Universidad de **Valladolid**

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ESCUELA DE INGENIERIAS INDUSTRIALES

Grado en Ingeniería Mecánica

Mecanismo elevador de los contenedores soterrados

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TFG REALIZADO EN PROGRAMA DE INTERCAMBIO

TÍTULO: Lifting Mechanism of the Underground Containers

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En el TFG realizado fue diseñado el mecanismo de elevación de los contenedores soterrados, el cual permitía elevar una mayor cantidad de carga en un menor tiempo de funcionamiento gracias al mecanismo doble de tijera diseñado.

Dicho mecanismo funcionaba gracias a dos cilindros para los cuales fue calculado toda la instalación hidráulica que requería el diseño, también fue calculadas las fuerzas y tensiones resultantes en cada barra del mecanismo para poder diseñar adecuadamente cada unión entre barras.

Mediante el software de diseño 3D (CATIA), toda la estructura, al igual que los elementos auxiliares de la instalación fueron modelados, también fue realizado el proceso de manufactura de una de las piezas mediante fresado.

Por ultimo un estudio económico sobre la factibilidad del proyecto fue calculado y expuesto.

Palabras Clave.

Mecanismo de tijeras, cilindros hidráulicos, gran capacidad, menor tiempo, medio ambiente.

Picture List

Table List

1. Introduction

Underground containers are getting popular in the main cities of the world however they continue suffering some problems related with the design or the facilities that these can offer.

Everybody knows that this kind of technology can improve the quality of a city becoming it in a greener and cleaner city, it has also some advantages since these kind of technology avoid people doing vandalism cause of the burying garbage, beside of this, the underground containers avoid the bad smell that the organic garbage makes when it is shined by the sunbeams or warmed by the own heat of the city.

In spite of the advantages, underground containers have still some kind of disadvantages related with several aspects as could be the load that the containers can support or the space that this new construction requires in the underground. It is common find troubles related with the time of the lifting and emptying of the containers, nevertheless all of these troubles can be removed studying a new design and introducing few improvements in the mechanism and structure of the containers, this is the target of this project.

According to the European normative every country must develop and implant these kind of environmental technology before the next ten years however most of the hottest countries have already implanted it before the accorded time in order to avoid the bad smell in the warmest months.

In the current project it has been studied the different mechanism and kind of underground containers in order to develop one of them which would be able to improve the oldest ones since they are obsolete in many aspects as could be specially the admissible load and the times of lifting, due to this the study includes all the calculations and possible designs which let my own mechanism get better facilities than the others.

Anyways this project can be carried out in every city which there are not underground containers yet, the popularity of this technology will increase during the following years so it must be had in mind that while the popularity is increasing and the European normative is getting more and more strict, there is no chance of refusing this new technology.

Another important advantage in this project is related with the financing that it can be gotten thanks to the local government and the European Union. As long as I know, many towns in Spain have received a grant for the installation of this new technology that avoids too many environmental troubles.

2. Analysis of similar designs

1. Loading systems

If we speak about the kinds of containers we must have in mind two important differences between them, on the one hand we can find the rubbish containers that we have had in the past and which we still have in many cities, however some years ago a law was proclaimed which said that in few years all the outside containers should be removed in order to replace them for underground containers.

This is one of the reasons why the underground containers must be developed and improved continuously.

If we study the differences between all of them it is necessary to have in mind the different kinds of containers as far as collection mechanism refers, most of them are lifted cause of a hydraulic system and afterwards the garbage can be put in the garbage truck, but this mechanism can vary between the different kind of containers so we will analyze the different cases of collecting the garbage.

1. Side loading systems

This kind of garbage collection system consists like everyone else in a lifting mechanism that let take out the containers to the work zone where you can pick up them in order to collect the garbage in the truck, the main difference that we can find is the kind of truck that you need to do this kind of collection since if you pretend to collect the garbage in an automatic way, it is necessary to have in mind several disadvantages of this system.

In spite of the fact that it is getting popular in several countries, there are many disadvantages that avoid implant it as well as other kind of system, this disadvantage is related with the automation of the collection, this must cause a renovation in every trucks of the city that requires this kind of collection since the side automatic system can be only used by a different kind of truck´s mechanism as we can see in the following picture.

Pic 1. Side loading garbage truck

As we can see in the picture the garbage truck has a mechanism in the right side of the truck which is able to pick up the containers that previously has been lifted by the lifting mechanism.

The collection´s process follows several steps, first of all the garbage truck must get near the containers in order to collect it, afterwards the lifting mechanism of the main containers plant lift the underground containers until a surface level, in this way the mechanism of the garbage truck can pick up the containers from the platform to the truck in an automatic way.

In spite of the fact that this kind of system allows working without the manual job, it has yet several problems due to the difficulty involved in the process since most of the times, this process takes a longer time than a manual process.

That problem before is the main reason why I have not chosen this system as my thesis development, such a slow system cannot be carried out in a capital city as Vilnius, beside of this, there is another problem related with the requirement of the renew in every truck which are nowadays working in the city, in fact this development would lead to more spending than the benefit that is achieved.

2. Dual hook crane system

This kind of collection is done by truck equipped with a pen, which rises the trash box and the container body on it, and later convert their content with the opening of the floodgates, this process can be apply in different kind of containers as could be paper, glass or organic containers. It does not matter the kind of container that the crane will lift since the process will be the same.

It does not matter the weight that the crane will lift, always working between reasonable limits, however between these limits the crane can lift whatever weight without excessive problems, the real problem appear when there is more weight than in the usual case, the hooks and the ring will suffer more friction what will become in large

wear that can provokes the breakdown in the mechanism and preventing its normal and daily use

The trucks which this process requires are completely different to the side loading collection´s trucks since it would be necessary to count with these trucks. In the following picture can be seen the mechanism of dual hook.

Pic 2. Mechanism of lifting (Hooks and rings)

Nowadays much of the cities have this crane garbage truck so the main disadvantage of these containers is not here since every city could improve their trucks to this kind of them. The main disadvantage is the long time which is taken when the crane is moving until you can grab the hook and the container´s rings.

Pic 3. Garbage truck picking up the containers thanks to a crane

Before lifting the container the crane will take a long time, in spite of the fact that the truck does not need to approach millimeter to the containers what makes that this step does not take a long time. The problem appear in the next step since when the driver try to approach the crane to the dual rings of the container, it must be too precise then, the drive who controls the crane must be such an experienced driver in order to make shorter the process, unless it would take a long time.
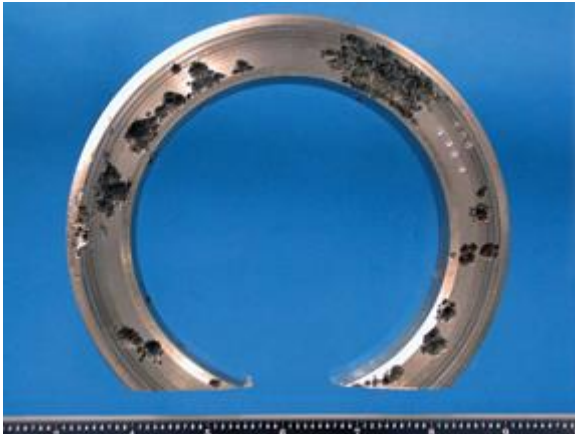
Pic 4. Ring which has suffered the effects of corrosion

Another issue on which it is harder to act is related with the rings and the deterioration due to the environmental agents and the friction with the hook of the crane. When the crane grabs the ring too many times, there will be a friction which helped of the atmospheric effect can produce breaking of the rings. In wet environmental as for example Lithuania, this effect is more likely to occur cause of metal oxidation occurs more easily when there is an oxidation corrosion, later that leads to the origin of small micro-breakages which over time can produce the service failure.

The problems of the necessary change and renovation of the trucks, the longtime of the process and the problems related with the corrosion the problems and friction in the rings of the trash box of the containers makes that this system has been rejected for my thesis since it would not be sufficiently profitable.

3. Swing crane system

It is a variant of the above, where the truck engages only the container which is under the trash box, leaving this befallen the sidewalk while the process is carried out. The mechanism of lifting should be similar to the others system except that the trash box is shot down leaving the container above ground level.
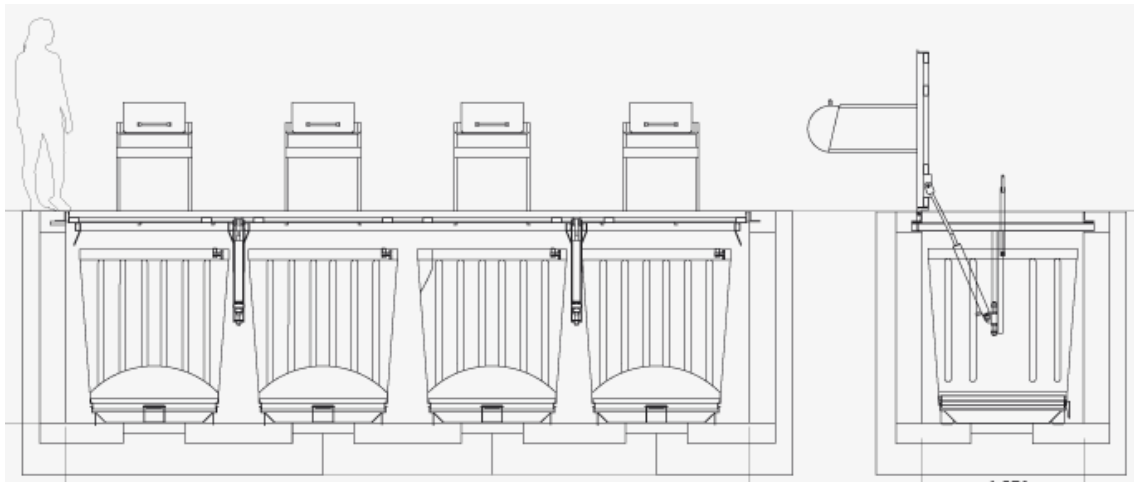
Pic 5. Movement of the container and the garbage box

As you can see in the picture above, which the process of movement of the container is shown, the container needs the help of a crane in order to deposit the garbage in the truck by opening the bottom of the container.

This system has almost the same disadvantages that the dual hook crane since you also need the crane to pick up the container what means that the process will take a longtime too, beside of this, the container can be destabilized while the process of lifting is being carried out.

The only advantage over the dual hook crane is that in this case the rings don't suffer corrosion and oxidation effects due to the fact that they are hidden under the garbage boxes and the rain or a wet environment has no impact on it, however the friction cause of the lifting process of the crane it cannot be avoided.

This system also requires a renewal of the entire existing fleet of trucks in the city since the common behind collection garbage trucks are not able to be useful since you must need a crane. This renewal requires a big invest of money so the swing crane system has several disadvantages that avoid that it could be chosen as a project to be carried out during the study of this bachelor thesis.

4. Underground compactors

This new system which is not yet developed consists in a big underground box in which the garbage is deposit in order to be compacted by a hydraulic machine, this kind of system let deposit too much garbage than others since each certain time the garbage is compacted so that the free space is increased.

A compactor has two main parts:

-An inlet of the waste, where machinery is.

-An iron box, where the waste is stored.

The residue is placed at the mouth of the compactor, where a presser plate, which is simply a metal plate, push the residue through the engine inwardly. The residue will be introduced in the iron box until it fills its interior.

Once filled, the next time the residue enter again and the pressing plate push it, all the residue begin to be compressed by the force of pressure of the machine.

In this way, the air bags will disappear and the lower volume of waste.

Pic 6. Underground Compactor

The main advantage of this system is the big load of garbage that can be deposit in it and the frequency of garbage collection by garbage trucks since this is less load than in other systems, however this system has also several disadvantages that become this system and mechanism in a not profitable one.

The main disadvantage is all the changes that this mechanism means, since the city must renew the entire fleet of garbage trucks due to the fact the truck required for the collection of this kind of garbage are what we can see in the following picture.

Pic 7. Garbage truck for compactors

These trucks also need a huge free place in order to load the containers so the civil works required is a high economic cost as well as the visual impact that is required to accommodate the prefabricated where containers are located.

This type of mechanism for these underground containers also represents a significant energy expenditure during the processes of collection, it is true that there is a kind of self-sufficient containers thanks to solar energy, although it is undergoing testing, it is ruled to be implanted in a country like Lithuania because to the few hours of sunlight during the cold months so that the overall balance makes the economic cost is higher than in other types of underground containers.

The process of lifting the compactor container takes the longest time over all the different systems studied, in spite of the fact that it is not necessary to be picked up as frequently as other systems, it is necessary to note that every time you want to discharge the waste, the mechanism must raise the compactor, after that the garbage truck will pick up trash compactor in order to download it in a landfill, during which time the ecological plant will be without compactor, or other logical solution would be replaced by another compactor.

All the above happens when the mechanism or the compactor runs smoothly, in case there is some kind of breakdown the economic cost of the repair increase highly. This mechanism is more expensive since the load that it needs to lift will be too much than in others mechanism, beside of the mechanism, the compactors are also more expensive than other systems both manufacturing and repairing.

5. Rear load system

The system is hydraulic, it can also work with a remote control, which lets the containers to grade the road to be manually removed by the operator of the service, pushing him toward the truck. The containers have wheels so that they can be pushed.

It is the most economic system cause of several reasons, first of all this system does not force the city to renew the fleet of trucks since the common trucks that work in the city are able to do the job of collecting the garbage as the garbage trucks did with the other old containers, the not underground containers.

Another advantage is the time that the lifting mechanism takes while the containers are being raised, this time is shorter than others types, however the load that you can deposit in these rear load system containers is pretty smaller than in others system, this is the unique disadvantage that we can find in this kind.

The civil work required is not too expensive since it involves an undercut in which the mechanism with the various hydraulic systems, containers and then finally boxes, where they can deposit the garbage is installed, the highest cost is the lifting mechanism, the main part for studying in this project.

Also it is necessary to study the way in which the garbage boxes will be opened since it is not the same when the rise together with the containers than when the containers open laterally.

In the first case, as the following picture shows, the garbage box is raised cause of the lifting mechanism.

