigma_y$, where $F$ is the force in the member, $\gamma$ is a safety factor (typically 1.5 but depending on building codes) and $\sigma_y$ is the yield tensile strength of the steel used.
The members under compression also have to be designed to be safe against buckling.

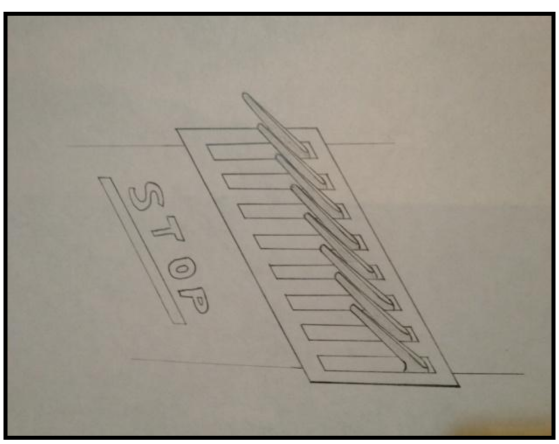
The weight of a truss member depends directly on its cross section—that weight partially determines how strong the other members of the truss need to be. Giving one member a larger cross section than on a previous iteration requires giving other members a larger cross section as well, to hold the greater weight of the first member—one needs to go through another iteration to find exactly how much greater the other members need to be. Sometimes the designer goes through several iterations of the design process to converge on the "right" cross section for each member. On the other hand, reducing the size of one member from the previous iteration merely makes the other members have a larger (and more expensive) safety factor than is technically necessary, but doesn't *require* another iteration to find a buildable truss. The effect of the weight of the individual truss members in a large truss, such as a bridge, is usually insignificant compared to the force of the external loads. (en.wikipedia.org)

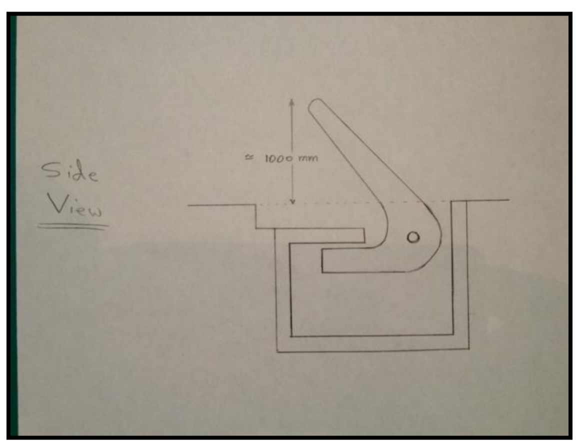
# 3. Design of the road blocker:

| Product Specification | |
|---|---|
| Height | 2.07 m |
| Clearance: | 2.81 m |
| Width (closed): | 4.44 m |
| Axle Loadings: | Will withstand any road vehicle (In-house test certificate).K12/M50 |
| Motor: | HP - 3<br>PH - 3<br>VOLTS - 230/460<br>RPM - 3450<br>AMP - 10/5<br>HZ - 50 |
| Options: | Work manually in case of power failure. |
| Normal Operating Speed: | 4-5seconds. |
| Accumulator Speed: | 1.5 seconds |
| Road blocker Finish: | Anti corrosive finish |
| Factor of Safety: | 3.2 |
| Durability: | CAD modeling shows the road blocker remains operational after impact. |

## 3.1. Crossed out innovations:

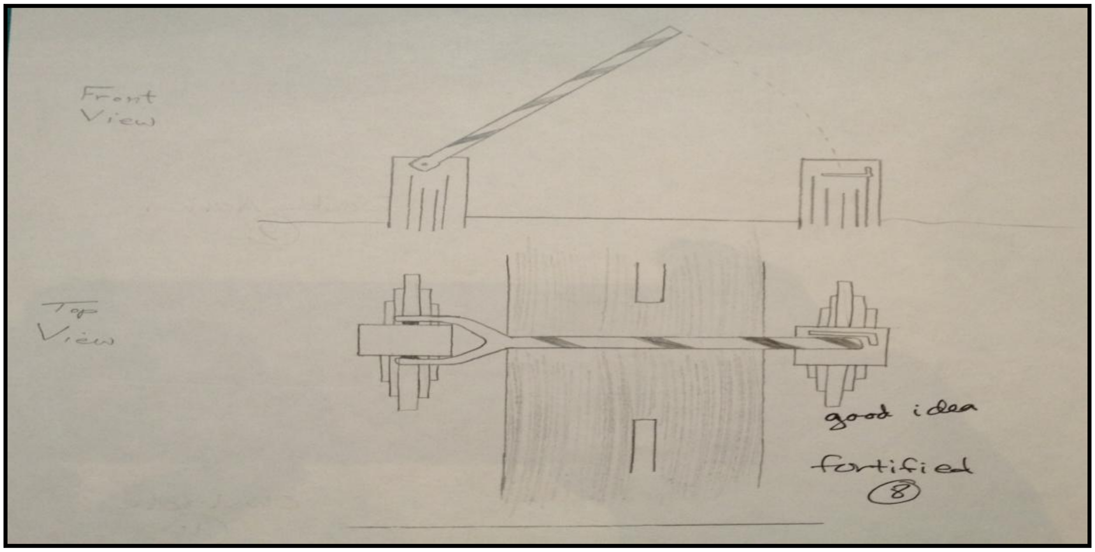
We went through a great deal of brain storming in the begging of this project to come up with the perfect innovative idea of a new road blocker that will meet the requirement of K12 and to apply our learning and aspects from our engineering courses, and these are the major ideas we came with and crossed out:



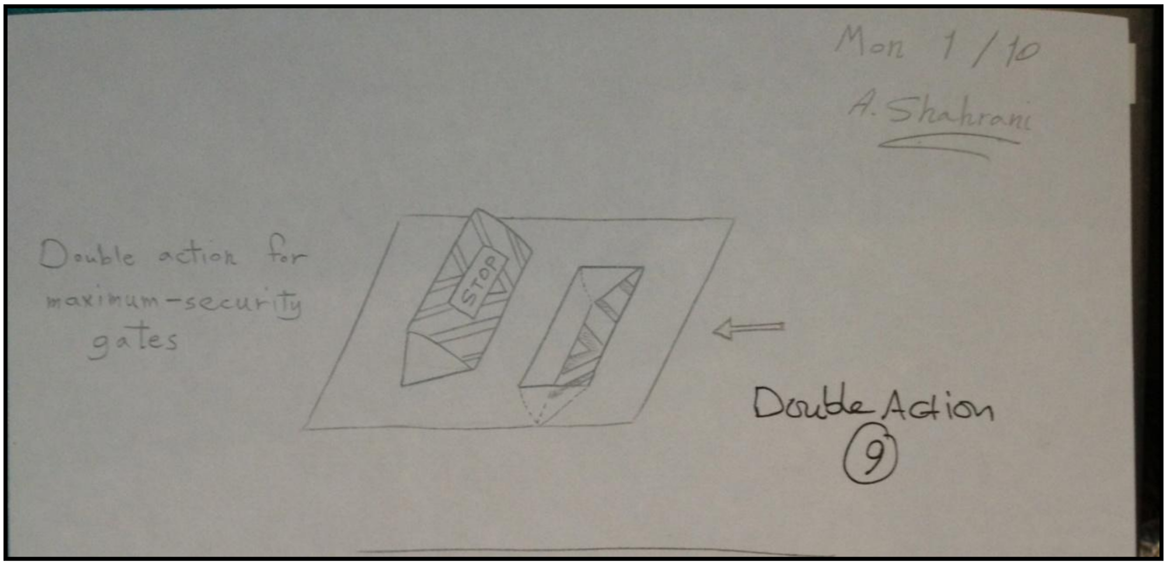
Big spikes blocker:

This is one of the first ideas we came with and we crossed that this idea because it wasn't innovative enough and it doesn't show all the competences and the materials that we learned in our engineering classes.



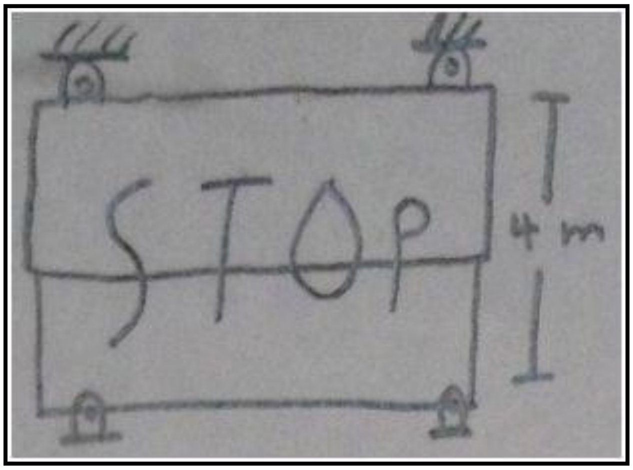

Pole road blocker:

This idea was crossed out because it was more of a civil engineer project than mechanical engineer, secondly the engineering used in this Idea is to simple, and it's not a total new innovation.



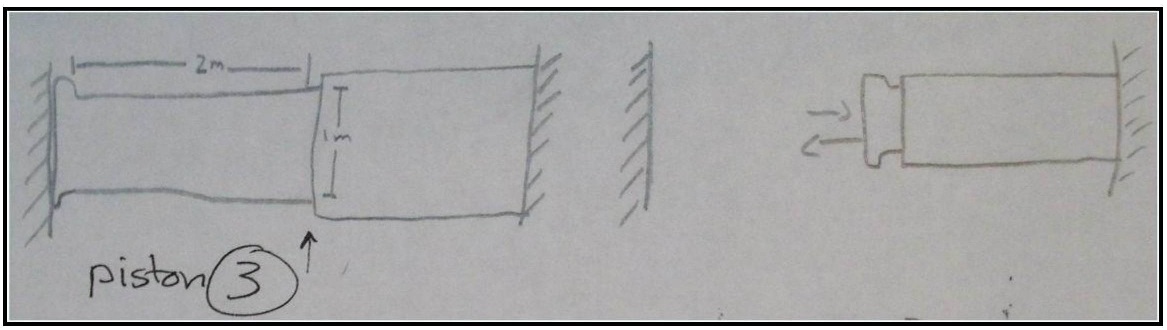

Double Action:

This idea was crossed out because it is more of development of an old idea than creating an new innovation.



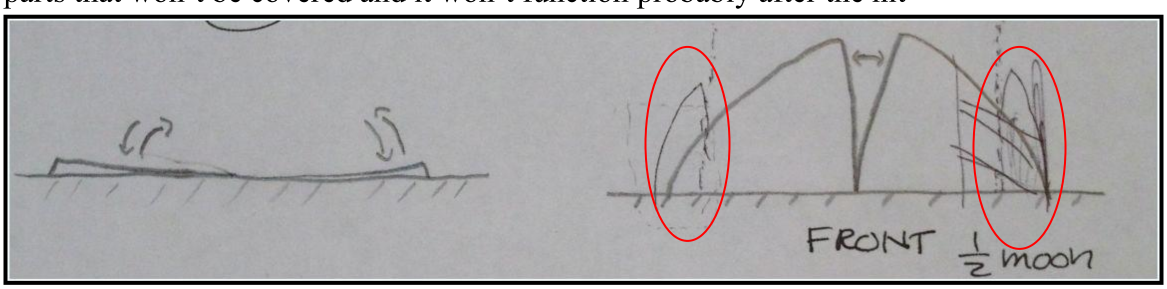

Roll down blocker:

We rolled this innovation because it's too weak and won't be functional after the hit.