Pic 9. Underground rise containers

When the hydraulic system is activated, the containers rise together with the garbage box, this system is more simple than the other one and the probability of a breakdown is

also less, however the space that it requires is higher cause of the height that the garbage box reach.

The other possibility of system is the laterally opening, this a more sophisticated and difficult to carry out, beside of this, if you have a breakdown the repair cost will be higher, it does not need such a high space than the other one, however you need more space in the sidewalk.

Pic 10. Side-opening underground containers

Finally the choice is for the vertical opening since it is easier to be designed and also to be carried out, the possibilities of breakdown are less than in the side-opening system. In spite of the fact that it is necessary a higher space in this system, from my point of view it is more uncomfortable when an object gets in the way of the own pedestrians than when an object is raise without obstructing pedestrians nothing else than the part already occupied at ground level, so simply creates a little ugly and unpleasant visual effect.

The last point to be discussed is the system of activation of the lifting mechanism, the mechanism will be able to rise cause of the hydraulic mechanism that allows the fluid flows along the pipes. Thanks to the hydraulic force applied over the cylinders of the mechanism, the mechanism can lift all containers and also garbage.

Since it is possible to choose between a remote control and a manual activation, we opted for the remote control mode, as with the simple action of pressing a button the mechanism will raise the containers without the need for the hydraulic connection from the garbage truck own.

It also allows an improvement with respect to time of up and down the mechanism itself and it can be activated faster than if the hydraulic hose mode connected to the garbage truck is used.

Pic 11. Remote control of opening containers

The mechanism´s structure will be designed in order to make the process of raising and lowering the containers as quickly as possible, this is achieved with a light structure but at the same time one that will not break when the full weight were on load and one which supports the efforts of tension.

As conclusion, I have chosen to design a lifting mechanism using a light steel as material which will be lifted thanks to a remote control, this remote control can activate the mechanism from the own truck.

The containers that it will contain will be raise vertically in order to avoid the obstructions on the sidewalk and the garbage truck will pick up the garbage with a rear load system.

This kind of collection system and the lifting mechanism has been chosen in this way in order to get the most economical-useful system, all the aspects as could be the required space, lifting time, maximum load and lifting height has been having in mind.

2. Analysis of cylinders

To develop the strength to raise the platform has been chosen the system of the hydraulic cylinder since they are elements capable of producing work by moving a linear acting load. There is a plunger located inside the cylinders which is pushed by the fluid causing the stem to move. Although there are several types cylinder, the most important are single-acting cylinders and double effect.

1. Single-acting cylindres

The work is done only in one movement direction, one spring let the plunger go back to the starting position. Some seals are placed between the piston and his plunger in order to prevent leakage of fluid between the piston and liner, they are made with a flexible material which is able to adapt to the walls of the liner, avoiding leakage.

The single-acting cylinders are only used when the force required and the rectilinear motions are small because the coil spring restricts movement. It is recommended that the stroke will not exceed 3 times the diameter. The typical hydraulic jack is a single-acting cylinder.

2. Double effect cylinders

These cylinders work in both directions, they don´t need spring and they can make longer strokes beside of placing the plunger in whichever intermediate position. The area of the rear face is less than that of the front face, then for the same pressure forces will be different. To avoid this problem, they are constructed with double-acting cylinders and double rod.

In order to choose the hydraulic cylinder required for the scissor mechanism, we have to have in mind the following parameters:

- Dimensions of both compressed and extended piston
- Stroke of the plunger
- Minimum diameter of the plunger in order to avoid buckling
- Working pressure of the fluid
- Wall cylinder thickness

3. Construction Calculations

1. Excavation

When an underground container´s project is going to be built, there are many parts in the project that must be studied before starting the building. The assembly of the project is composed by several parts that are related directly with the lifting machines, however before starting with the design of the mechanism it is totally necessary to dig a hole in the ground in which all the assembly is going to be hidden during the repose position.

There could be some excavations in which water can enter in the dig, so this wet surface would be removed as soon as possible and after this be replaced with concrete, also the unexpected places, as can be holes from stones extracted must be filled with concrete.

The trench walls must be vertical and clean to avoid falling stones, filling in concrete. The fund will be clean, tamped and perfectly horizontal before to proceed with concrete filling.

We need to know the free space that I have for the mechanism design, if the space for the containers can not be more than **26.5m³**, I have to choose some values for the measures that allows that the volume will not be bigger than that.

$Lenght$: **5970** mm
$Width$: **1960** mm $\quad Volume = L \times W \times H = \textbf{26.56} \textbf{m}^3 \, of\ free\ space$
$Height$: **2270** mm

These values are enough in order to build a space with that volume and beside of this, the precast will be designed with 90mm width walls of concrete so it is not such a difficult task calculate the total dimensions of the sand excavated in order to place the precast.

$Dimensions\ of\ the\ cube\ of\ sand\ excavated$:

$Lenght = 5970 + 2 * 90 = \textbf{6150} \textbf{mm}$
$Width$: $1960 + 2 * 90 = \textbf{2140} \textbf{mm}$
$Height$: $2270 + 90 = \textbf{2360} \textbf{mm}$

$$Volume = L \times W \times H = \textbf{31.06} \textbf{m}^3 \, of\ ground\ excavated$$

After this excavation of the main hole, there are also two holes in which the cylinders will be located so for this reason we have to calculate also the volume of both holes.

$Lenght$: **750** mm
$Width$: **450** mm $\quad Volume = L \times W \times H = \textbf{0.24} \textbf{m}^3 \, of\ cylinder\ hole$
$Height$: **700** mm

The dimensions of the hole excavated will be bigger since we must keep in mind that it should be reinforced with concrete so the measures will increase.

$Lenght: 750 + 2 * 90 = \textbf{930mm}$
$Width: 450 + 2 * 90 = \textbf{630mm}$
$Height: \textbf{700mm}$ The height won´t increase.

$$Volume = L \times W \times H = \textbf{0.41m}^3 of\ ground\ excavated$$

Since there is two holes, and one big cube excavated, the total amount will be:

$Total\ amount = 2 * 0.41 + 31.06 = \textbf{31.88m}^3$

If we want to study approximately how much concrete is required for this case, we just have to know the volume that the precast occupies.

The quantity of volume that is required to be excavated is around **32m³.**

This is the volume that let install the lifting mechanism which lifts 4 big containers, we must know that beside of the lifting machines, the containers and the structure which holds them have to fit in the free space of the cube.

After the excavation is necessary to strengthen the walls with concrete, this precast concrete pit is made of H-25 concrete and with an armature formed by steel frame S-275.

The average strength of precast concrete and the steel as well according to the control quality is around 420 Kg./cm² after 7 days of curing, which gives them high resistance to shock, breakages and even fire, this strength is cause of the mix of steel and concrete, which assures that the walls are not going to be ruined during the shelf life.
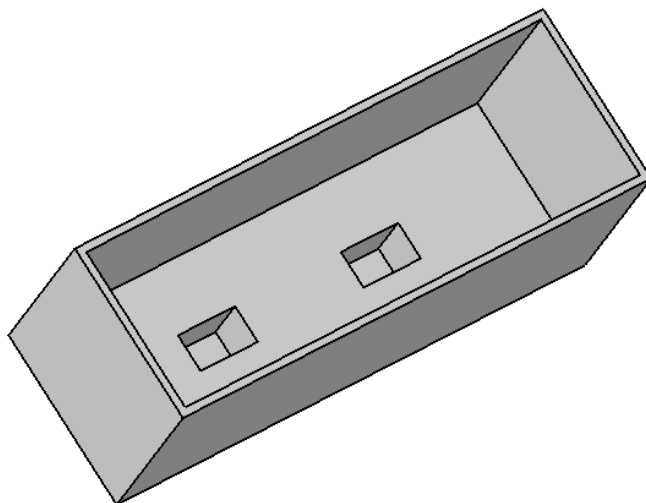
Pic 12. Design of precast concrete pit.

This precast concrete frame has been designed with 90mm width walls around the entire perimeter in which the lifting mechanism will be installed, so we have to calculate how much concrete we need in the design, first of all we know the volume excavated, which was **32m³**

Once I designed the hole, using the CAD software it is not such a difficult task to calculate the volume of concrete that is required when the 90mm width walls and the floor surface are built, using the command "*Measure Item*" I got a value of **4,486m³.**

$Concrete\ Volume: \mathbf{4,846m^3}$

$Concrete\ density: \mathbf{2320\frac{kg}{m^3}}$

$$Mass\ of\ Concrete = V \times d = 4.846 \times 2320 = \mathbf{11242.72Kg}$$

2. Steel plates

The lifting mechanism fixes in a large steel plate, this plate is installed over the bottom surface of the concrete precast, this plate cover almost all the free surface that there was available in the bottom of the precast.

There will be also two plates in the bottom of the holes in order to join the cylinders to the bottom of these holes.
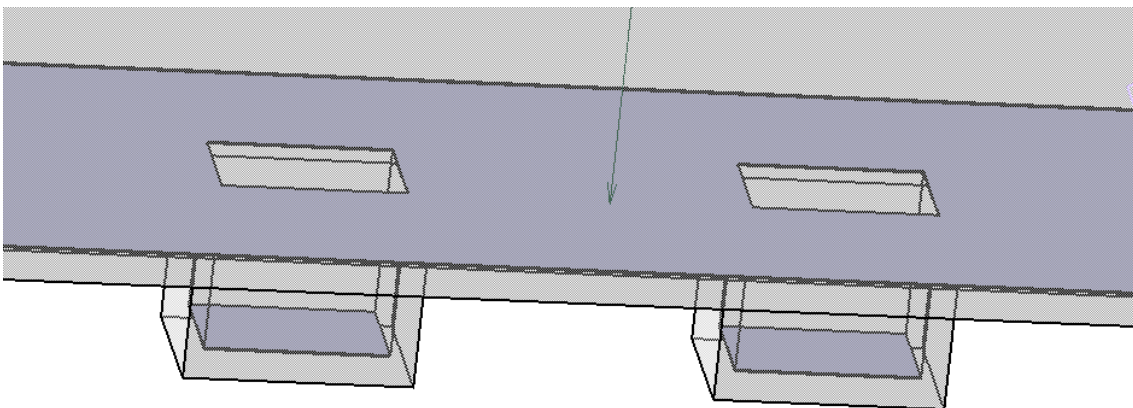
Pic.13 Plates in the bottom of the holes

Improving the way of fixing the mechanism to the surface is the main target that the plate has, this plate is built with a steel material called Sanicro28, it is a high-alloy multi-purpose austenitic stainless steel for service in highly corrosive conditions. The grade is characterized by:

- Very high corrosion resistance in strong acids
- Very good resistance to stress corrosion cracking (SCC) and intergranular corrosion in various environments

- High resistance to pitting and crevice corrosion
- Good weldability

Sandvik Sanicro 28 possesses good weldability. Suitable welding methods are manual metal-arc welding with covered electrodes and gas-shielded arc welding, such as TIG and MIG. The heat input should be maximum 1 kJ/mm and the interpass temperature maximum 150°C (300°F). A stringer bead welding technique should be used. The current should not exceed 100-120 A in TIG welding. Welding should be undertaken without preheating and, if correctly performed, there will be no need for any subsequent heat treatment. To maintain full corrosion resistance of the weld joint, welding must be followed by thorough cleaning to ensure removal of all oxides and slag particles.

3. Scissors mechanism

The scissors mechanism has been designed with the following structure:
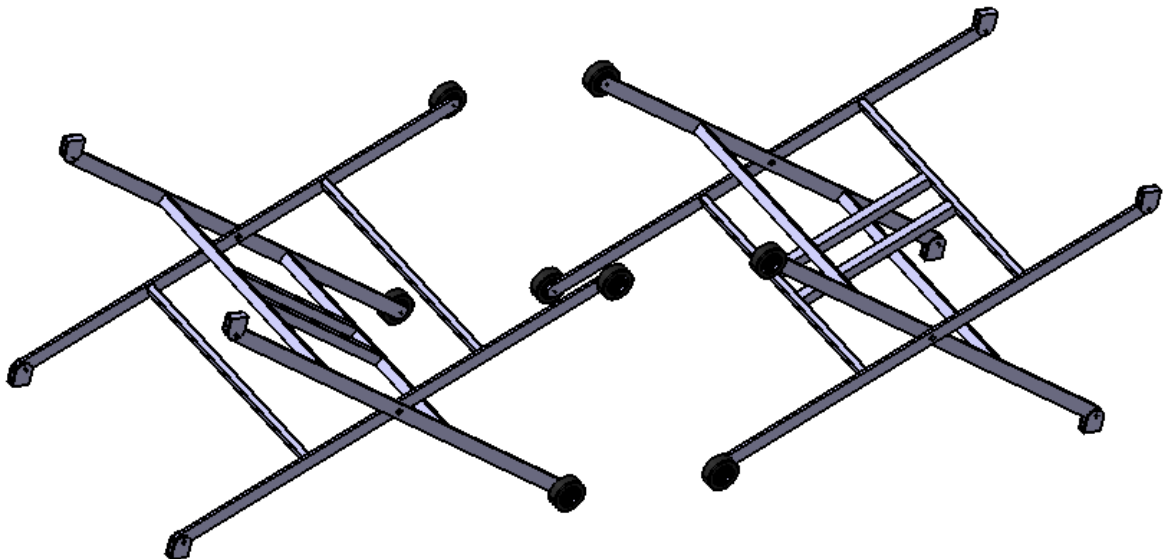
Pic 14. Design of the scissors lifting mechanism.

This mechanism has been designed for lifting a huge weight so it needs 4 scissors in order to allow a quickly and easy lift of the containers.

The bottom of the mechanism will be joined to the steel plate cause of welding, this welding will be carried out between the hitch and the plate of the bottom surface, both of the materials have good weldability with allows them to be joined strongly.
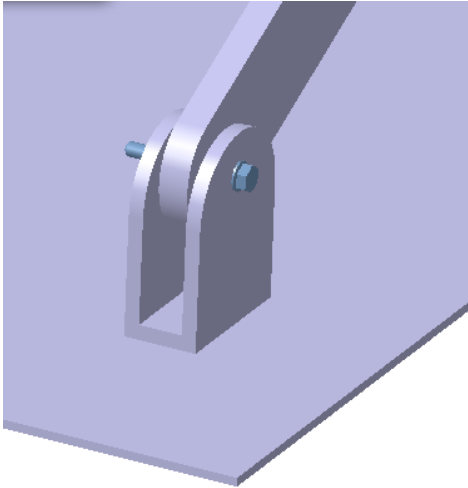
Pic 15. Joint between hitch, steel plate and bar

Once that the hitch is joined to the bottom plate it is necessary to design how the steel bar which is one of the main parts of the mechanism must be joined to the hitch, this bar needs to have an axis rotation movement respect to the hitch, so the best way to allow it is using a bolt.

The hole that the hitch has is 10mm, beside of this we have to have in mind the width that the parts have:

$Hitch: External\ width \rightarrow 50mm$
$Hitch: Internal\ width \rightarrow 30mm$
$Bar: Width \rightarrow 20mm$

The bolt which must be chosen has to be longer than 50mm, even much longer since it is joined using a nut, in this case the internal width of the hitch is 30mm however the bar is designed with a width of 20mm, anyways washers are required in this kind of rotation joints since the friction is decreased because such a big mechanical stress can not rotate while almost all the surface is rubbing with the other surface, this is the reason why the washers have been used.

Since the bolt´s width has to be longer than 50mm and beside of this the there is another length cause of the nut that is added, the bolt chosen is:

ISO 4016 BOLT M10x80 STEEL GRADE C HEXAGON HEAD

The characteristics that the bolt has are the followings values:

$$Lenght \rightarrow 80mm$$
$$Diameter \rightarrow 10mm$$
$$Threaded\ lenght \rightarrow 30mm$$

In this way the bolt has a length without thread which covers the length required for the hitch, the threaded length is almost 30 mm so there is enough space for the nut.

The specification of the nut is the following:

ISO 4034 NUT M10 STEEL GRADE C HEXAGON HEAD

Four washers are used as well, however the washers used are different, there is one of them which is placed between the head of the bolt and one of the surfaces of the hitch, and the other one which is placed between the nut and the other surface of the hitch.

Both of them are the same: ISO 7089 WASHER 10x20 STEEL GRADE A PLAIN NORMAL SERIES

However the other two washers that I chose for avoiding that the bar twists are different, the specification is the following one: ISO 8738 WASHER 10 STEEL GRADE A PLAIN WASHER FOR CLEVIS PIN
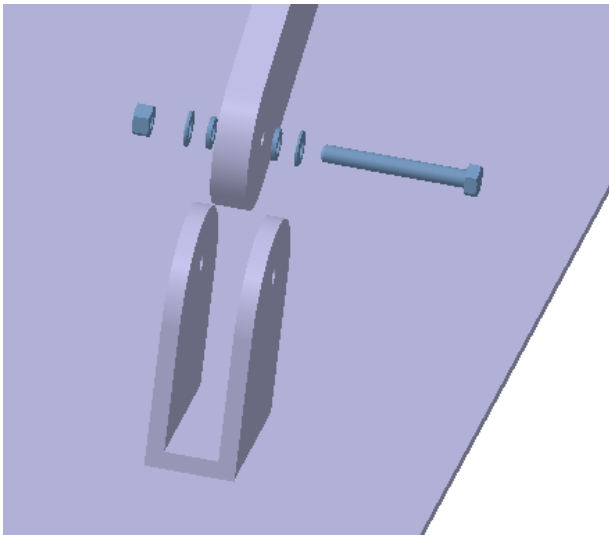
Pic 16. Joint between hitch, steel plate and bar (Bolt)

After knowing how the hitch and the joint are, it is necessary to say that in the assembly there will be eight couples of these, four in each corner of the steel bottom place, and another four in the top surface that support the containers.

The material which is used in the hitches is ASTM A484 304 Stainless Steel, The main characteristics of this steel are that it is semi-smooth, it also has a dull grey finish and the legs are tapered.

The workability is great since it is a good candidate for some processing techniques and it has a great corrosion resistance as well, this steel is usually used in areas where high strength, corrosion resistant and structural support is needed, in other words, it is the most common and the best for be used in metallic mechanism and structural architecture as well.

The physical properties that it has are these following:

$$Density: 8003 \frac{kg}{m^3}$$

$$Electrical\ Resistivity: (25ºC) \rightarrow 72 \frac{\mu\Omega}{cm}$$

$$Thermal\ Conductivity: (25ºC) \rightarrow 14,3 \frac{W}{m} K$$

$$Mean\ Coefficient\ of\ Thermal\ Expansion: (0-100ºC) \rightarrow 16,9 \frac{\mu m}{m} K$$

$$Magnetic\ permeabilit: H = 200$$
$$Modulus\ of\ Elasticity: 193\ \times 10^3 MPa\ in\ tension \quad 78 \times 10^3 MPa\ in\ torsion$$

Type 304 has a very good drawability. Their combination of low yield strength and high elongation permits successful forming of complex shapes. However, these grades work harden rapidly. To relieve stresses produced in severe forming or spinning, parts should be full annealed or stressrelief annealed as soon as possible after forming.

The austenitic class of stainless steels is generally considered to be weldable by the common fusion and resistance techniques. Special consideration is required to avoid weld "hot cracking" by assuring formation of ferrite in the weld deposit. Type 304 is generally considered to be the most common alloys of this stainless class.

The bolts nuts and washers are made of a steel material called AISI 8620 alloy steel, AISI 8620 alloy steel is a common, carburizing alloy steel. This alloy steel is flexible during hardening treatments, thus enabling improvement of case/core properties. The following datasheet will provide more details about AISI 8620 alloy steel.

$$Density: 7840 \frac{kg}{m^3}$$

$$Thermal\ Conductivity: 46.6 \frac{W}{mK}$$

Properties	Metric	Imperial
Tensile strength	530 MPa	76900 psi
Yield strength	385 MPa	55800 psi
Elastic modulus	190-210 GPa	27557-30458 ksi
Bulk modulus (typical for steel)	140 GPa	20300 ksi
Shear modulus (typical for steel)	80 GPa	11600 ksi
Poisson's ratio	0.27-0.30	0.27-0.30
Izod Impact	115 J	84.8 ft.lb
Hardness, Brinell	149	149
Hardness, Knoop (converted from Brinell hardness)	169	169
Hardness, Rockwell B (converted from Brinell hardness)	80	80
Hardness, Vickers (converted from Brinell hardness)	155	155
Machinability (hot rolled and cold drawn, based on 100 machinability for AISI 1212 steel)	65	65

Table 1 Mechanical properties of annealed AISI 8620 alloy steel

With respect to the bars, they have been designed with the same material than the hitches, the ASTM A484 304 Stainless Steel which allows them such a great strength and a good resistance to the stress. These bars are joined to the hitch in one end as I explained previously, and to the wheel in the other end.

The mechanism has 8 bars in total, also 8 wheels. It means that the mechanism is formed by 8 wheels, 8 hitches and 8 bars. The bars are joined between them by a clevis pin which must be longer than the length between the two bars and the free space that allow them twist each other.

$$Width\ of\ the\ bar: 20mm$$
$$Diameter\ of\ the\ hole: 20mm$$

It is useful to add a washer in order to allow a better twist between them since if you do not use it the friction between the bars will be bigger than if the washers are not used, so if the mechanism needs a washer between the two bars, and another 2 washers in the end of the clevis pin, the widths of the washers must be had in mind as well, then:

$$Width\ of\ a\ washer: 3mm$$
$$Minimal\ width = 20 * 2 + 3 * 3 = 49mm$$

This means that the clevis pin has to be at least longer than 50mm, beside of this there is a free space that includes the bolt and the nut which work as stop in the end.

Cause of the previously explained, I chose a clevis pin with a 65mm length since it is enough for including everything required for the properly rotation joint of the clevis pin.

The normalized names of the parts that we need for the assembly (clevis pin, 3 washers, nut and bolt) are the following:

ISO 2341 CLEVIS PIN 20x65 STEEL WITH HEAD TYPE B WITH SPLIT PIN HOLE

ISO 7089 WASHER 20x37 STEEL GRADE A PLAIN NORMAL SERIES

ISO 4014 BOLT M5x25 STEEL GRADE A HEXAGON HEAD

ISO 4032 NUT M5 STEEL GRADE A HEXAGON
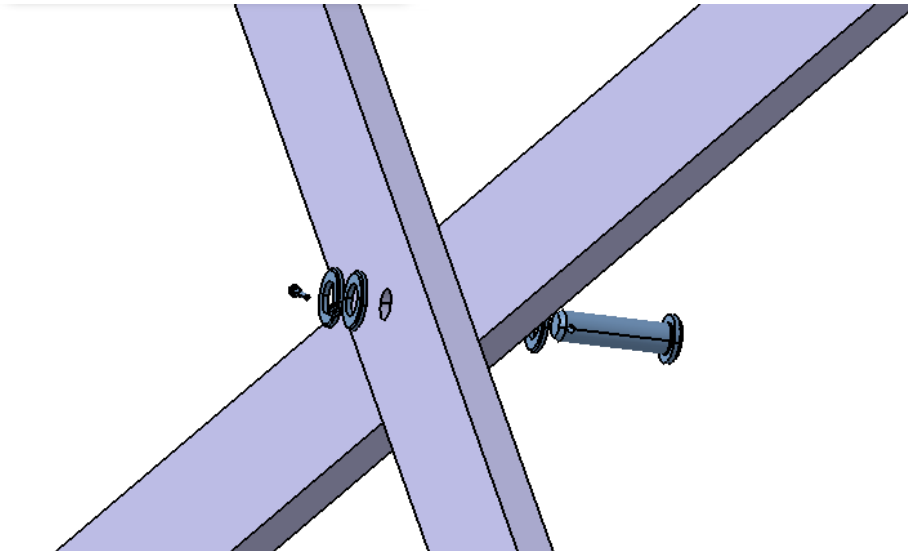
Pic 17. Mechanical rotation joint of both of the bars

In the mechanism we can find 4 of these joints, that allow the perfect rotation between the bars through the same axis.

These rotation joints are located in the middle of the bar, however there are another rotation joints in the end of the bar, these joints are which join the wheel with the bars and allow the translation and rotation of the wheel.

The study of both of these joints can be seen in the part of study of the bolts in critical joints.

This rotation joint requires also a little study about what bolt is the most suitable, first of all I need to know the width of the parts that I would like to join, and in this case it is just the wheel and the bar, it is also appropriate adding a small space where the washer should be placed.
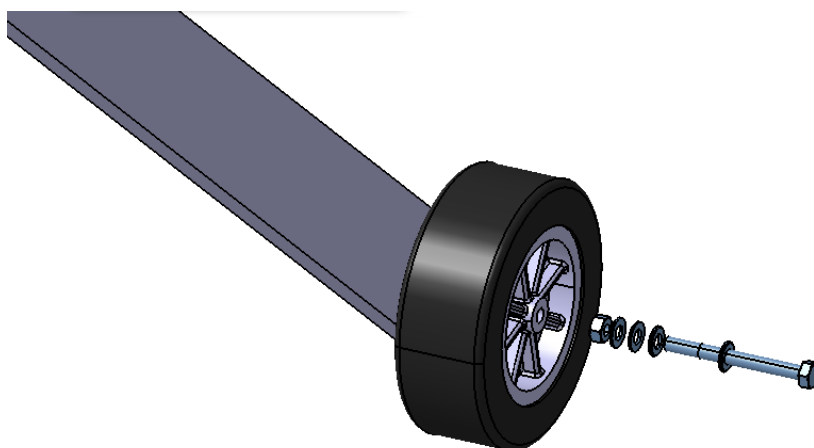
Pic 18. Rotational joint between wheel and bar.

$$Width\ of\ the\ bar: 20mm$$
$$Diameter\ of\ the\ hole: 10mm$$
$$Width\ of\ the\ wheel: 60mm$$

In this rotational joint there are 4 washers, two of the located in each end of the bar, and the other two between the bar and the wheel.

The washers chosen have the following name: ISO 7089 WASHER 10x20 STEEL GRADE A PLAIN NORMAL SERIES

In this joint a nut is also required in order to avoid that the bolt moves, so the following one has been chosen ISO 4032 NUT M10 STEEL GRADE A HEXAGON

$$Width\ of\ the\ washer: 2mm$$

$$Width\ of\ the\ nut: 8{,}4mm$$

Knowing these the minimum length that the bolt requires can be calculated:

$$Width\ of\ the\ bolt: 4*2+\ 20+60+8{,}4=96{,}4mm$$

So the bolt must be longer than 100mm at least, however 100mm is a suitable value for the length of the bolt since the threaded length will be only along the nut´s length, since 100 mm is a suitable length it can be chosen and the normalized name will be the following one ISO 4016 BOLT M10x100 STEEL GRADE C HEXAGON HEAD.

There are some important parts in the assembly of the mechanism, these parts are the wheels since thanks to them, the mechanism can be raised and lowered, these wheels are made with a steel disc in the main part of it, and the rubber tyre around the steel.