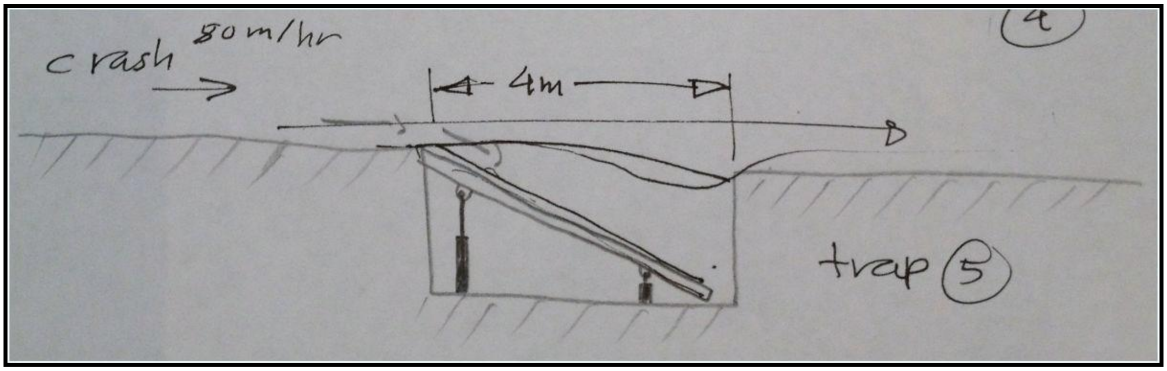

Horizontally collapsible blocker:

A very great idea but was crossed out because its design will have so many precision parts that won't be covered and it won't function probably after the hit

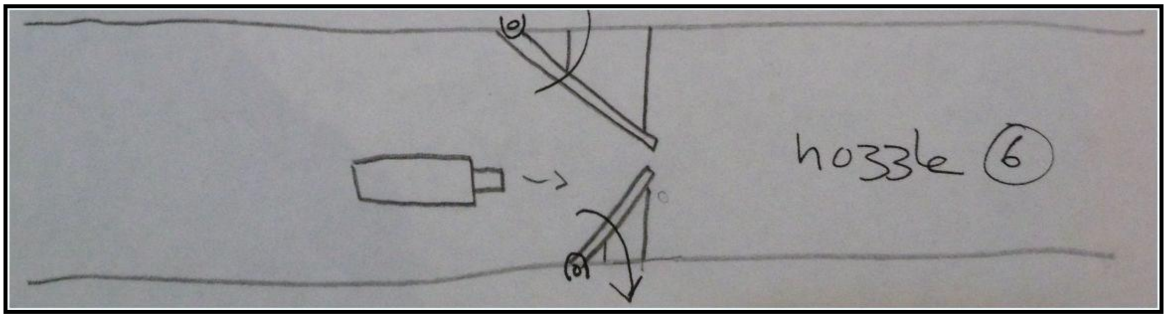



Half circle blocker:

A good idea that we almost worked with but as shown in the picture we crossed this innovation out because of the circled areas where we sensed it will be a weak area.




Trap blocker:
An idea the team was really excited for but was rolled out because of its complication and the difficulty of expecting the result, such in the case of speeding car.

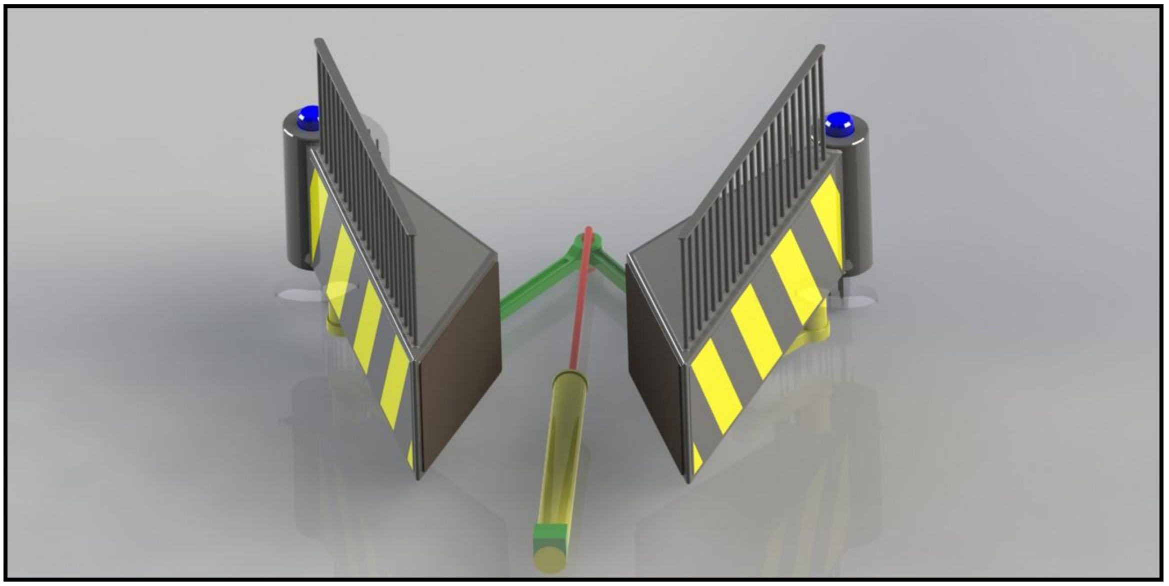



Nozzle blocker:
This drawing is the seed of our blocker and the idea we went through with.

3.2. Parts and Dimension:

The design and its calculation was the most crucial part of this project, every single beam, structure, fillet, crank, and knot was thoroughly calculated and measured and in this part of the report we will talk about each major part and its specification.

The doors:

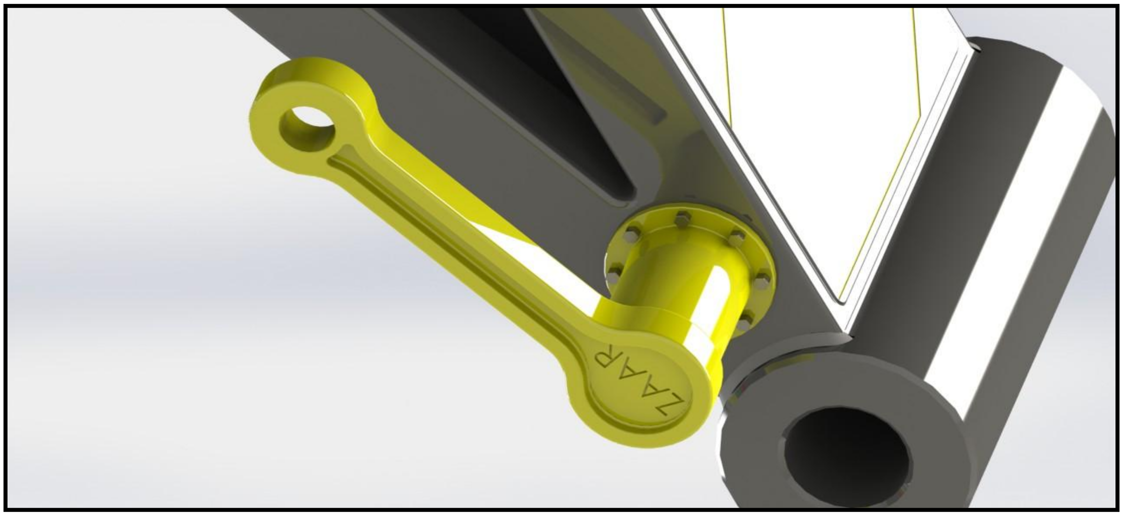


The main parts and the innovative idea of the design, they was designed in the shape of two triangles to benefit from its truss engineering shape to resist the greatest force possible, as it was explained before the material used to manufacture this door is aluminum alloy 2014-T3 to give it a light weight and a strong structure, it's moved by a hydraulic motor and it has one tier in each door to ease its move and it can be manually moved in case of power failure, it also have a rubber padding in the faces where the two doors meet, these rubber padding will prevent friction from happening between the surfaces of the two doors. To increase its security a shield of bars was welded to the doors to prevent any trial of human preach to the place intended to be secure. It contains of three parts, the structure of the door itself, the sheet metals, and the bars above the door. Door dimension is shown in the figure below:

| Door Specification | Dimension | Bars Specification | Dimension |
|---|---|---|---|
| Total high | 2.07 m | High | 1.1 m |
| Total mass | 728.5 kg | width | 2.8 m |
| Surface area | 41.06 $m^2$ | | |
| Width | 3.56 m | | |
| Length | 0.98 m | | |

Note: these are the dimension of one door only

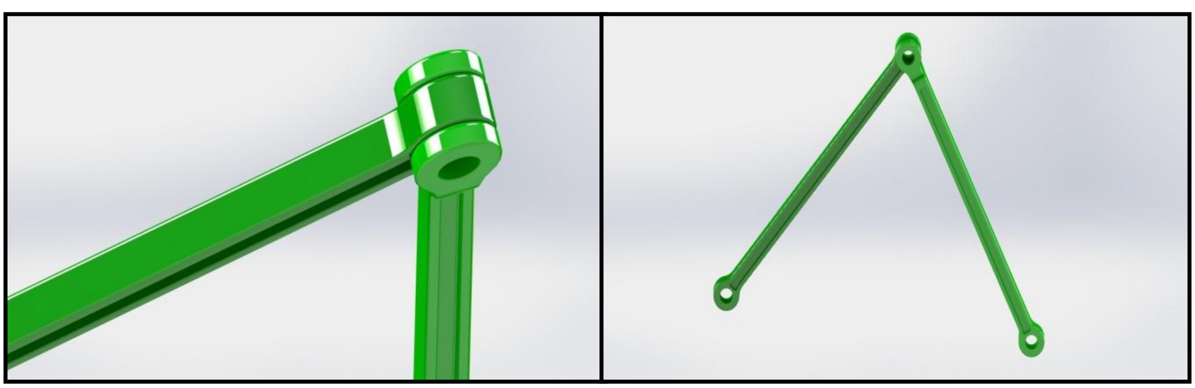
The Crank:



The part responsible of connecting the door to the hydraulic links, this part is meanly responsible of moving the door and a lot of load will be concentrated on it, this part was designed with high consideration of the hydraulic stroke, this part will be designed of commercial stainless steel and not aluminum alloy, and we precisely calculated its dimension. And its dimension showed in the figure below:

| Crank Specification | Dimension |
|---|---|
| Length | 0.89 m |
| Height | 0.45 m |
| Width | 0.29 m |
| Mass | 132.8 kg |
| Surface Area | 1.09 $m^2$ |

The links:

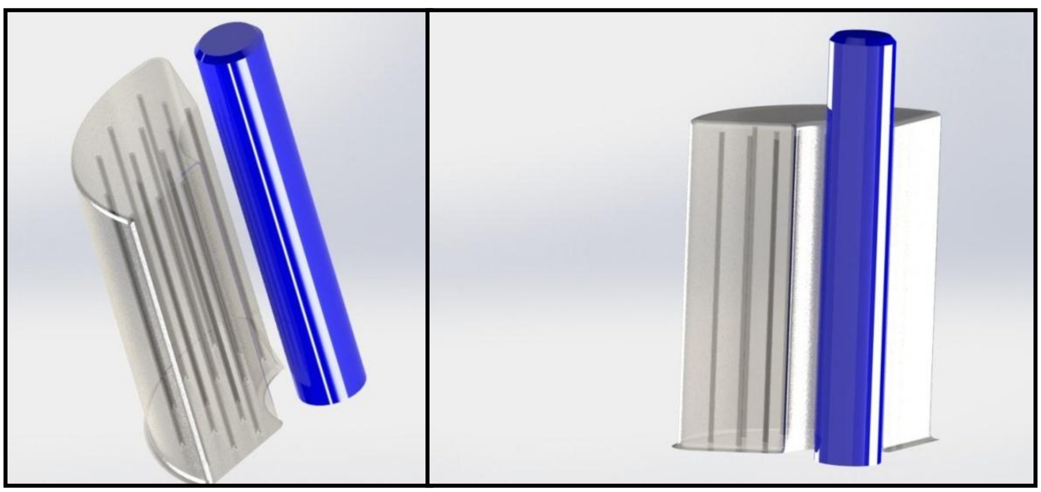


In our design we have two links that link the hydraulic actuation machine with the crank of the door, one of them is a two headed link to join the other link to be connected to the hydraulic machine, these link will be exposed to high force in order to move the 1.45 ton doors. And these are the dimension

| Link specification | Dimension | D-Link specification | Dimension |
|---|---|---|---|
| Length | 2.4 m | Length | 2.4 m |
| Height | 0.09 m | Height | 0.2 m |
| Width | 0.21 m | Width | 0.21 m |
| Mass | 181.8 kg | Mass | 170.9 kg |
| Surface area | 1.32 $m^2$ | Surface area | 1.25 $m^2$ |

Note: D-link stands for (Double-headed link)

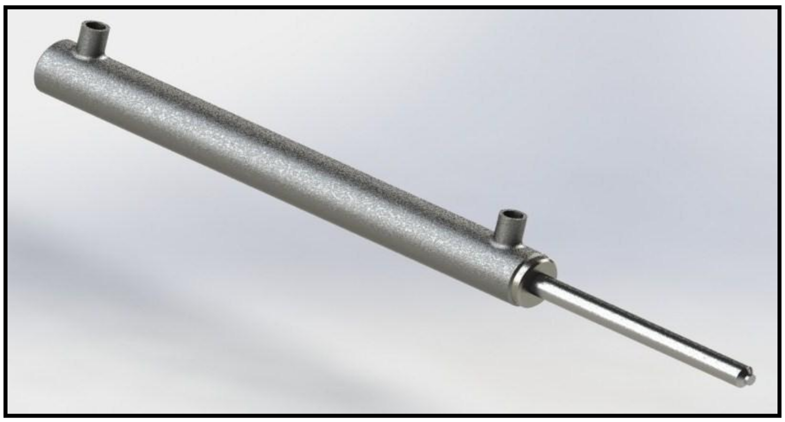
The Support Structure:



These two parts are the only fixed parts in our design; the beam will act as a hinge for the door to be fixed and move around. The beam also will absorb an amount of the shock after it transfer from the door so it need to be tough enough to absorb some of the distributed shock, it will be designed of concrete raped with a sheet metal to smooth the movement of the door. The support behind the beam will be a concrete structure, its main use would be supporting the two doors and creating a stop and meeting point for them. And these are the dimension:

| Beam specification | Dimension | Support specification | Dimension |
|---|---|---|---|
| Height | 1.3 m | Height | 1 m |
| Length | 0.22m | Length | 0.86 m |
| Width | 0.22m | Width | 0.55 m |
| Mass | 120 kg | Mass | 600 kg |
| Surface area | 0.97 $m^2$ | Surface area | 3.55 $m^2$ |

Hydraulic Piston-Cylinder:



This is one of the main parts of the design and our actuation method, the Hydraulic piston cylinder will be directly connected to a motor and it will be responsible directly of the movement of the hall design, it was carefully calculated to be as short and small as possible so it won't need a large place, but also still function with ease. It will be designed out of stainless steel and will be connected to a motor of 3hp. The dimensions of the piston cylinder are as follow:

| **Piston specification** | **Dimension** |
|---|---|
| Total Length | 4.06 m |
| Diameter | 0.25 m |
| Mass | 343.86 kg |
| Surface Area | 3.61 $m^2$ |

### 3.3. Material selection:

Materials are selected on the basis of four general criteria:

- Performance characteristics (properties)
- Processing (manufacturing) characteristics
- Environmental profile
- Business consideration

So, based on the criteria and the specification we need for our design which is a material with high weight to strength ratio, available in the market, and have a competitive value. After searching for the perfect material we found out that the best material to use in manufacturing our doors is Aluminum alloy 2040-T3, and to use commercial stainless steel to manufacture the other parts.
What is Aluminum alloy 2040-T3?
Aluminum alloy 2024 is an aluminum alloy, with copper as the primary alloying element. It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance. The best welding method for this alloy is friction welding, it is often clad with aluminum or Al-1Zn for protection, although this may reduce the fatigue strength.

It has a density of 2.78 $g/cm^3$ (0.1 $lb/in^3$), electrical conductivity of 30% IACS, Young's Modulus of 73 GPa (10.6 Msi) across all tempers, and begins to melt at 500 °C (932 °F). Its composition roughly includes 4.3-4.5% copper, 0.5-0.6% manganese, 1.3-1.5% magnesium and less than a half a percent of silicon, zinc, nickel, chromium, lead and bismuth.

T3 temper 2024 sheet has an ultimate tensile strength of 58-62 ksi (400-427 MPa) and yield strength of at least 39-40 ksi (269-276 MPa). It has elongation of 10-1. (en.wikipedia.org)

### 3.4. Safety Factor:

safety factor (SF), is a term describing the structural capacity of a system beyond the expected loads or actual loads. Essentially, how much stronger the system is than it usually needs to be for an intended load. Safety factors are often calculated using detailed analysis because comprehensive testing is impractical on many projects, such as bridges and buildings, but the structure's ability to carry load must be determined to a reasonable accuracy.
There are several ways to compare the factor of safety for structures. All the different calculations fundamentally measure the same thing: how much extra load beyond what is intended a structure will actually take (or be required to withstand). And the factor of safety is calculated by:

$$\text{Factor of Safety} = \frac{\text{Material Strength}}{\text{Design Load}}$$

Components whose failure could result in substantial financial loss, serious injury, or death may use a safety factor of four or higher (often ten). Non-critical components generally might have a design factor of two. Risk analysis, failure mode and effects analysis, and other tools are commonly used. Design factors for specific applications are often mandated by law, policy, or industry standards.

Buildings commonly use a factor of safety of 2.0 for each structural member. The value for buildings is relatively low because the loads are well understood and most structures are redundant. Pressure vessels use 3.5 to 4.0, automobiles use 3.0, and aircraft and spacecraft use 1.2 to 3.0 depending on the application and materials. Ductile, metallic materials tend to use the lower value while brittle materials use the higher values. The field of aerospace engineering uses generally lower design factors because the costs associated with structural weight are high (i.e. an aircraft with an overall safety factor of 5 would probably be too heavy to get off the ground). This low design factor is why aerospace parts and materials are subject to very stringent quality control and strict preventative maintenance schedules to help ensure reliability. A usually applied Safety Factor is 1.5, but for pressurized fuselage it is 2.0, and for main landing gear structures it is often 1.25.

In some cases it is impractical or impossible for a part to meet the "standard" design factor. The penalties (mass or otherwise) for meeting the requirement would prevent the system from being viable (such as in the case of aircraft or spacecraft). In these cases, it is sometimes determined to allow a component to meet a lower than normal safety factor, often referred to as "waiving" the requirement. Doing this often brings with it extra detailed analysis or quality control verifications to assure the part will perform as desired, as it will be loaded closer to its limits.

For loading that is cyclical, repetitive, or fluctuating, it is important to consider the possibility of metal fatigue when choosing factor of safety. A cyclic load well below a material's yield strength can cause failure if it is repeated through enough cycles. (en.wikipedia.org)

**Calculation:**

In our design the material selected was aluminum alloy 2024-T3 for the doors and after calculating the factor of safety by Solid Work it gave us that the factor of safety is 3.3. (refer to the Solid Work report in p.41 for more information)

### 3.5. Von mises stress:

The von Mises yield criterion suggests that the yielding of materials begins when the second deviatoric stress invariant $J_2$ reaches a critical value. For this reason, it is sometimes called the $J_2$-*plasticity* or $J_2$ flow theory. It is part of a plasticity theory that applies best to ductile materials, such as metals. Prior to yield, material response is assumed to be elastic.

In materials science and engineering the von Mises yield criterion can be also formulated in terms of the von Mises stress or equivalent tensile stress, $\sigma_v$, a scalar stress value that can be computed from the stress tensor. In this case, a material is said to start yielding when its von Mises stress reaches a critical value known as the yield strength, $\sigma_y$. The von Mises stress is used to predict yielding of materials under any loading condition from results of simple uniaxial tensile tests. The von Mises stress satisfies the property that two stress states with equal distortion energy have equal von Mises stress.

Because the von Mises yield criterion is independent of the first stress invariant, $I_1$, it is applicable for the analysis of plastic deformation for ductile materials such as metals, as the onset of yield for these materials does not depend on the hydrostatic component of the stress tensor.

Although formulated by Maxwell in 1865, it is generally attributed to Richard Edler von Mises (1913). Tytus Maksymilian Huber (1904), in a paper in Polish, anticipated to some extent this criterion. This criterion is also referred to as the Maxwell–Huber–Hencky–von Mises theory.

So for the general state of stress given by

$$\left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right]^{1/2} \geq S_y$$

If we had a simple case of tension σ , then yield would occur when $\sigma \geq S_y$ . Thus, the left of the general stress equation can be thought of as a *single, equivalent,* or *effective stress* for the entire general state of stress given by $\sigma_1$, $\sigma_2$, and $\sigma_3$. This effective stress is usually called the *von Mises stress,* $\sigma'$, named after Dr. R. von Mises, who contributed to the theory. where the von Mises stress is

$$\sigma' = \left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right]^{1/2}$$

(Shigley's Mechanical Engineering Design, 2006)

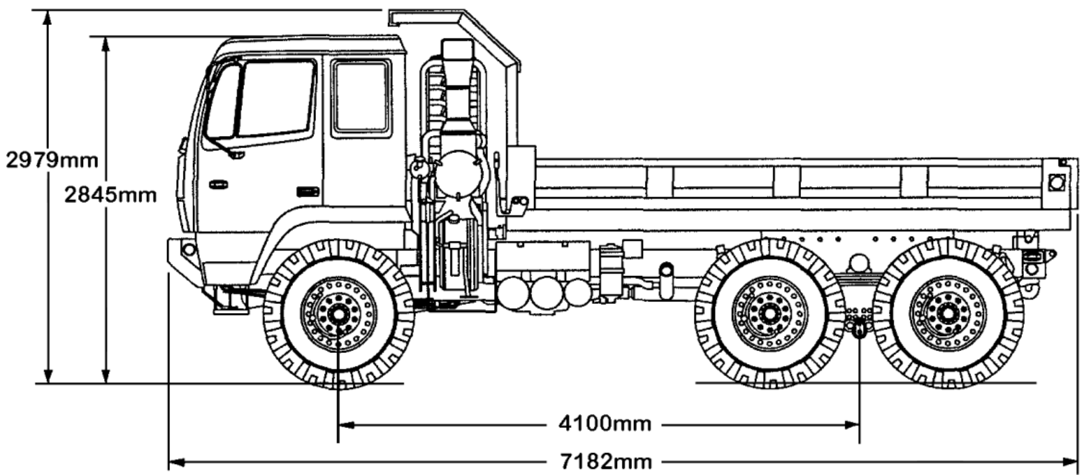
**Calculation:**

And after creating the parts in Solid Work it calculated the Von Mises stress of our project is 102 MPa (refer to the SolidWork report for more details p. 41)

## 3.6. Force analysis:

### 3.6.1. Assumption:

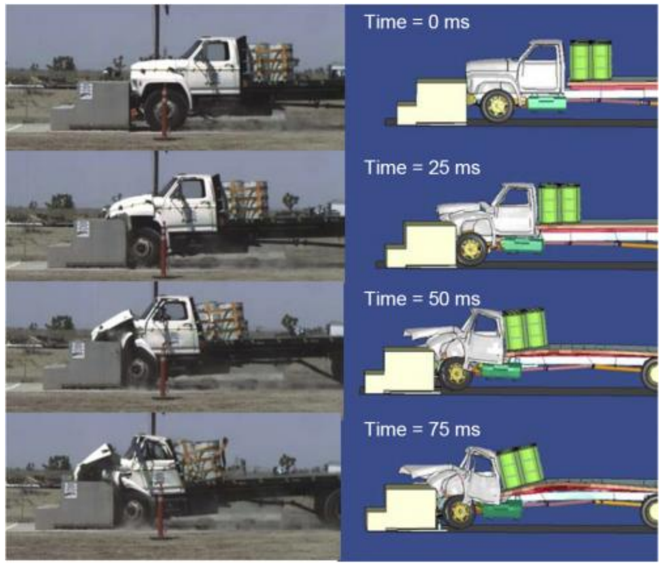
Truck dimensions:




Based on the K12 requirement we have
The velocity of the truck is 80 Km/h, and that's almost to be 22.222 $\frac{m}{s}$.
The mass of the truck is 6180 Kg.
The Area that will hit the road blocker is (2.6 $m$ in width and 2.34 $m$ in height) = 6.1 $m^2$

### 3.6.2. Calculations:

The impact force equation is $F = \frac{m \times v}{\Delta t}$, where $m$ is in Kg, and $v$ is in $\frac{m}{s}$, finally $\Delta t$ is the impact time as shown:

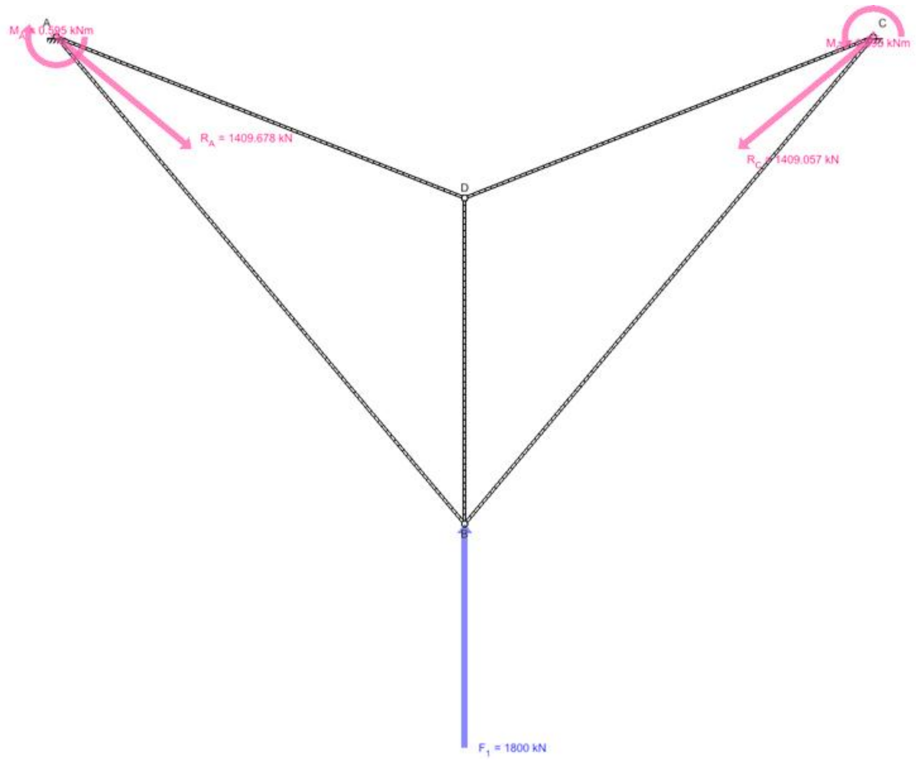



Where $\Delta t$ is 75 ms = 0.075 s.