The wheel rotates around the axis made between the bar and itself and beside of this it moves along the profile rolling, 4 profiles rolling has been installed in the mechanism along the each longitudinal edge.
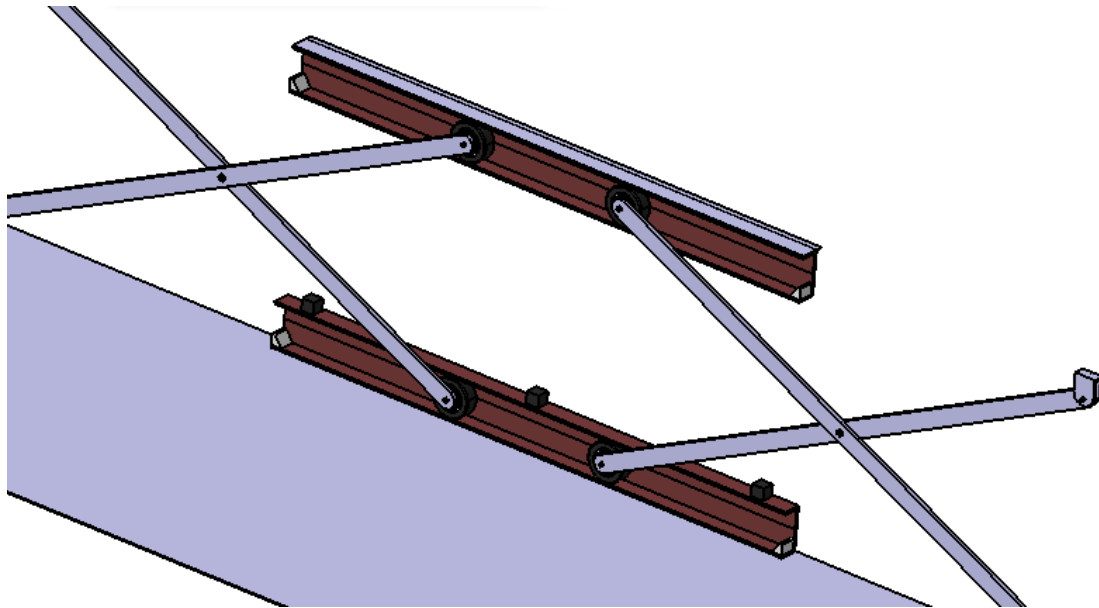
Pic 19. Rolling profiles.

The function of the profiles appear in the picture, how the wheels can move along them profiles until, which allows that the mechanism could be raised and lowered, in the end of the profiles I decided to install some stops in each end of it since they can avoid that the wheels get out the profile.

There are also some stops over the lower profile in order to absorb the movement when the upper profile reach its lowest limit, it is have been designed since when the mechanism is during the rest position and the containers are hidden, the hydraulic mechanism will not need to be acting so strong, since all the weight of the containers and the structure will be supported over the stops located on the profile.

In the picture 19, only the right side of the mechanism appears since the other side is hidden, it is true to say that the complete mechanism have scissors bars in both of the sides, these sides are joined with crossbars which give more stability and a better supporting to the stress suffered by the weight of the containers.

These crossbars are made with ASTM A484 304 Stainless Steel, they are steel profiles with the following measures, 60x40x4, one of them is longer than the other and they are joined to both of the scissors mechanism, bar by bar, there are 8 crossbars in total, 4 long and other 4 pretty shorter than the others, which guaranteed the perfect raising and lowering without suffering any kind of twist the structure of the mechanism.

Anyways there are 2 bars parallel to the longer bars, these bars are located and joined both of the cross bars. They have been designed in order to avoid the broken when the hydraulic cylinders are working over the cross bars.
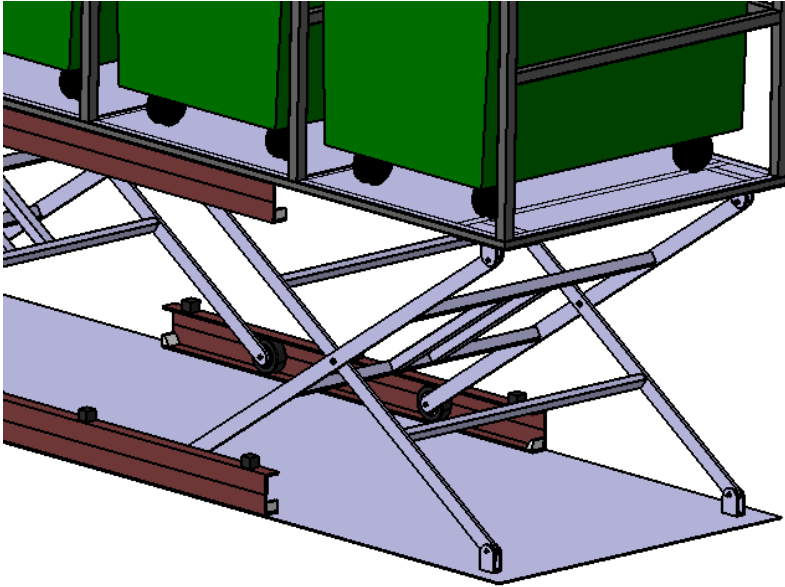
Pic 20. Crossbars which join both of the scissors bars.

There are two steel sheets which join the upper profile and the structure, these sheets are necessary since the structure is made of profiles, and the surface that would be welded is not large enough, so the best choice in order to guaranteed a good joint is using these steel sheets between the profile and the structure of the containers.

These sheets are made with ASTM A484 304 Stainless Steel, which allows a good weldability between the structure´s profile and the wheel´s profile.
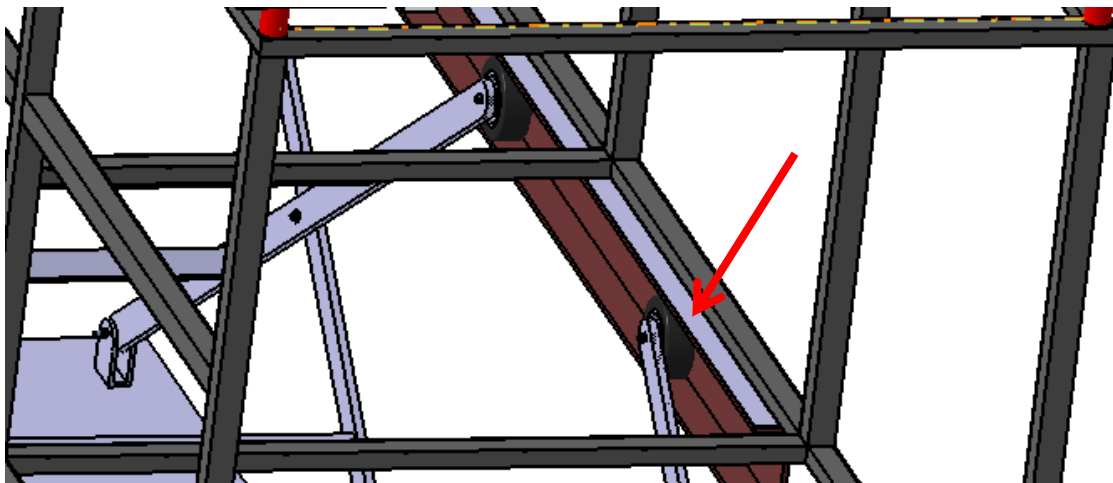
Pic 21. Steel welding sheet

4. Structure

The next part of the assembly is the structure for the containers, the structure for the containers is formed by several ASTM A484 304 Stainless steel profiles, there are some profiles different, for example the bottom structure and the top structure, which are made with a rectangular profile while the others are square profiles.

Since the objective was use 2600 litres containers, there is enough space for them cause of the maximum container´s measures are the following ones:

$Depth$: **$1750mm$**
$Width$: **$1210mm$** $Volume = L \times W \times H = \textbf{3.13}\textbf{\textit{m}}^{\textbf{3}} of\ free\ space$
$Height$: **$1480m$**
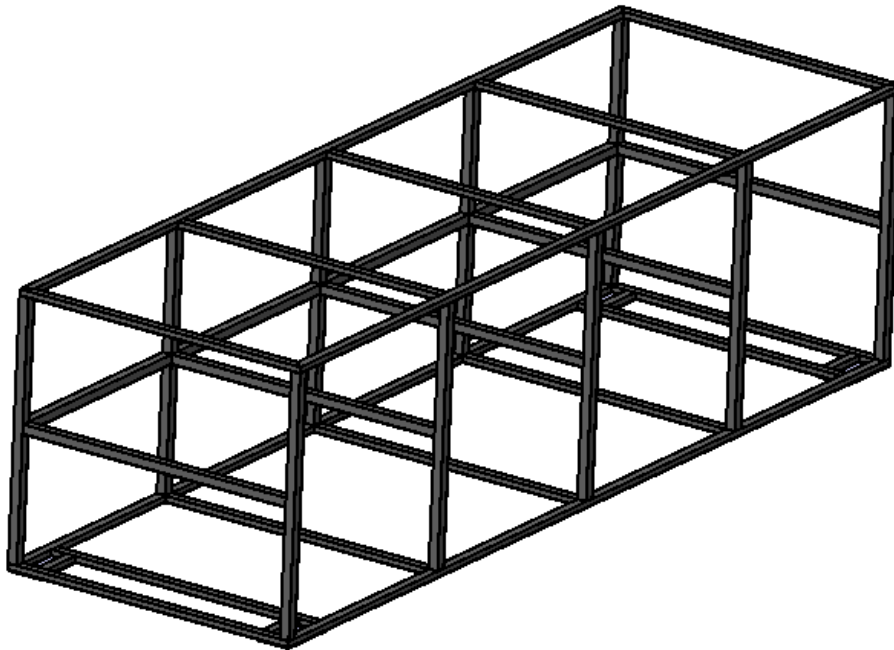
Pic. 22 Steel profile structure

As it can be seen in the previously picture, there are several cross profiles in all the structure, designing the structure in this way, it is totally strong and resistant to any kind of stresses and strains.

The profiles which are used in the structure are shown in the following table.

Part	Units
Profile 60x60x3x1780	5
Profile 60x60x3x1590	10
Profile 60x60x3x1400	4
Profile 60x40x3x5900	4
Profile 60x40x3x1900	4
Profile 60x40x3x1780	8
Profile 60x40x3x280	4

Table 2 Summary of the profiles

In the bottom of the structure, there is one small sheet in each corner in order to be used as lifting surface, the upper hitches are welded in this sheet and thanks to it and the movement of the bars, the structure can be lifted while the steel profile structure is not damaged.
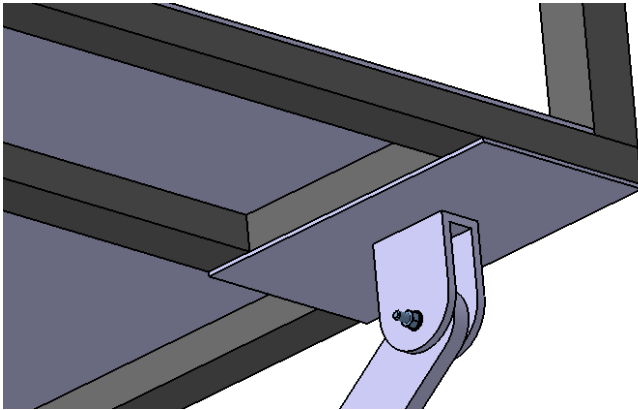
Pic. 23 Small sheet in the bottom

The floor of the structure will be made with 6mm sheets of ASTM A484 304 Stainless steel, this sheets will be over the perimeter profile and over the cross profiles as well.
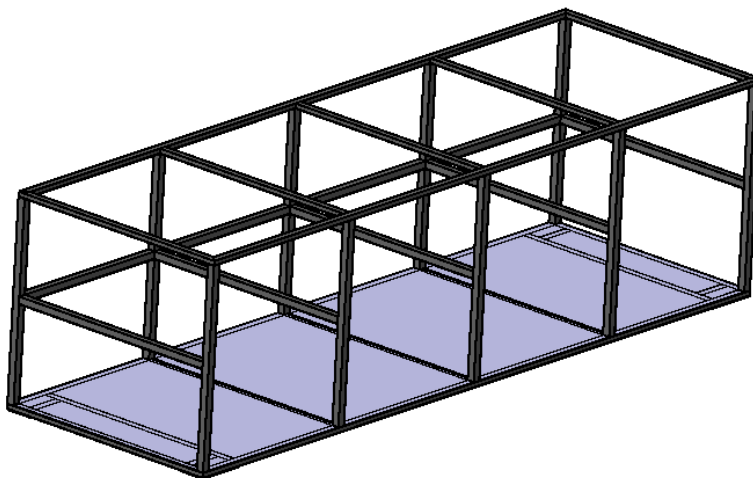
Pic. 24 Structure with steel sheets.

As we can see in the picture of the structure, there are 4 different spaces, in each of these spaces there are steel sheets which can be taken out when the mechanism requires to be repaired.

The containers will be located over these sheets; there is a huge free space in each of the divisions that has the following values:

$Depth$: $\mathbf{1840mm}$
$Width$: $\mathbf{1400mm}$ $Volume = L \times W \times H = \mathbf{4.08m^3} of\ free\ space$
$Height$: $\mathbf{1584mm}$

The free space that we have in each of the divisions is around 4m^3 which is bigger than the containers volume (**3.13m^3**) so it is enough.

5. Ramp regulation cylinders

Once that the structure is already explained, the following part is important since it is one element that can regulate uneven grounds, this component is a telescopic hydraulic cylinder which can be adjusted depending the ramp of the ground.

The assembly counts with six regulation cylinders, 4 of them in each corner of the upper structure and two of them in between corner and corner in each side of the upper structure, the objective of this is regulate each one of them with a different value of the cylinder stroke in order to absorb the ramp.

These cylinders are made with a AISI-SAE 1045 steel.
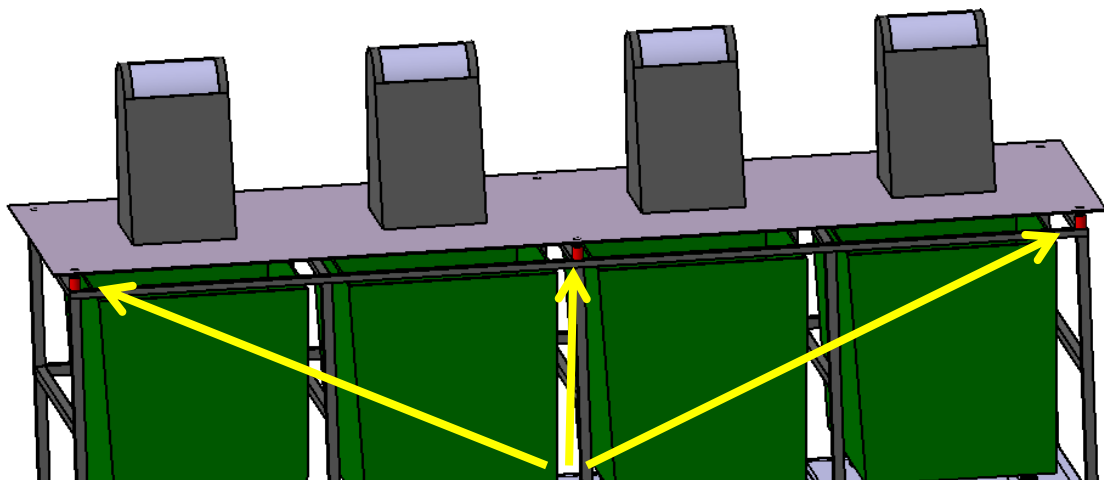
Pic. 25 Uneven ground regulators

After choosing these cylinders, the maximum ramp will be calculated, first of all it is necessary to know the telescopic cylinder stroke.