F = $\frac{6180 \times 22.222}{0.075}$ = 1831092.8 N = 1.83 MN.

3.7. Autodesk Report:

After acquiring this information, the team used (Auto Desk Force Analysis) to analyze the force on our structure, and after inserting the information it gave us this report:




Inputs:

Elements

| Element | Length |
|---|---|
| A-B | 3.080 m |
| B-C | 3.080 m |
| B-D | 1.580 m |
| D-A | 2.126 m |
| D-C | 2.127 m |

Forces

| Force | Size | Angle |
|---|---|---|
| $F_1$ | 1800.0 kN | 90.0° |

Results:

Over constrained System: No equations available.

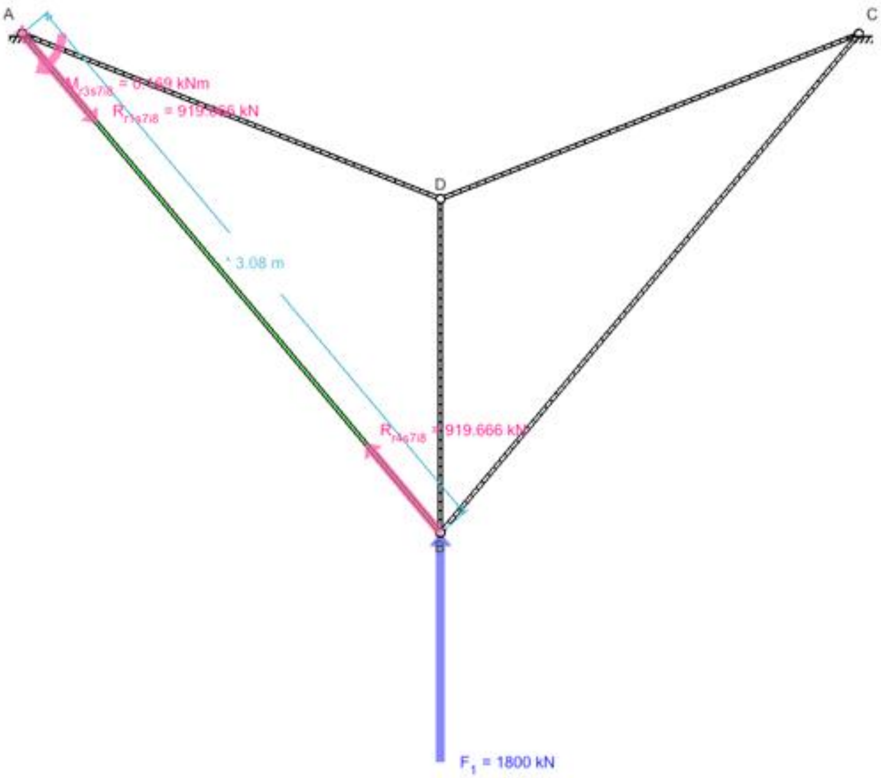
Reaction Forces

| Force | Size | Angle |
|---|---|---|
| $R_A$ | 1409.678 kN | 320.3° |
| $R_C$ | 1409.057 kN | 219.7° |

Reaction Moments

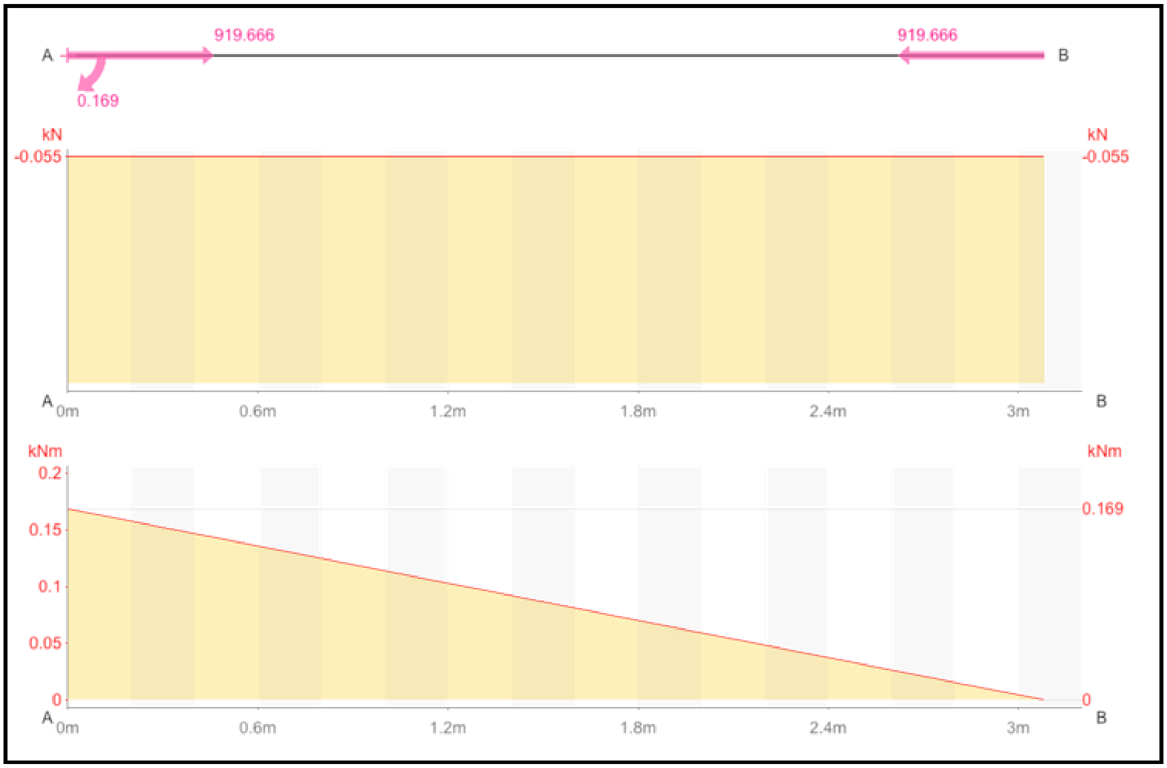
| Moment | Size |
|---|---|
| $M_A$ | 0.595 kNm |
| $M_C$ | 0.595 kNm |

Element A-B



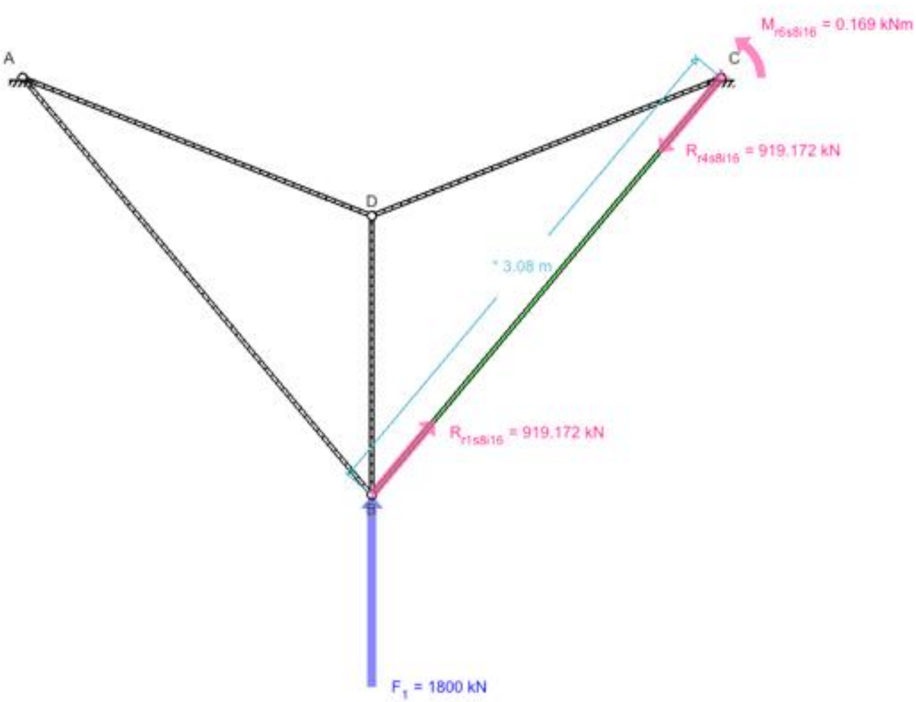

| Results | | |
|---|---|---|
| $M_{r3s7i8}$ = −0.169 kNm | $R_{r1s7i8}$ = 590.464 kN | $R_{r2s8i22}$ = 390.486 kN |
| $M_{r3s8i16}$ = 0.000 kNm | $R_{r1s8i16}$ = 590.464 kN | $R_{r4s22i7}$ = 494.117 kN |
| $M_{r3s8i22}$ = 0.000 kNm | $R_{r1s8i22}$ = 0.000 kN | $R_{r4s7i8}$ = −590.464 kN |
| $M_{r6s22i7}$ = −0.427 kNm | $R_{r2s7i8}$ = −705.079 kN | $R_{r5s22i7}$ = −195.407 kN |
| $M_{r6s7i8}$ = 0.000 kNm | $R_{r2s8i16}$ = 704.435 kN | $R_{r5s7i8}$ = 705.079 kN |

Shear Force and Moment Diagrams



A
919.666
919.666
B
0.169
kN
-0.055
kN
-0.055
A 0m
0.6m
1.2m
1.8m
2.4m
3m
B
kNm
kNm
0.2
0.15
0.1
0.05
0
0.169
0
A 0m
0.6m
1.2m
1.8m
2.4m
3m
B