$Cylinder\ Stroke$: $\mathbf{270mm}$

$$Distance\ between\ cylinders: \textbf{5830}\textbf{\textit{mm}} \qquad \%\ ramp = \frac{270}{5830} * 100\% = \textbf{4.63}\%$$
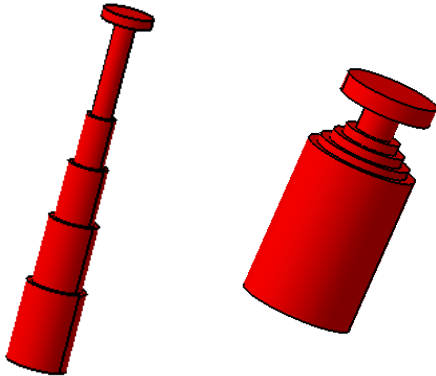
Pic. 26 Telescopic ramp regulation cylinders

Using these telescopic uneven cylinders, the maximum ramp that where we can implement this assembly is 4.5%, it is enough since the length of the assembly is too long in order to implement it in steep ramps.

6. Trash boxes

The last part of this mechanism is the platform where the trash boxes will be located, this platform will be implemented over the telescopic uneven cylinders. This platform is a ASTM A484 304 Stainless steel sheet, it is 8mm width.

It has also some holes which are designed in order to let the garbage trash go through them towards the container, these holes are under each garbage box.

These garbage containers which are located over the platform are normal ones, they are made with brass, which gives them a great resistance against corrosion and oxidation. This material can not be broken easily so it is a great metal in order to avoid the vandalism.
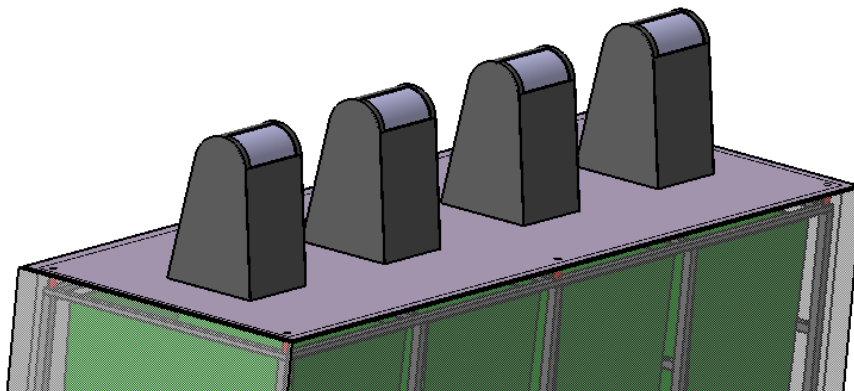
Pic. 27 Platform with the garbage boxes.

This is the assembly design made for the mechanism and all the parts that is required for a properly working, the containers that are used for this design are made of a mix of plastics, these plastics are the following ones with their densities

.

$LLDPE: \mathbf{910 \dfrac{kg}{m^3}}$

$PP: \mathbf{946 \dfrac{kg}{m^3}}$ $\qquad Average = \dfrac{910 + 946}{2} = \mathbf{928 \dfrac{kg}{m^3}}$
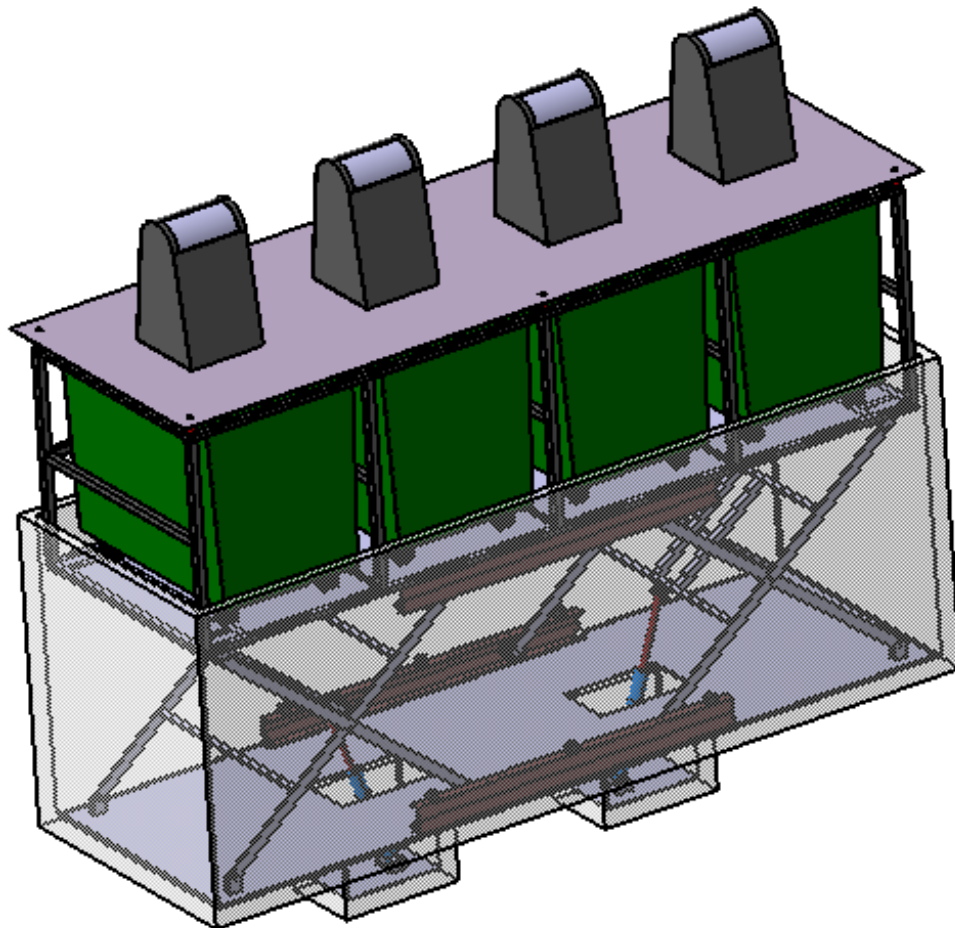
Pic 28. Assembly of the mechanism.

7. Weight to lift

Once done the study of the design of each part, the next step is calculate the weight that the hydraulic mechanism, which has not been included in the previously pictures, should lift.

These calculations can be done knowing the mass of each part, since all of these parts has been designed and implemented in CAD, it is not such a difficult task knowing the volume that they occupy, once that we know the volume and the material´s density, it is easy to know the mass.

There are some parts of the assembly that don´t requires to know the mass since they are not intervening in the lifting process as can be the 2 wheel profiles in the over the bottom surface.

The parts involved in the weight that the mechanism is going to lift are the following one:

- Platform with the garbage boxes
- Structure, steel sheet and ramp telescopic cylinders
- Bars of the scissors mechanism
- 4 hitches
- 2 wheel profile and their steel sheets for welding
- 4 wheels
- Containers

PART	MATERIAL	Nº	DENSITY(Kg/m3)	VOLUMEN(Unit) m3	MASS Kg
SCISSORS MECHANISM					
Bars	ASTM A484 304 Stainless Steel	8	8003	0,004	256,096
Upper hitches	ASTM A484 304 Stainless Steel	4	8003	0,000271	8,675252
Short cross profiles	ASTM A484 304 Stainless Steel	4	8003	0,0012	38,4144
Long cross profiles	ASTM A484 304 Stainless Steel	4	8003	0,0013	41,6156
Reinforcements of cyl. Bar	ASTM A484 304 Stainless Steel	4	8003	0,0006327	20,2539924
WHEELS					
Wheels	Steel+Rubber	4	Not Uniform	0,001	17,48
Wheels profile	ASTM A484 304 Stainless Steel	2	8003	0,011	176,066
Stops	Rubber	4	910	0,0001219	0,443716
Welding Sheet	ASTM A484 304 Stainless Steel	2	8003	0,0009048	14,4822288
STRUCTURE					
Profiles of the structure	ASTM A484 304 Stainless Steel	1	8003	0,04724	378,06172
Steel sheet	ASTM A484 304 Stainless Steel	4	8003	0,01675	536,201
Hitch steel sheets	ASTM A484 304 Stainless Steel	4	8003	0,00044	14,08528
Telescopic cylinders	AISI-SAE 1045 (UNS G10450) Steel	6	7870	0,000293	13,83546
PLATFORM					
Garbage boxes	Brass	4	8261	0,018	594,792
Platform sheet	ASTM A484 304 Stainless Steel	1	8003	0,091	728,273
SCREWS					
Wheel	AISI 8620 alloy steel	4	7840	0,0000125	0,392
Hitches	AISI 8620 alloy steel	4	7840	0,00001118	0,3506048
Bars	AISI 8620 alloy steel	4	7840	0,00001828	0,5732608

Table 3 Mass of each part

$$Total\ weight\ of\ the\ mechanism = 2840kg$$

Once that I know the weight of each part involved in the mechanism, there are another parts which should have in mind. These parts are the containers and the garbage that can fit inside.

The containers are made of the following plastics:

LLDPE (Linear-low-density-polyethylene): $\mathbf{910 \frac{kg}{m^3}}$

PP(Polypropylene): $\mathbf{946 \frac{kg}{m^3}}$

$$Average \ = \frac{910 + 946}{2} = \mathbf{928 \frac{kg}{m^3}}$$
$$Volume = \mathbf{0.152 m^3}$$

$$Mass(4\ containers) = \mathbf{4 * 0.152 m^3 * 928 \frac{kg}{m^3} = 565 kg}$$

So the maximum weight without garbage would be $565kg + 2840kg = \mathbf{3405kg}$

After knowing this value, it is necessary to make a estimation about the maximum garbage´s weight that it can fit in a container, these containers are designed for a capacity of 2600litres.

$$2600\ litres = 2.6\ m^3$$

2.6m^3 is the capacity of a container however I should know the mass that it can fit in one container. After doing a researching, I could found that the average of weight´s garbage is between 200 and 300 kg/m^3 so I will choose a louder value since this is just an average and sometimes it can vary, so the value chosen is 350kg/m^3.

$$Mass\ garbage\ (4\ containers) = \mathbf{4 * 2.6 m^3 * 350 \frac{kg}{m^3} = 3640 kg}$$
$$Maximum\ weight = 3640 + 3405 = \mathbf{7045 kg}$$

This is the maximum weight since in spite of the fact that a person could be walking over the platform, this stress due to the weight would not be had in mind since the platform is supported by the concrete precast during the rest position of the mechanism when the mechanism is in the lowest height.

8. Construction of cylinders
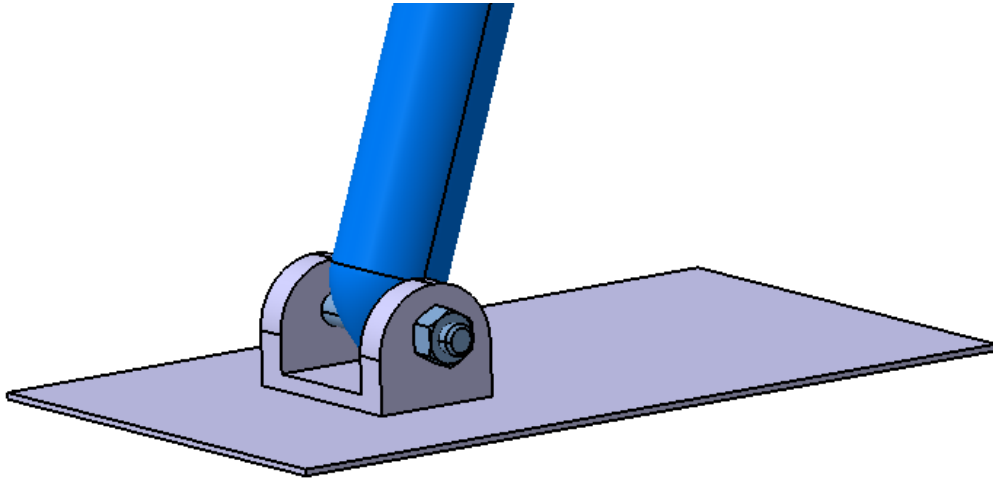
Pic 29. Bottom of the cylinder.

The hydraulic cylinders will be located in the steel sheets in the bottom of the precast, this has been designed in this way in order to avoid the big forces that would be required.

There is one hitch in each cylinder that let it twist while the angle between the cylinder and the sheet is changing due to the lifting of the mechanism.

The joint of these two parts, cylinder and hitch is going to be thanks to a bolt and a nut, the specification of these is the following one:

ISO 4014 BOLT M30x220 STEEL GRADE B HEXAGON HEAD

ISO 4032 NUT M30 STEEL GRADE A HEXAGON

The top of the cylinder´s plunger will be joined to the corresponding hitch in a similar way than the previously one, the unique difference is the length of the bolt since in this case the specification is the next one.