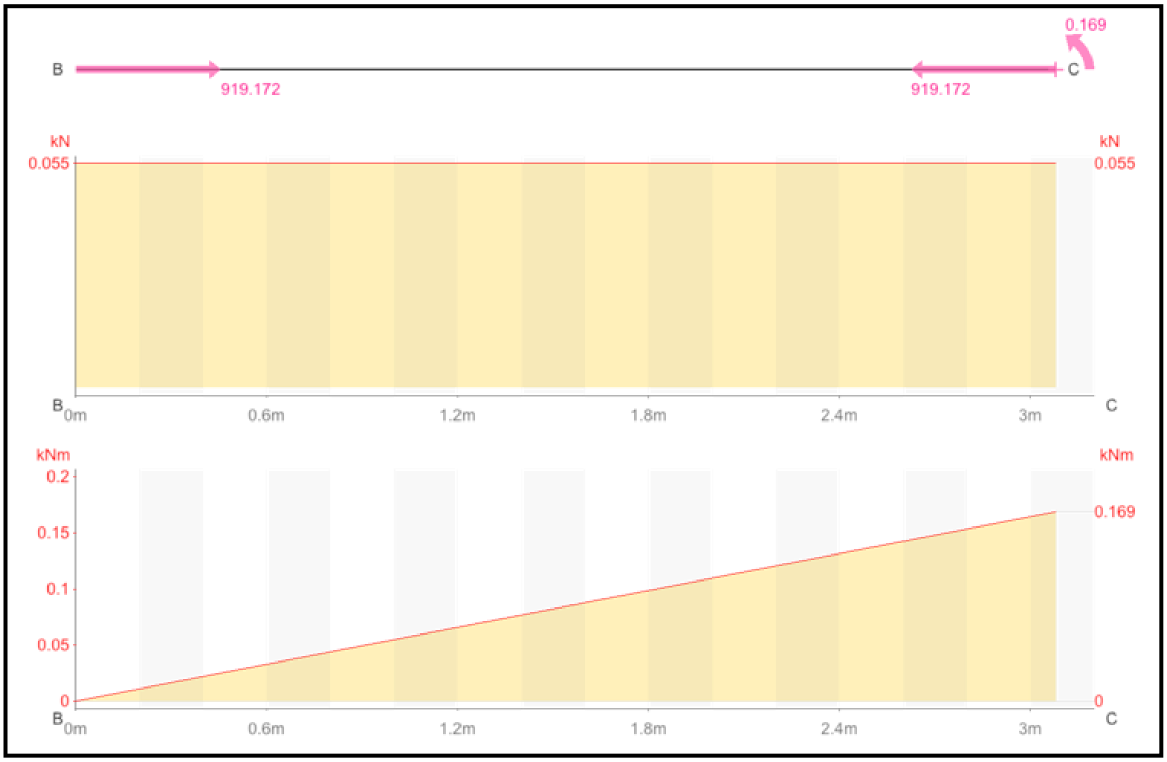

Element B-C



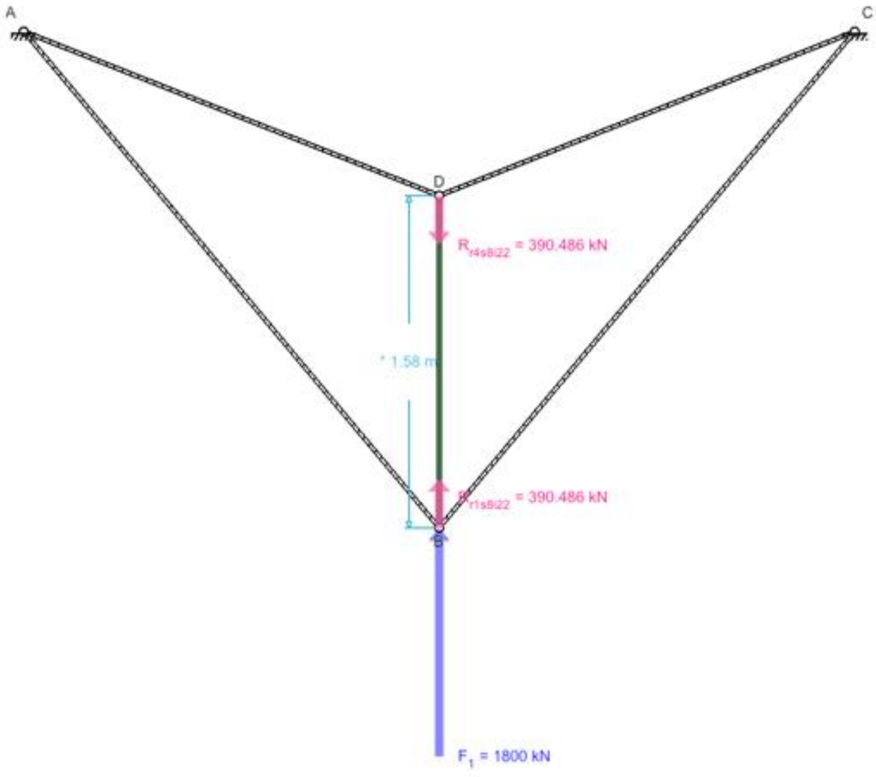
A
C
D
$M_{r6s8i16}$ = 0.169 kNm
$R_{r4s8i16}$ = 919.172 kN
3.08 m
$R_{r1s8i16}$ = 919.172 kN
$F_1$ = 1800 kN

| Results | | |
|---|---|---|
| $M_{r3s8i16}$ = 0.000 kNm | $R_{r1s8i16}$ = 590.464 kN | $R_{r4s7i8}$ = −590.464 kN |
| $M_{r3s8i22}$ = 0.000 kNm | $R_{r1s8i22}$ = 0.000 kN | $R_{r4s8i16}$ = −590.464 kN |
| $M_{r6s22i16}$ = 0.427 kNm | $R_{r2s8i16}$ = 704.435 kN | $R_{r5s22i16}$ = −195.079 kN |
| $M_{r6s7i8}$ = 0.000 kNm | $R_{r2s8i22}$ = 390.486 kN | $R_{r5s7i8}$ = 705.079 kN |
| $M_{r6s8i16}$ = 0.169 kNm | $R_{r4s22i16}$ = −494.117 kN | $R_{r5s8i16}$ = −704.435 kN |

Shear Force and Moment Diagram



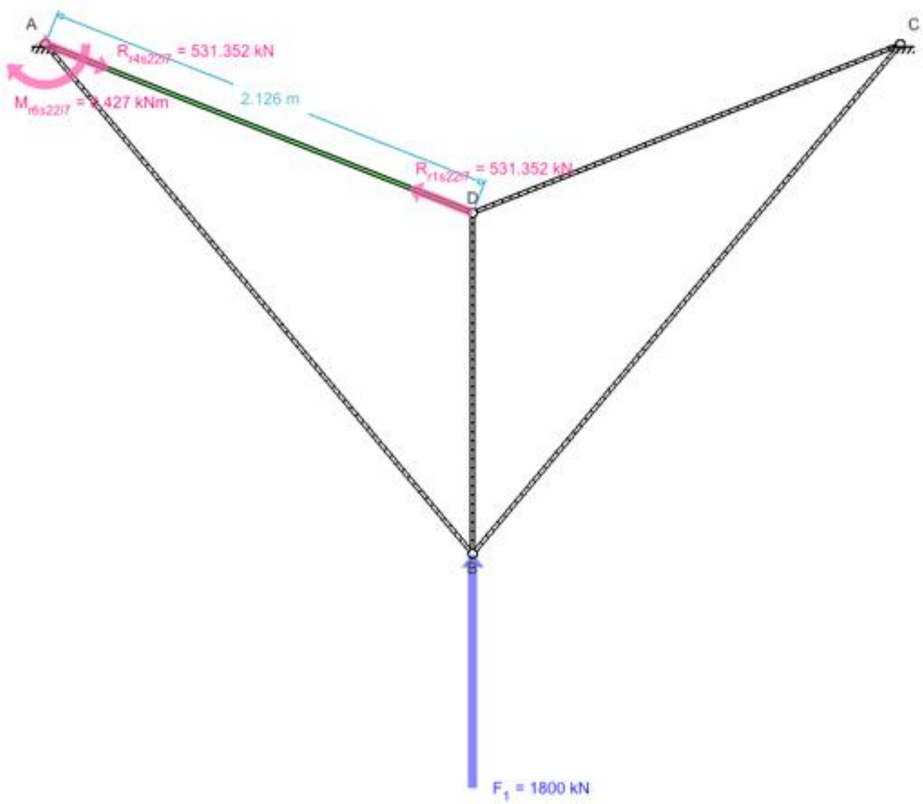
Element B-D




| Results | | |
|---|---|---|
| $M_{r3s22i16}$ = 0.000 kNm | $R_{r1s22i16}$ = 494.117 kN | $R_{r2s8i16}$ = 704.435 kN |
| $M_{r3s22i7}$ = 0.000 kNm | $R_{r1s22i7}$ = −494.117 kN | $R_{r2s8i22}$ = 390.486 kN |
| $M_{r3s8i16}$ = 0.000 kNm | $R_{r1s8i16}$ = 590.464 kN | $R_{r4s7i8}$ = −590.464 kN |
| $M_{r3s8i22}$ = 0.000 kNm | $R_{r1s8i22}$ = 0.000 kN | $R_{r4s8i22}$ = 0.000 kN |
| $M_{r6s7i8}$ = 0.000 kNm | $R_{r2s22i16}$ = 195.079 kN | $R_{r5s7i8}$ = 705.079 kN |
| $M_{r6s8i22}$ = 0.000 kNm | $R_{r2s22i7}$ = 195.407 kN | $R_{r5s8i22}$ = −390.486 kN |

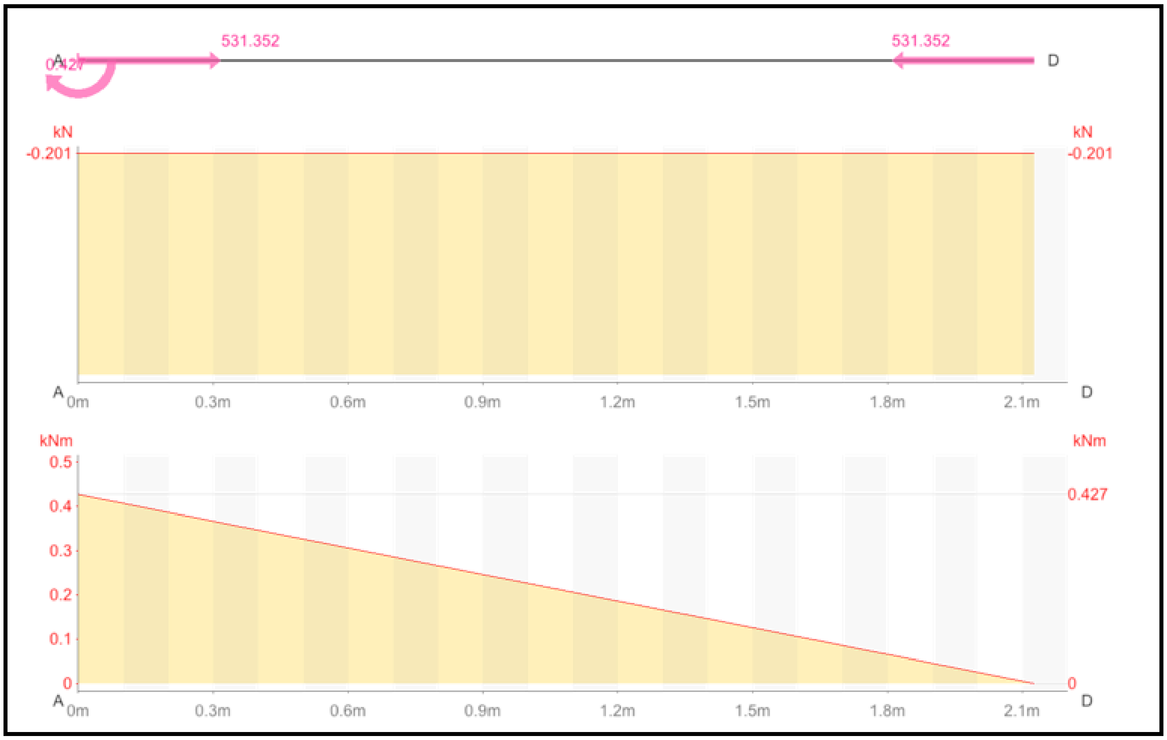
Shear Force and Moment Diagram


Element D-A

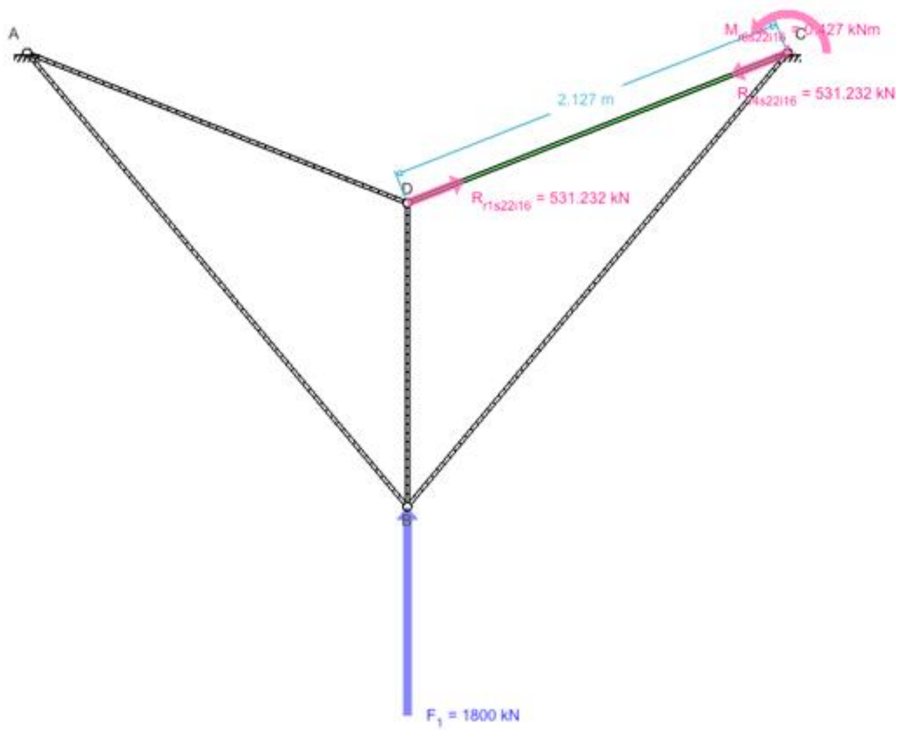


| Results | | |
|---|---|---|
| $M_{r3s22i16} = 0.000$ kNm | $R_{r1s22i16} = 494.117$ kN | $R_{r2s7i8} = -705.079$ kN |
| $M_{r3s22i7} = 0.000$ kNm | $R_{r1s22i7} = -494.117$ kN | $R_{r4s22i7} = 494.117$ kN |
| $M_{r3s7i8} = -0.169$ kNm | $R_{r1s7i8} = 590.464$ kN | $R_{r4s8i22} = 0.000$ kN |
| $M_{r6s22i7} = -0.427$ kNm | $R_{r2s22i16} = 195.079$ kN | $R_{r5s22i7} = -195.407$ kN |
| $M_{r6s8i22} = 0.000$ kNm | $R_{r2s22i7} = 195.407$ kN | $R_{r5s8i22} = -390.486$ kN |