ISO 4014 BOLT M30x110 STEEL GRADE B HEXAGON HEAD
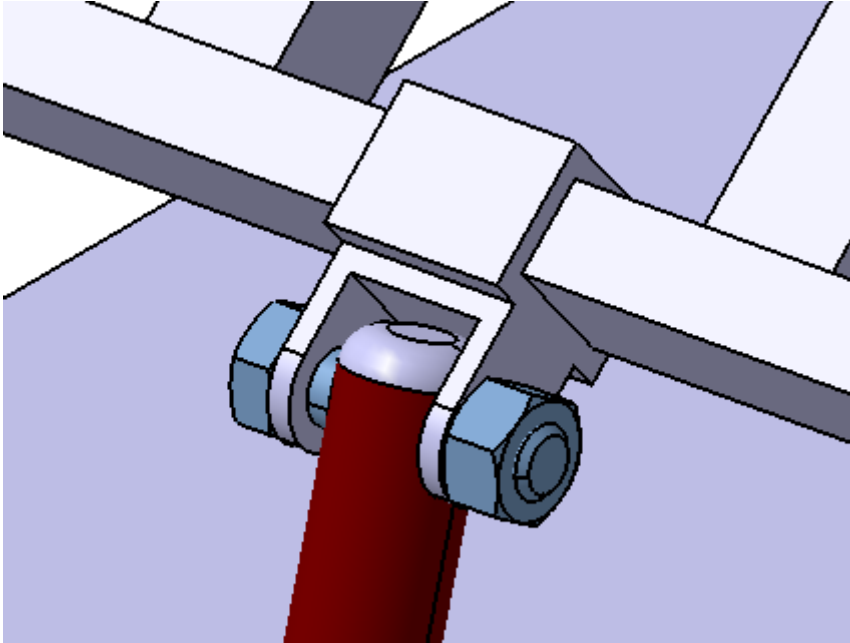
Pic. 30 Top of the cylinder.

In this case there is one critical point which must be studied, in the joint between the plunger and the hitch, the bolt may suffer such a big stress due to the force applied by the cylinder.

In the hydraulic calculations topic, it has been calculated the value of the forces that the cylinders were going to develop so for these calculates those values will be used.

The position of the cylinders will be changing continuously so the force that is required will also change as well, anyways the calculation must be done in the most unfavourable case that it will be when the force must be **38446.77N** as it is explained in the hydraulic calculations.

Then the bolt has been simulated with the FEM software.

Both of the ends of the bolt are fixed since the force will be applied over the surface of the middle of it, since the force required was 38446.77 N, it has been simulated with a 40000N force applied over the surface of it.

The results which have been gotten are shown in the following picture.
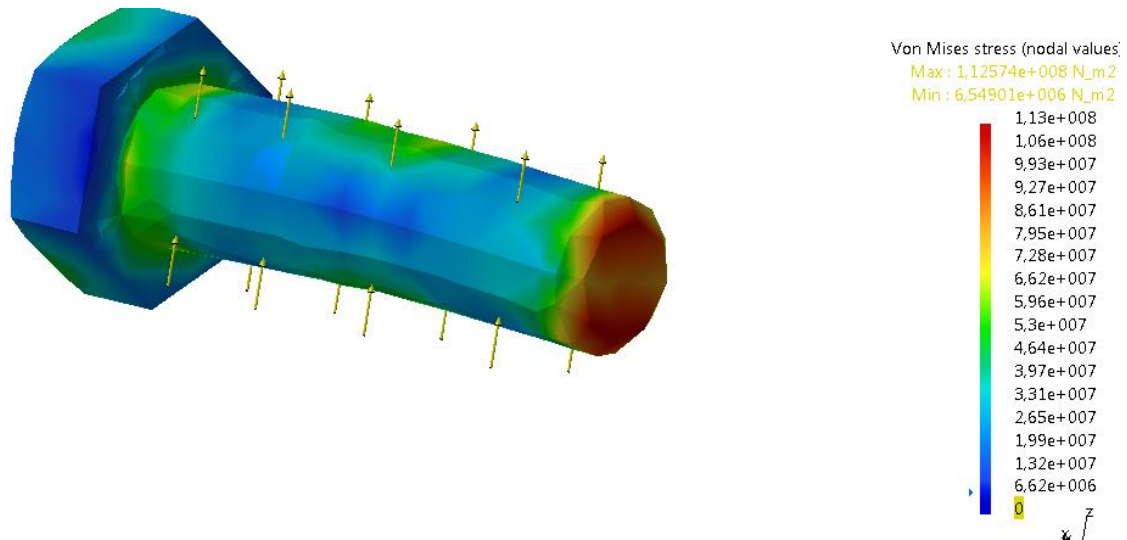
Pic. 31 FEM analysis.

The most critical point are in the end of the bolt, the values of the Von Misses forces are smaller than the yield stress so this bolt is valuable.

The biggest Von Mises stress is: **113Mpa**

The yield stress is **385Mpa**

$$Maximun\ Von\ Mises \ll Yield\ Stress$$
$$113Mpa \ll 385Mpa$$

This bolt can be used in this mechanism as element that will receive all the force of the hydraulic cylinders.

9. Study of the bolts in critical joints.

In order to study the stress in the bolts in the joints, first of all it is necessary to study the forces that will be applied in this joints, knowing the weight that it will be lifted and the force that the cylinders will develop (Force required), the mechanism has been carried out with the software "Working Model".

This software can calculate the forces in each point of the mechanism always that it had been properly modelled.

Since the mechanism has symmetry, the model has been done for just one side and the values of the forces just must be divided by 2 sides, so the model in the critical position with the values in the joints that we will study is the following one.

Stress in Bolt Up	
Fx	-18.142 N
Fy	-1.503e+004 N
IFI	1.503e+004 N

Stress Clevis Pin	
Fx	-1.625e+004 N
Fy	6.024e+004 N
IFI	6.240e+004 N

Stress in Bolt Down	
Fx	1.625e+004 N
Fy	-2.025e+004 N
IFI	2.597e+004 N
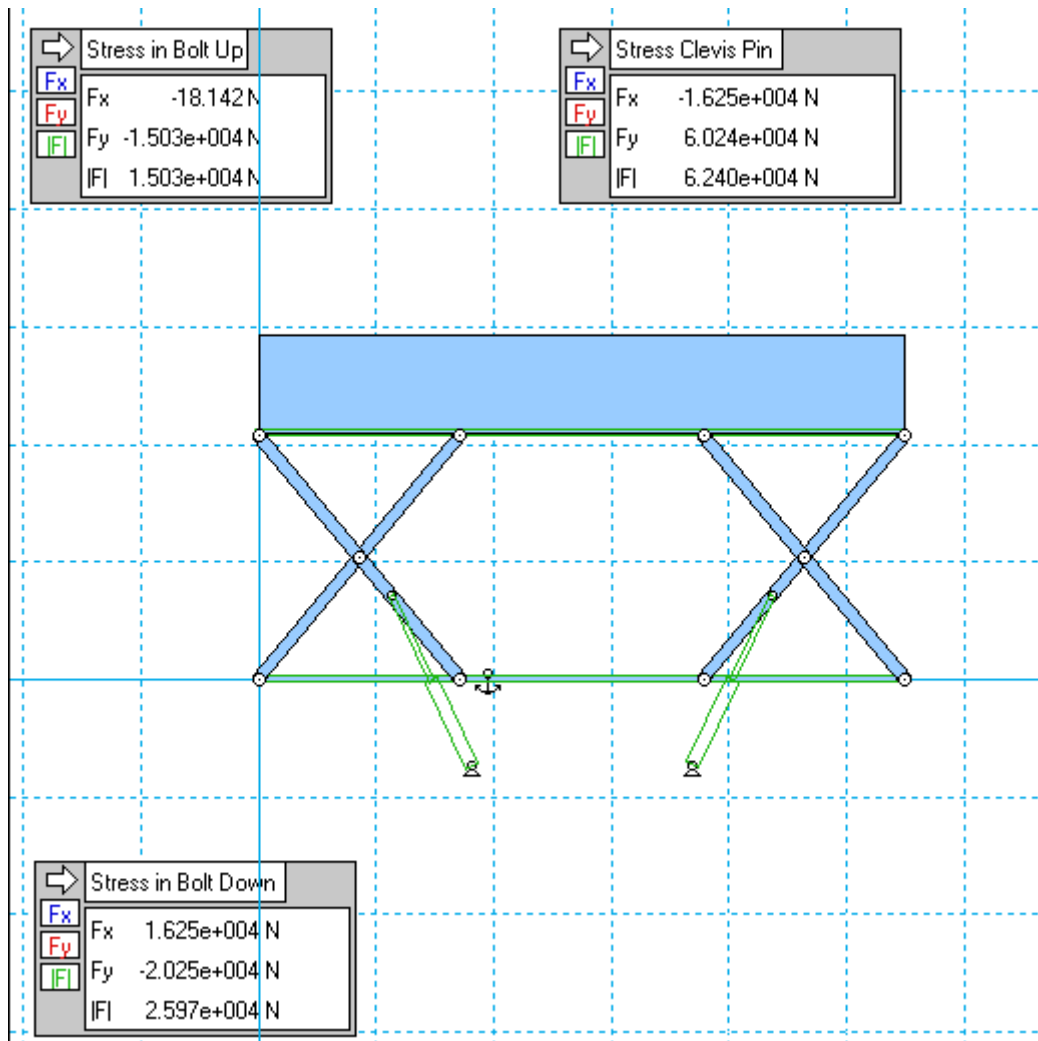
Pic. 32 Working Model Analysis.

The critical stresses are the following ones:

$$Bolt\ of\ Hitch\ upper: \frac{15030N}{2} = 7515N$$
$$Bolt\ of\ Hitch\ lower: \frac{25970N}{2} = \mathbf{12985N}$$
$$Clevis\ Pin\ between\ bars = \frac{62400N}{2} = \mathbf{31200N}$$

In the case of the bolts of the hitches, we only need to study the one which supports such a bigger stress.

This study can be carried out with the FEM software as it has been done in the case studied previously.
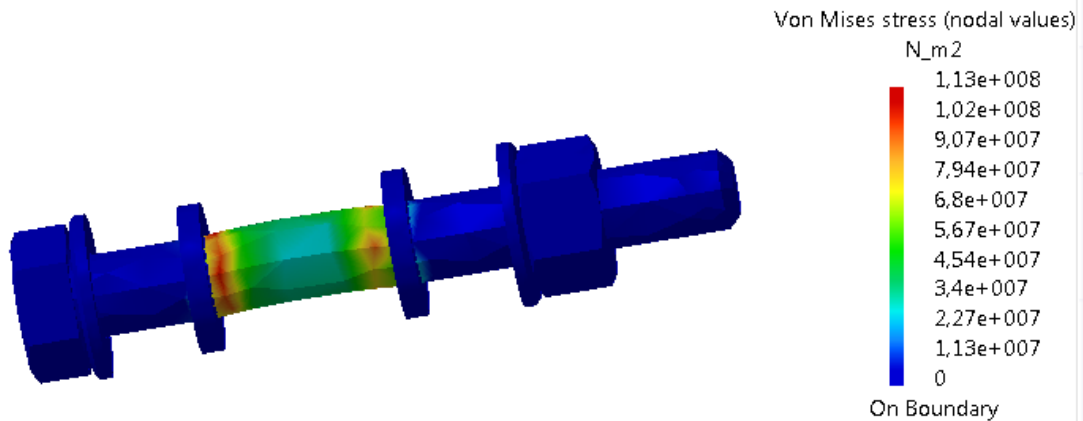
Pic. 33 FEM analysis M10 bolt

In this case the biggest Von Misses stress is in the side where the bar is acting, since in there are no big stresses in the places where it is joined to the hitch.

The biggest Von Misses stress is: **113Mpa**

113<385Mpa

This means the this bolt which its measures will be available for the mechanism.

The next study will be carried out with the clevis pin which joins both bars in the middle allowing them the rotation each other.
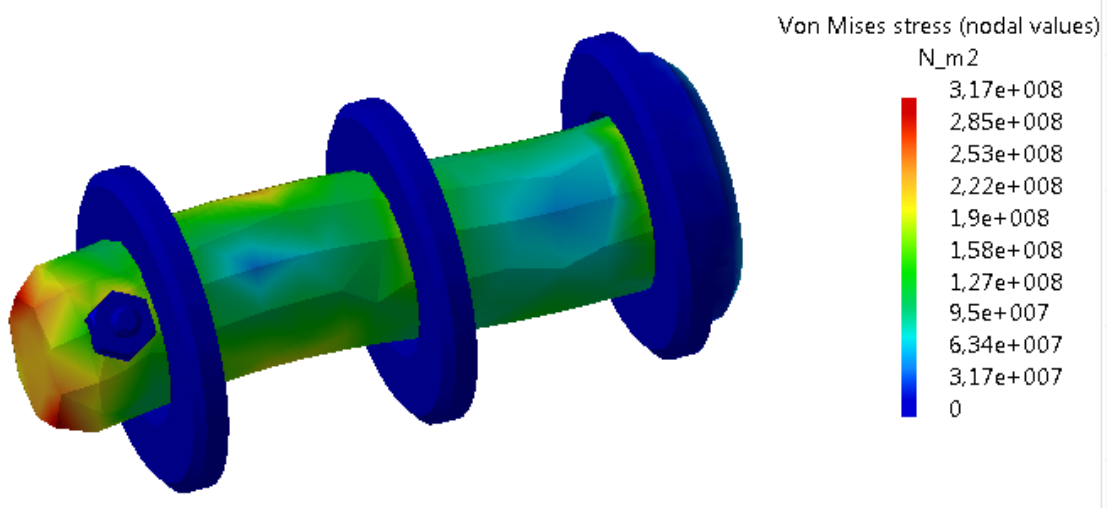
Pic. 34 FEM Analysis Clevis Pin M16

In this case, when the pin has a 16mm diameter, the Von Misses stresses that will be developed are higher than other cases, it does not reach the critical stress but it is still high.

317<385Mpa

Cause of this, it has been thought to develop a thicker pin in order to avoid such a big maximum stress in the end of the bolt, the following study shows how a 20mm diameter pin can avoid these big stresses and reduce the internal forces in it.
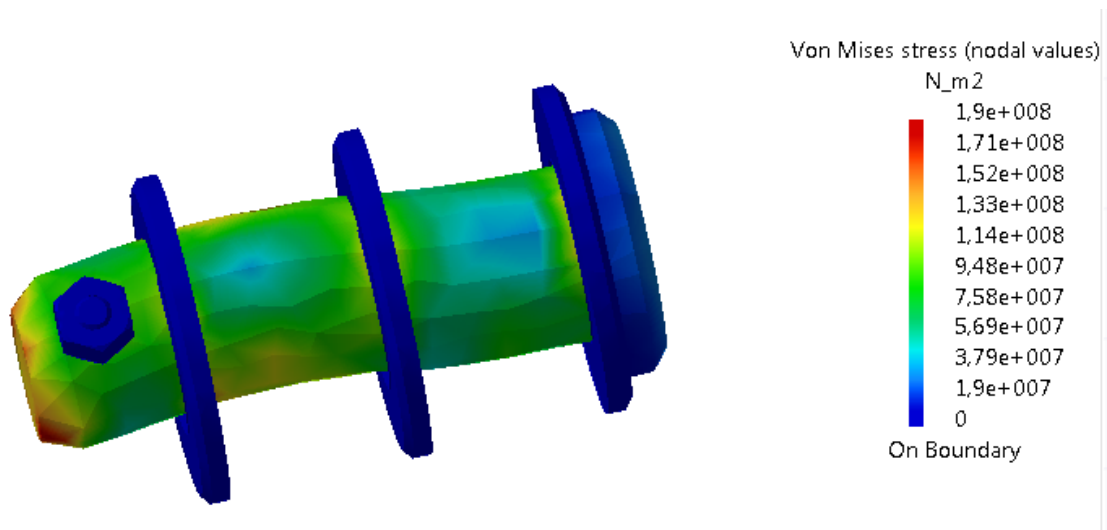
Pic. 35 FEM Analysis Clevis Pin M20

As we can see in the previously picture, if the diameter is increased the stresses will be lower so it is better to use this since the difference between the higher Von Misses stress and the Yield Stress is much bigger.

190<385Mpa

4. Kinematic Calculations

1. Cylinders position

Once the cylinders where chosen cause of the requirements of force, stress and pressure that they need, the next step is knowing how the cylinder´s stroke is influenced in the mechanism since the space between the sheet which join the cylinders and the bars is limited.

The height between the sheet for the cylinder´s hitches and the platform is: 700mm.

The main objective of these extra holes is avoid the huge force that would be required if the cylinders will start the lifting movement from a horizontally position.

The characteristics of the cylinder chosen in which respect of lengths are the following ones:

$$Repose\ position: 885mm$$
$$Extended\ position: 1600mm$$
$$Stroke = 715mm$$

Since the fixed objective was getting a lifting height lower than 1750mm, it is important to manage the best combination according to the lengths and the free space that there is in the mechanism.

While the containers are in the low position, the cylinders are almost vertical what allows them working with a smaller force cause of the components of the forces.

While the mechanism is moving, the angle between the cylinder´s axis and the steel sheet that join them is changing, it changes from a almost vertically position until a medium angle position.

When the mechanism is in the lowest position, the angle is almost 90º.
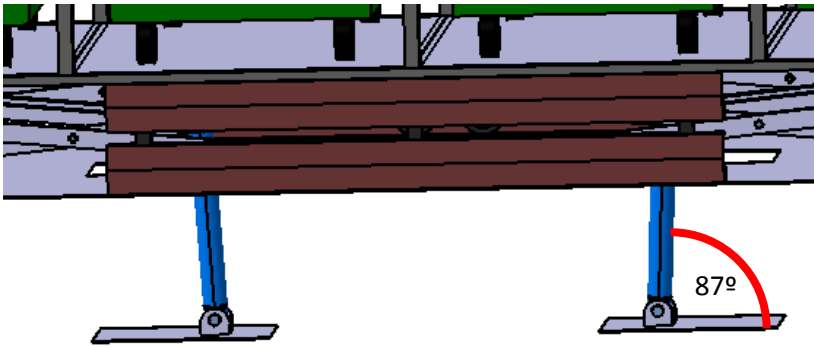
Pic.36 Maximum angle of the cylinders

When the cylinders are moving and the plunger is extending, the angle between the cylinder and the steel sheet decrease because the bars are moving up and to the side, so the angle decreases until it reaches
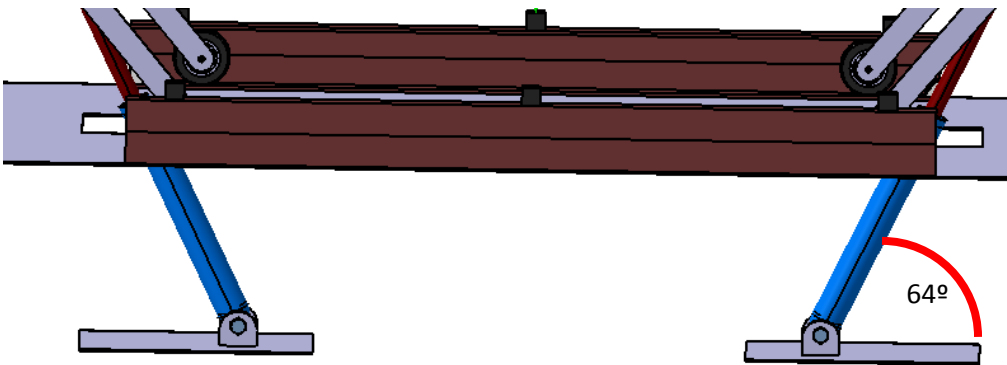
Pic. 37 Minimum angle of the cylinders

While the cylinders are working, all the platform rises, the cylinders allow the mechanism rise the platform in which the containers are located from the bottom to a height of **1750mm,** beside of this height, they stroke of the cylinders is smaller than it but cause of the system of bars and the mechanism it can reach such a high elevation.

2. Movement of the platform.

The next step is calculate the time that is required for the cylinders in order to move and extend themselves, knowing the following values is more than enough.

$$Stroke = 715mm$$
$$Speed\ of\ cylinders = \frac{150mm}{s}$$
$$Time = \frac{Stroke}{Speed} = \frac{715}{150} = 4.76s \approx \textbf{5 seconds}$$

The lowest position of the platform is when the upper wheeling profile is in contact with the stops that are located over the lower wheeling profile, this position is 0mm over the

bottom, what it means that all the mechanism is hidden in the concrete precast, however when the mechanism needs to be lifted, all of it will rise 1750mm until the sheet of the platform which contains the containers is going to be at the same level than the ground of the street.
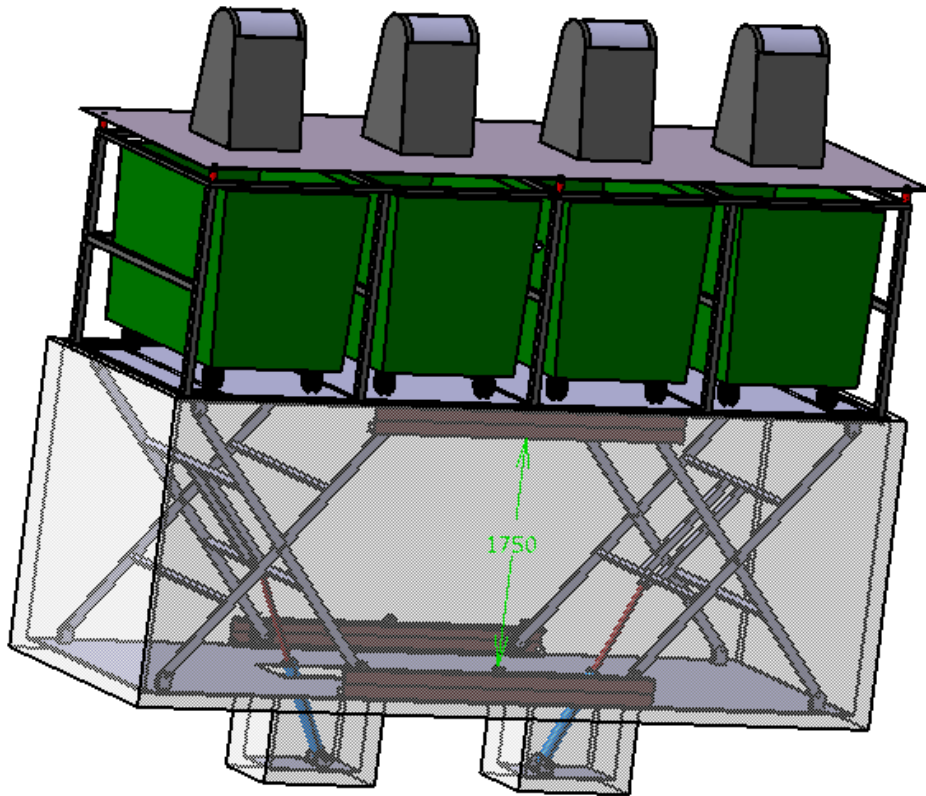
Pic. 38 Platform with the containers in the upper position

For the movement of the containers, it is important to know the lineal speed with the containers and the platform rises, knowing the distance that the platform moves and the time required for the total extending of the cylinders, this tasks is not more complex than a simple equation.

$$Track = 1750mm$$
$$Time = 5\ seconds$$

$$Speed = \frac{Track}{Time} = \frac{1750}{5} = \frac{\textbf{350mm}}{\textbf{s}}$$

This value means that the platform will go up and down with a speed of **0.35m/s.**

3. Angle between bars

The lifting of the platform is notoriously caused by the movement of the bars, once that the cylinder is extending and thanks to the rotation and translation of the wheels, these will cause that the angle between the two bars will change.

In the off position, the bars will be almost horizontally so the angle between both of them are quite big.
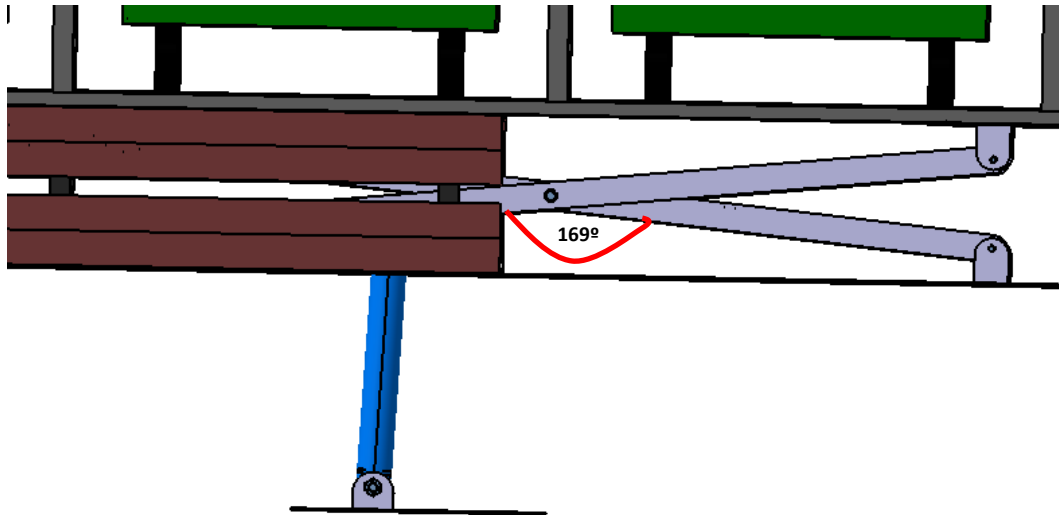
Pic. 39 Angles between bars in the off position.

When the wheels are moving towards the end of the profiles, the bars will close each other, in other words, the angle between the bars is going to decrease cause of this movement which allows the platform rise.

In the case of the Clevis pin, the middle point of the bars, it will moves with the speed that will be calculated in the following equation:

$$Clevis\ Pin\ height\ (Low\ position) = 232.5mm$$
$$Clevis\ Pin\ height\ (Up\ position) = 1107.5mm$$

$$Difference\ of\ heights = 1107.5 - 232.5 = 875mm$$

$$Clevis\ Pin\ Speed = \frac{875mm}{5seg} = \frac{175mm}{s}$$

The speed which the clevis pin rises is **175mm/s.**

Once that the platform has been lifted, we can know the angle between bars and in this way calculate the value that the angle decrease and the average speed with which it decreases.
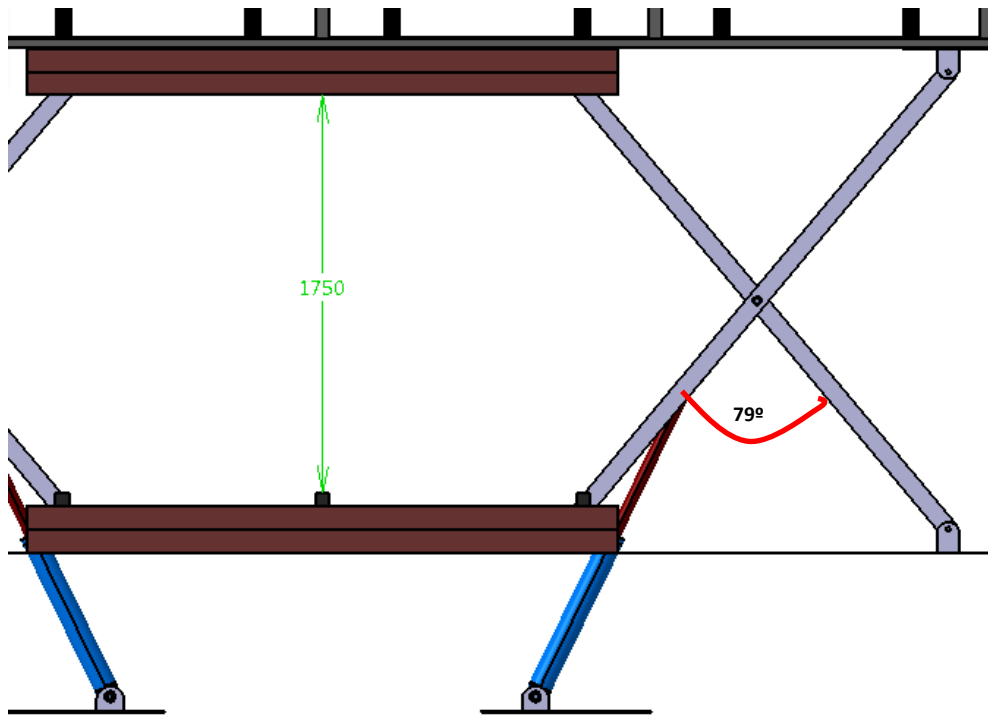
Pic. 40 Angles between bars in the up position.