Shear Force and Moment Diagram

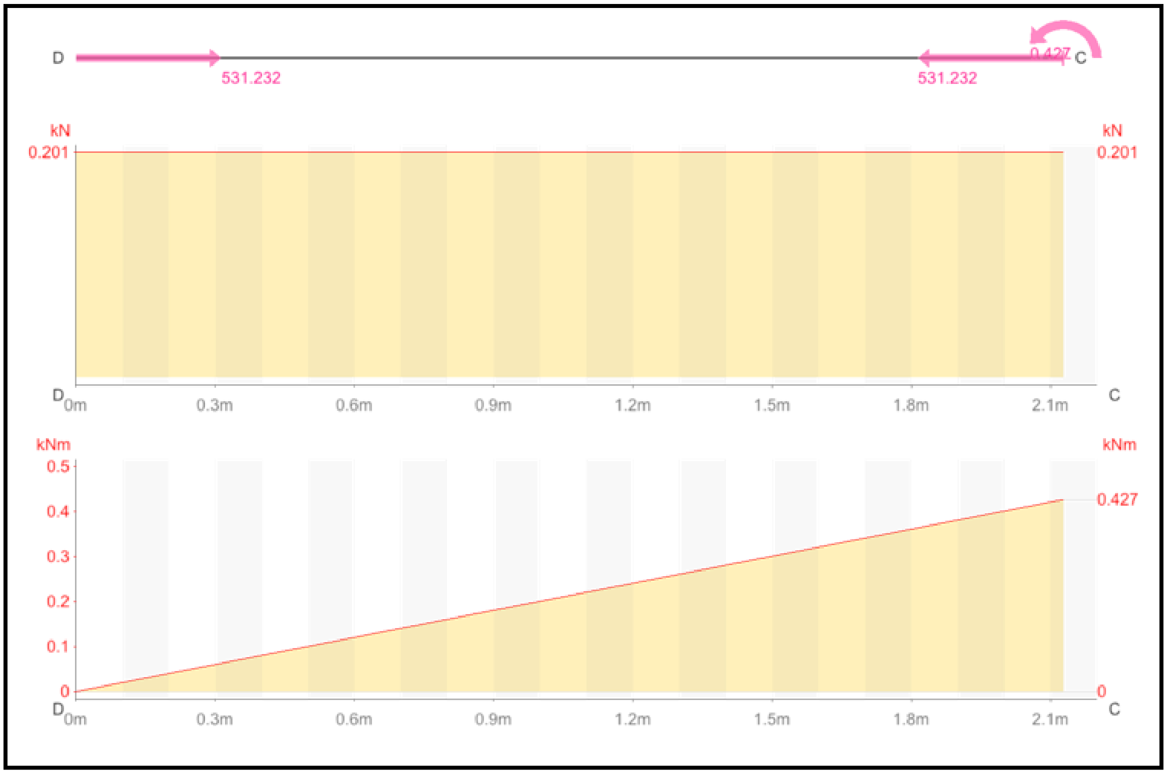


Element D-C




| Results | | |
|---|---|---|
| $M_{r3s22i16} = 0.000$ kNm | $R_{r1s22i16} = 494.117$ kN | $R_{r4s8i16} = -590.464$ kN |
| $M_{r3s22i7} = 0.000$ kNm | $R_{r1s22i7} = -494.117$ kN | $R_{r4s8i22} = 0.000$ kN |
| $M_{r6s22i16} = 0.427$ kNm | $R_{r2s22i16} = 195.079$ kN | $R_{r5s22i16} = -195.079$ kN |
| $M_{r6s8i16} = 0.169$ kNm | $R_{r2s22i7} = 195.407$ kN | $R_{r5s8i16} = -704.435$ kN |
| $M_{r6s8i22} = 0.000$ kNm | $R_{r4s22i16} = -494.117$ kN | $R_{r5s8i22} = -390.486$ kN |

Shear Force and Moment Diagram




So after acquiring this information we did our own calculation of the force on each material based on the law of

$$\sigma = \frac{F}{A}$$

$$\sigma = normal\ stess$$
$$F = force$$
$$A = area$$

And we calculated this result

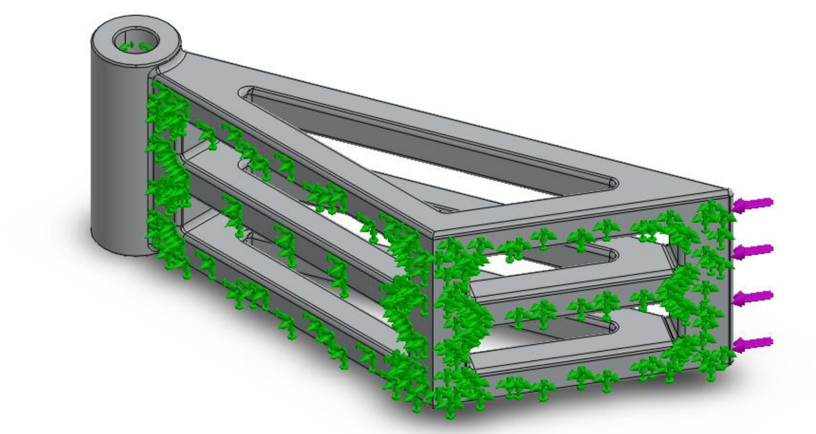
| Single Force Study | | |
|---|---|---|
| **Member** | **Reaction Force kN** | **Reaction Moment kN-m** |
| **A-B** | 532 | 0.427 |
| **A-D** | 920 | 0.189 |
| **D-B** | 391 | 0 |
| **C-B** | 532 | 0.189 |
| **C-D** | 920 | 0.189 |

| The Over All Study | | | | |
|---|---|---|---|---|
| **Member** | **Cross-sectional Area ($m^2$)** | **Reaction Force kN** | **σ kPa** | **σ MPa** |
| **A-B** | 0.0076 | 177.33333 | 23333.33 | 23.33333 |
| **A-D** | 0.0076 | 306.66667 | 40350.88 | 40.35088 |
| **D-B** | 0.0076 | 65.166667 | 8574.561 | 8.574561 |
| **C-B** | 0.0076 | 177.33333 | 23333.33 | 23.33333 |
| **C-D** | 0.0076 | 306.66667 | 40350.88 | 40.35088 |

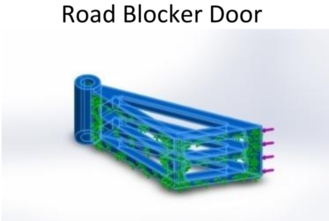
### 3.8. SolidWork force analysis:

We used SolidWork to do us the force analysis and we chose the front of the door for the program to do the analysis at since it's where the impact will happen, the report is as follow:

## Model Information



**Model name** Road Blocker Door Impact Study
**Current Configuration:** Front Impact

| Solid Bodies | | | |
|---|---|---|---|
| | **Treated As** | **Volumetric Properties** | |
| Road Blocker Door  | Solid Body | **Mass:728.537 kg**<br>**Volume:0.262064 $m^3$**<br>**Density:2780 $kg/m^3$**<br>**Weight:7139.66 N** | |

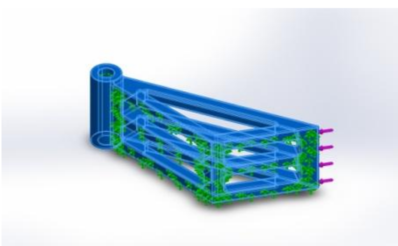
## Study Properties

| | |
|---|---|
| **Analysis type** | Static |
| **Mesh type** | Solid Mesh |
| **Thermal Effect:** | On |
| **Thermal option** | Include temperature loads |
| **Zero strain temperature** | 298 Kelvin |
| **Compute free body forces** | On |

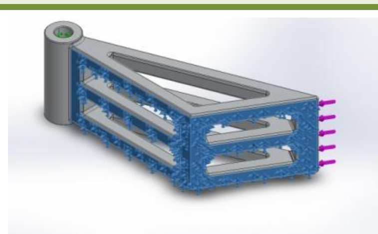
## Units

| Unit system: | SI (MKS) |
|---|---|
| Length/Displacement | mm |
| Temperature | Kelvin |
| Angular velocity | Rad/sec |
| Pressure/Stress | $N/m^2$ |

## Material Properties

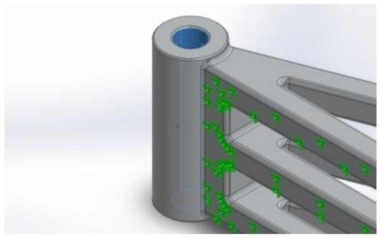
| Model Reference | Properties | Components |
|---|---|---|
|  | **Name:** 2024-T3<br>**Model type:** Linear Elastic Isotropic<br>**Default failure criterion:** Max von Mises Stress<br>**Yield strength:** 3.45e+008 $N/m^2$<br>**Tensile strength:** 4.85e+008 $N/m^2$<br>**Elastic modulus:** 7.24e+010 $N/m^2$<br>**Poisson's ratio:** 0.33<br>**Mass density:** 2780 $kg/m^3$<br>**Shear modulus:** 2.8e+010 $N/m^2$<br>**Thermal expansion coefficient:** 2.32e-005 /Kelvin | Road Blocker Door |

## Loads and Fixtures

| Fixture name | Fixture Image | Fixture Details |
|---|---|---|
| Fixed-1 |  | **Entities:** 2 faces<br>**Type:** Fixed Geometry |

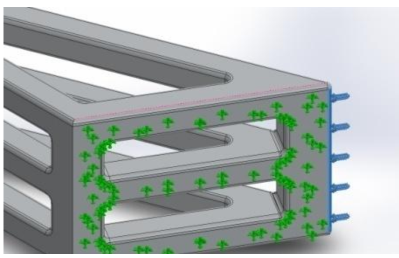
**Resultant Forces**

| Components | X | Y | Z | Resultant |
|---|---|---|---|---|
| Reaction force(N) | 461091 | -18.1421 | -770102 | 897586 |
| Reaction Moment(N-m) | 0 | 0 | 0 | 0 |

| | | |
|---|---|---|
| Fixed-2 |  | **Entities:** 1 face<br>**Type:** Fixed Geometry |

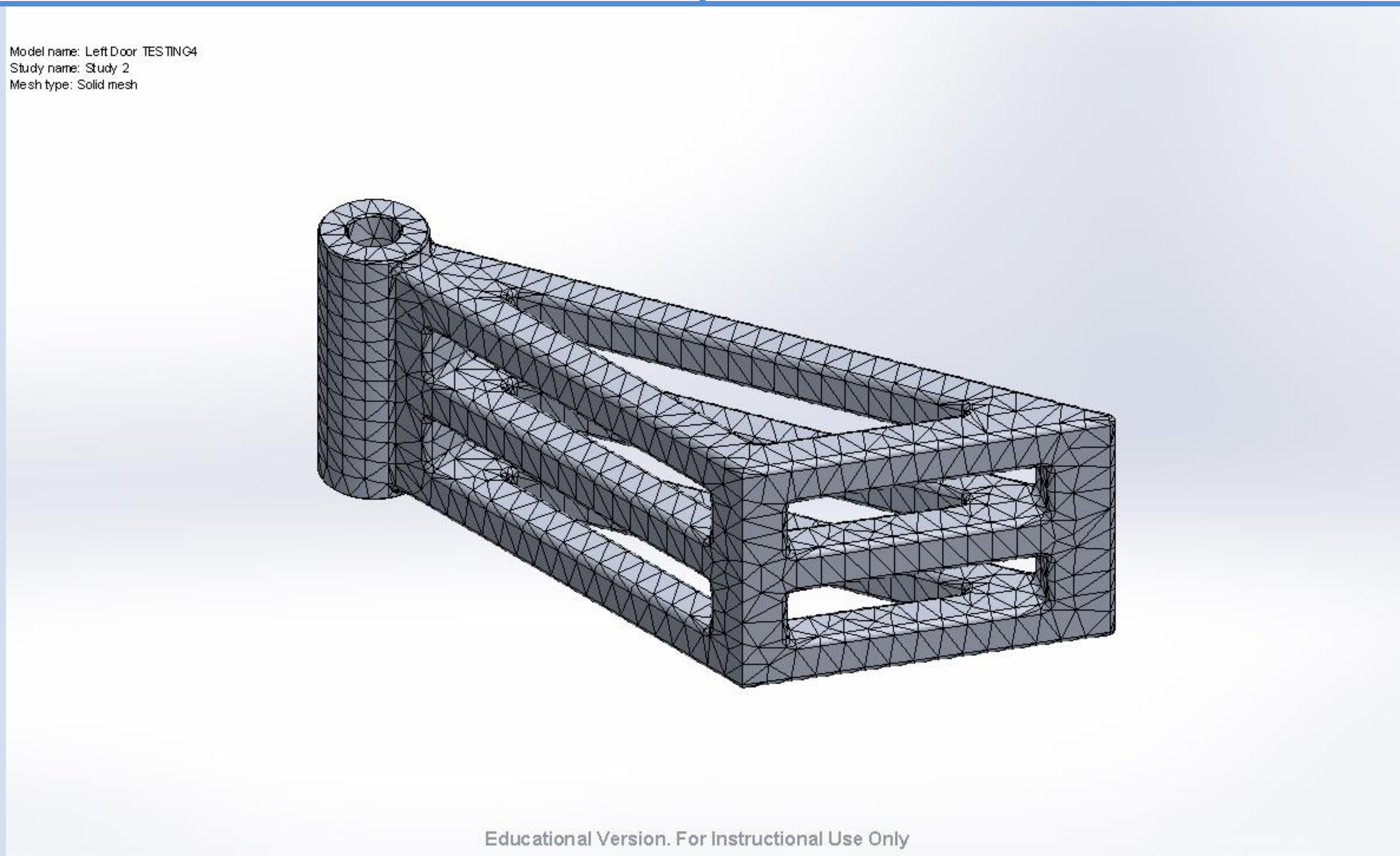
**Resultant Forces**

| Components | X | Y | Z | Resultant |
|---|---|---|---|---|
| Reaction force(N) | 2442.12 | 9.64207 | -1349.73 | 2790.3 |
| Reaction Moment(N-m) | 0 | 0 | 0 | 0 |

| Load name | Load Image | Load Details |
|---|---|---|
| Force-1 |  | **Entities:** 1 face<br>**Reference:** Edge< 1 ><br>**Type:** Apply force<br>**Values:** -900000 N |

## Mesh Information - Details

| | |
|---|---|
| **Total Nodes** | 30105 |
| **Total Elements** | 16073 |
| **Maximum Aspect Ratio** | 73.163 |
| **% of elements with Aspect Ratio < 3** | 3.91 |
| **% of elements with Aspect Ratio > 10** | 22.4 |
| **% of distorted elements(Jacobian)** | 0 |



## Resultant Forces

### Reaction Forces

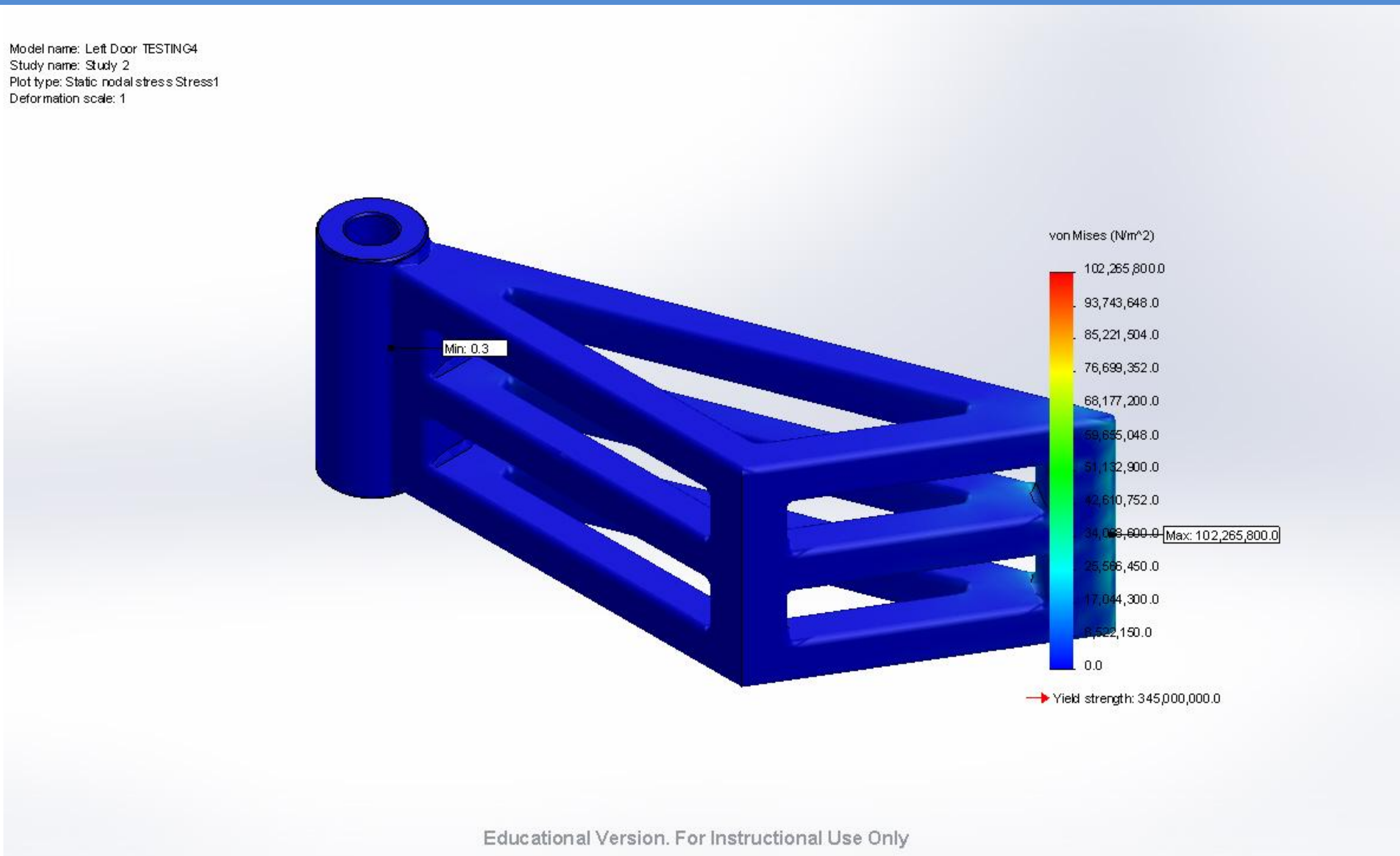
| Selection set | Units | Sum X | Sum Y | Sum Z | Resultant |
|---|---|---|---|---|---|
| Entire Model | N | 463533 | -8.50004 | -771451 | 900000 |

### Reaction Moments

| Selection set | Units | Sum X | Sum Y | Sum Z | Resultant |
|---|---|---|---|---|---|
| Entire Model | N-m | 0 | 0 | 0 | 0 |

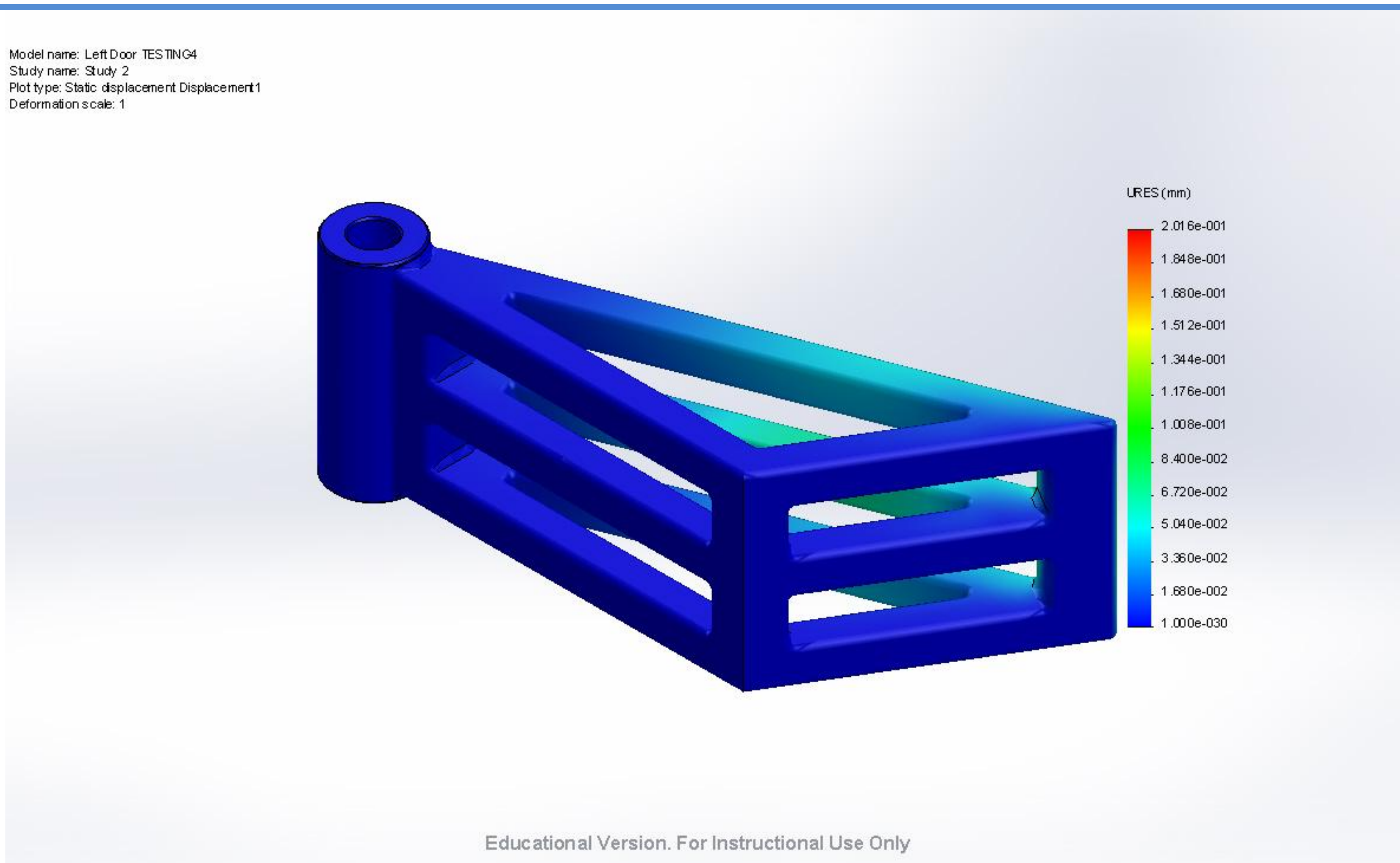
## Study Results

| Name | Type | Min | Max |
|---|---|---|---|
| Stress1 | VON: von Mises Stress | 0 $N/m^2$<br>Node: 8413 | 1.02266e+008 $N/m^2$<br>Node: 12470 |



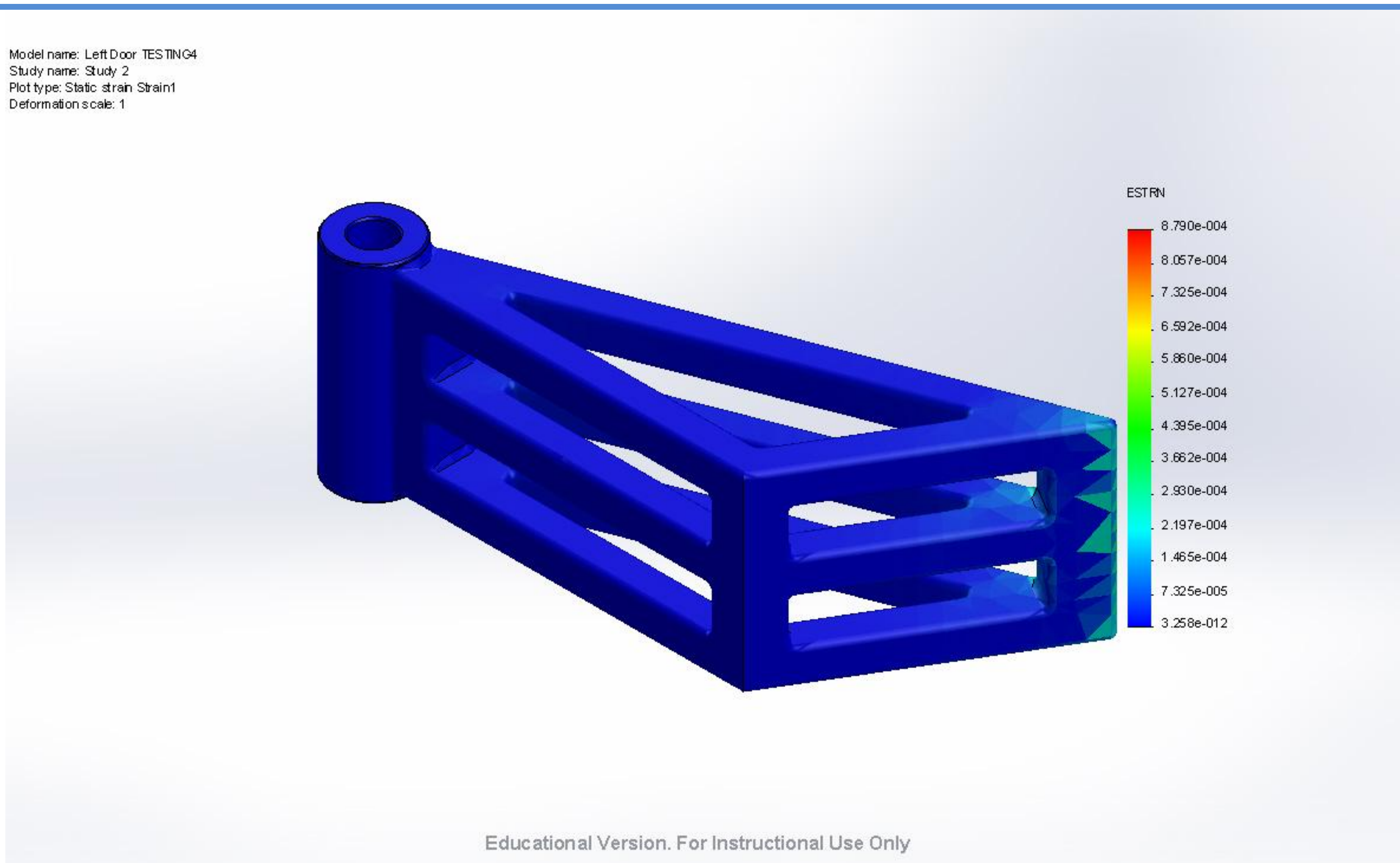

Road Blocker Door Impact Study (2-Stress-Stress1)

| Name | Type | Min | Max |
|---|---|---|---|
| Displacement1 | URES: Resultant Displacement | 0 mm<br>Node: 1 | 0.201599 mm<br>Node: 8953 |



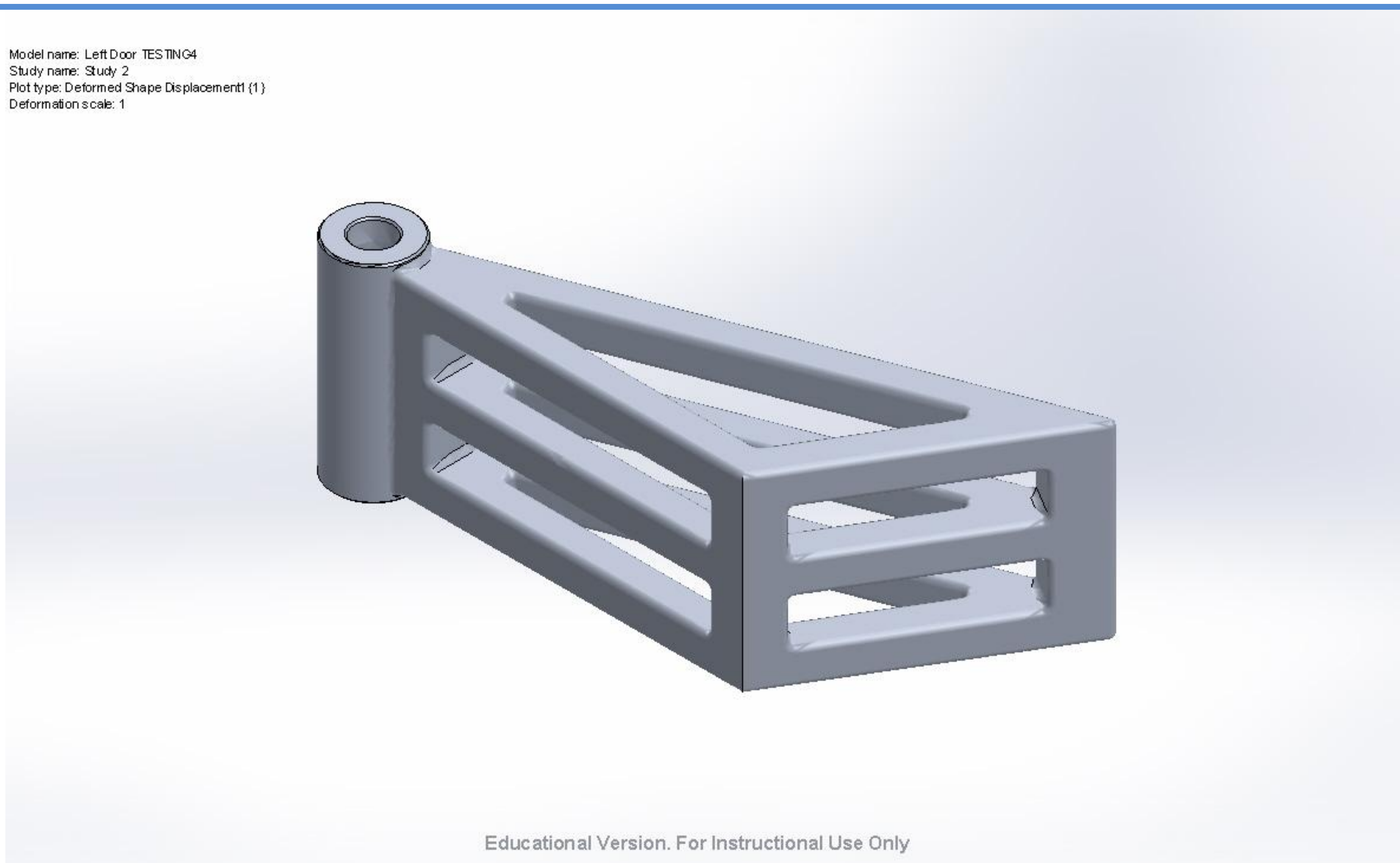

Road Blocker Door Impact Study 2-Displacement-Displacement1

| Name | Type | Min | Max |
|---|---|---|---|
| Strain1 | ESTRN: Equivalent Strain | 3.25811e-012<br>Element: 8306 | 0.000878978<br>Element: 11271 |



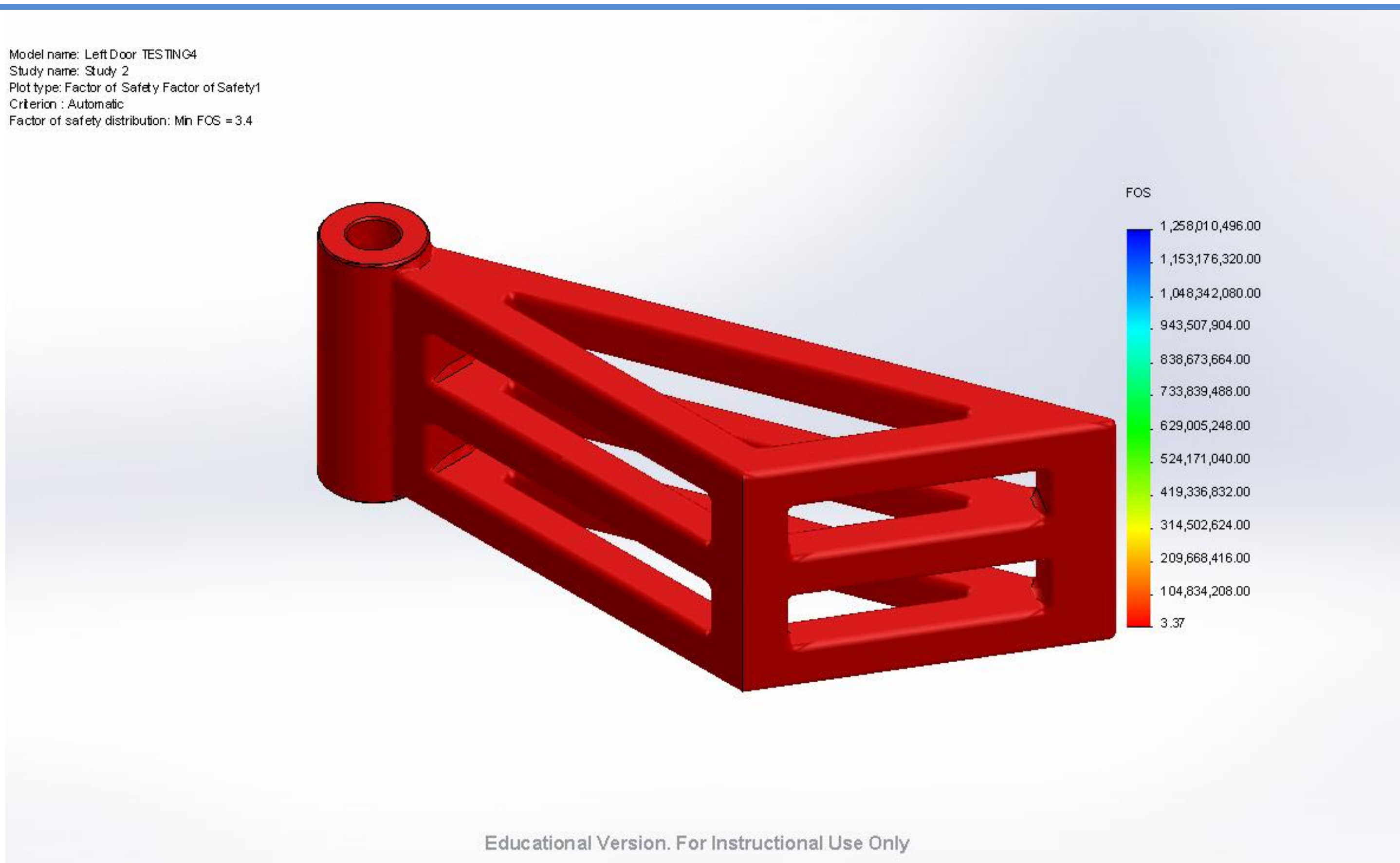
Road Blocker Door Impact Study 2-Strain-Strain1

| Name | Type |
| --- | --- |
| Displacement1{1} | Deformed Shape |



Road Blocker Door Impact Study 2-Displacement-Displacement1{1}

| Name | Type | Min | Max |
|---|---|---|---|
| Factor of Safety1 | Automatic | 3.37356<br>Node: 12470 | 1.25801e+009<br>Node: 27835 |




Road Blocker Door Impact Study - Factor of Safety

3.9. Estimated worth:

After having figure out the material we will use for the door and other parts we could've calculate an estimated calculation for the material. And the calculation is as follow

| Material | Weight (Ton) | Price/ton (US $) | Total Price | |
|---|---|---|---|---|
| | | | US $ | SAR |
| **2024-T9** | 1.45 | 1000 | 1457 | 5463 |
| **Stainless steel** | 0.84 | 3300 | 2772 | 10395 |
| **Concrete** | 0.72 | 134 | 97 | 364 |

That give a total of 4326$ (16222 SR) which is the worth of the material only and due to time constrains we couldn't take an accurate estimated price for the manufacturing process. We searched extensively for prices of competitive hydraulic road blockers and we found out that the average prices of road blockers in the market is 9000$ (33750 SAR), so after estimation we will be having a very competitive price in the market, a price that will give us an advantage especially that the project will be manufactured inside Saudi Arabia which will give us an economical advantage.

## 4. Conclusion:

This project gave us the chance to really test our knowledge and apply our learning; we used the knowledge gained from every engineering and non engineering course we took. We finally came with this project that we are proud of, a new innovation of a road blocker that meets the international requirement and even exceeds it, and we applied all of our learning to choose the idea, design, material, and every other aspect of the project. We hope one day this project see the light, it was the seed of our work and knowledge.

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