The grades that the angle will decrease can be calculated with the following relation:

$$Angle \ (Low \ position) = 169º$$
$$Angle \ (Up \ position) = \ 79º$$

$$Difference \ of \ angles = 169º - 79º = 90º$$

$$Bars \ angle \ speed = \frac{90º}{5seg} = \frac{\mathbf{18º}}{\boldsymbol{s}}$$

4. Movement of the wheels

In this mechanism there are eight wheels which allows the mechanism lifting, the objective of these are wheeling along the profile in order to favor the lifting of the mechanism since the friction is lower than when there are no wheels.
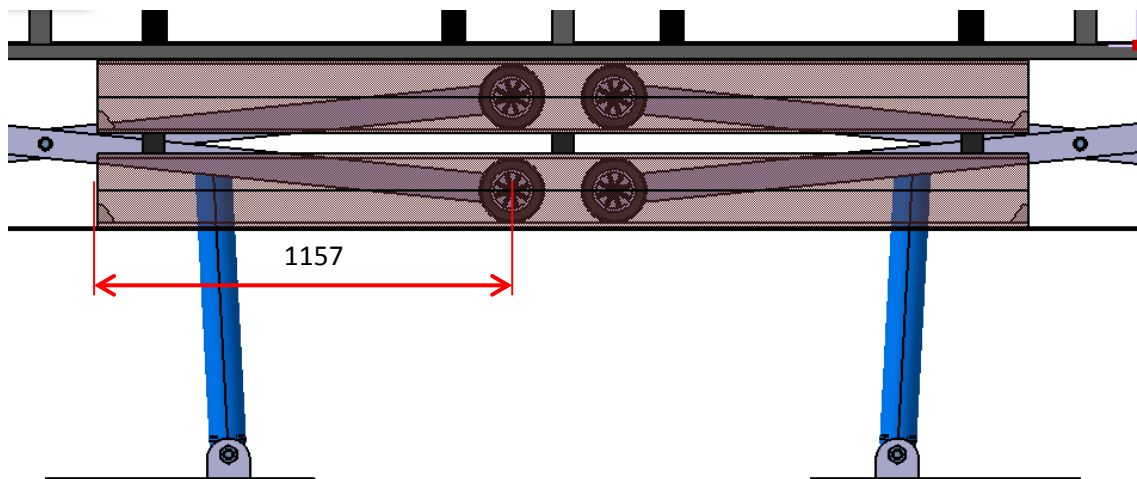
Pic. 41 Position of the wheels when the platform is down

This is the position in which both wheels are near, they cannot get nearer cause of the stops that there are between of the wheels profiles, also the cylinders work as stops since there is no too much stroke in order to go down, anyways the top sheet will be touching with the precast so it is impossible that the up profile go down and therefore the wheels get nearer.

The position of the wheels will move until they reach almost the end of the profile, however the profile has been designed with some stops in order to avoid the problems that could cause a derailment of the wheels.

In spite of the fact that the strokes of the cylinders is limited since it cannot reach such a higher distance, it would be better prevent the problematic than a derailment of the wheels could cause.

So the next step will be calculate how the translation of the wheels is influence since knowing it is possible to know the rotation speed that it will develop the wheels, so for this case the horizontally distance that the wheels moved can be calculated knowing the distance of the wheels in the up position.
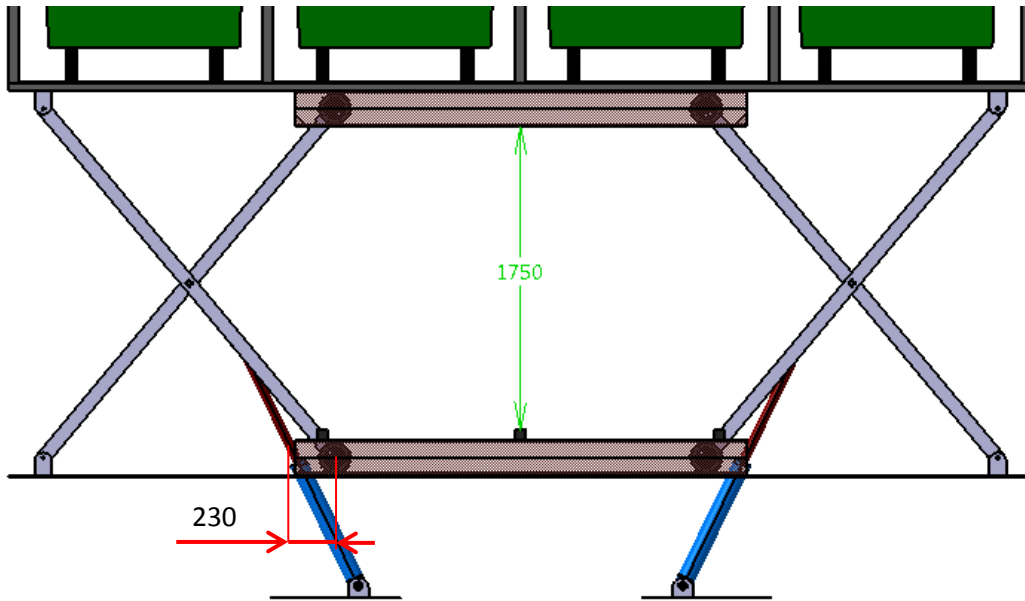
Pic.42 Position of the wheels when the platform is up

$$Distance\ (platform\ down) = 1157mm$$
$$Distance\ (platform\ up) = 230mm$$
$$Distance = 1157 - 230 = 927mm$$

$$Lineal\ average\ speed = \frac{927mm}{5sec} = \frac{185.4mm}{s} = \boldsymbol{\frac{0.185m}{s}}$$

$$Radio\ of\ the\ wheel = 90mm$$
$$Circunference\ of\ the\ wheel = 2\pi r = 0.56m$$

$$Rotation\ Speed = \frac{s}{r} = \frac{0.185\ m/s}{0.09m} = \frac{2.05rad}{s} = \boldsymbol{19.62rpm}$$

Knowing the length and the circumference of the wheel, the amount of laps can be calculated.

$$Laps_{wheel} = \frac{distance}{circunference_{wheel}} = \frac{0.927m}{0.56m} = \boldsymbol{1.64laps}$$

Each wheel needs less than 2 laps in order to make the track in the profile.

5. Hydraulic Calculations

1. Force required

The first step in the hydraulic calculations is the election of the hydraulic cylinders that will raise the structure with the containers, once that we know the weight that the mechanism should raise, we have to design were the cylinders are located and their characteristics.

$$Maximum\ weight = 3640 + 3385 = \mathbf{7045kg}$$
$$Force = 7045kg * \frac{9.81m}{s^2} = \mathbf{69111.45N}$$

This is the force which belongs to the weight of the containers and the platform in a vertical way, we must have in mind that the force that the cylinders will make is going to be pretty bigger due to the fact that they are not lifting the mechanism totally vertical.

Cause of the position of the cylinders, in the most adverse position due to the angle of the lifting, the cylinders will have to make such a bigger force.

$$Less\ angle = \mathbf{64^{\underline{o}}}$$

The normal force over the surface of the cylinder can be calculated following the next trigonometric equation.

$$Vertical\ Force = Cylinder\ Force * sen(64^{\underline{o}})$$
$$Cylinders\ Force = \frac{69111.45}{sen(64^{\underline{o}})} = \mathbf{76893.53N}$$

Since the mechanism has two scissors lifting mechanism, it will require 2 hydraulic cylinders in each side of the mechanism, these cylinders will be located and welded in the steel sheet of the bottom and also joined to a cross profile.

There will be a rotation joint in each end of the cylinder, which allows the mechanism rotate in order to avoid the twist that could be produced when the structure lowers and raises.

In order to calculate the value of the force that each cylinder should make, just knowing that we have two cylinders and the maximum force of the weight, we can calculate it.

$$Force\ (1Cylinder) = \frac{76893.53N}{2} = \mathbf{38446.77N}$$

2. Design of parameters

Once we know the force required, it is mandatory to have in mind that one of the most important aspects in the design is studying the plunger since the cylinder is too long, and we need to avoid that the cylinder develops buckling.

Once that we study the different positions, the cylinder will occupy around **885mm** while the reposes position, however it will occupy when it is extended **1600mm**.

The minimum diameter that the cylinder plunger should have can be calculated using the Euler´s equation.

$$F = \frac{\pi^2 * E * I}{v * L_k^2} \rightarrow I = \frac{v * F * L_k^2}{E * \pi^2}$$

$$E = Steel\ modulus\ of\ elasticity = \frac{210000N}{mm^2}$$

$$I = Moment\ of\ inertia\ (circle\ section) \rightarrow I = \frac{d^4 * \pi}{64} \rightarrow d = \sqrt[4]{\frac{64 * I}{\pi}}$$

$$v = Security\ factor = 3,5$$
$$L_k = \beta * L = Free\ buckling\ lenght$$

When there are rotation joints in both ends of the cylinder, the **β** is **2.0**

$$L = Plunger\ stroke\ length$$
$$= Extended\ length\ of\ the\ cylinder$$
$$- Compressed\ length\ of\ the\ cylinder = 1600 - 885 = \mathbf{715mm}$$

$$d = Rod's\ diameter$$
$$F = \frac{\pi^2 * E * I}{v * L_k^2} \rightarrow I = \frac{v * F * L_k^2}{E * \pi^2} = \frac{3.5 * 38446 * (715 * 2)^2}{210000 * \pi^2} = 132762mm^4$$

$$I = \frac{d^4 * \pi}{64} \rightarrow d = \sqrt[4]{\frac{64 * I}{\pi}} = \sqrt[4]{\frac{64 * 132762}{\pi}} = \mathbf{40.55mm}$$

Since there are not plungers with those values, it would be better decide one pretty bigger in order to avoid problems, so the election is a 45mm diameter plunger, now we

check that the force which is necessary for the buckling with that diameter is bigger than the force which the mechanism is working.

$$I = \frac{d^4 * \pi}{64} = \frac{45^4 * \pi}{64} = 201288,959 mm^4$$

$$F = \frac{\pi^2 * E * I}{v * L_k^2} = \frac{\pi^2 * 210000 * 201288.959}{3,5 * (2 * 715)^2} = \mathbf{58290.64 > 38446.725N}$$

The cylinder which will be chosen belongs to the group of CHSG which can works with different pressures between 3,5MPa and 16MPa, this group of cylinders is designed with long strokes

The following pictures and table show the different parts of the cylinder and the main characteristics   as   well.
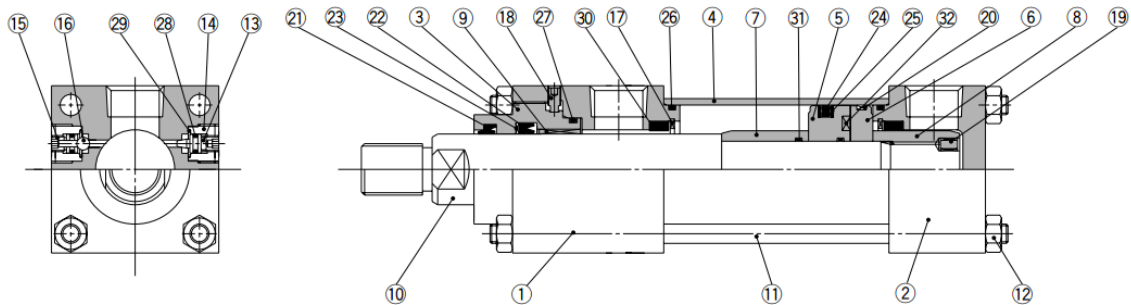
Parts List

No.	Description	Material	No.	Description	Material
1	Rod cover	Carbon steel	17	Retaining ring	Carbon tool steel
2	Head cover	Carbon steel	18	Set screw	Alloy steel
3	Seal holder	Carbon steel	19	Pin	Stainless steel
4	Cylinder tube	Stainless steel	20	Wear ring	Resin
5	Piston	Stainless steel	21	Scraper	NBR
6	Magnet plate	Stainless steel	22	Rod seal	NBR
7	Cushion ring	Carbon steel	23	Back-up ring	Resin
8	Cushion ring nut	Carbon steel	24	Piston seal	NBR
9	Bushing	Copper alloy	25	Back-up ring	Resin
10	Piston rod	Carbon steel	26	Cylinder tube gasket	NBR
11	Tie-rod	Chromium molybdenum steel	27	Holder gasket	NBR
12	Tie-rod nut	Carbon steel	28	Valve seal	NBR
13	Cushion valve	Alloy steel	29	Valve holder gasket	NBR
14	Valve holder	Carbon steel	30	Cushion seal	—
15	Air release valve	Alloy steel	31	Piston gasket	NBR
16	Check ball	Bearing steel	32	Magnet	—

Pic.43 Parts and materials of each part

After knowing the first estimation about the diameter, we will check if it can works properly cause of the stroke.

Bore size (mm)	Rod size (mm)
32	18
40	22
50	28
63	36
80	45
100	56

Table 4 Equivalence between bore and rod sizes.

Then once that the diameter has been chosen, one that guarantees the properly working of the mechanism, the next step is checking that the stroke can be chosen for ours.

Anyways this study will be carried out with the two possibilities of diameter that I can imagine the chosen previously and one which assure a safer working.

Specifications

Bore size (mm)		32	40	50	63	80	100
Action		Double Acting: Single Rod					
Fluid		General mineral hydraulic fluid					
Nominal pressure		16 MPa					
Maximum allowable pressure		20 MPa					
Proof pressure		24 MPa					
Minimum operating pressure	With pressure at rod side	0.25 MPa					
	With pressure at head side	0.15 MPa					
Ambient and fluid temperature	Without magnet	-10 to 80°C					
	Built-in magnet	-10 to 60°C					
Piston speed		8 to 300 mm/s					
Cushion		Cushion seal					
Thread tolerance		JIS 6 g/6 H					
Stroke length tolerance	100 mm or less	0 to +0.8 mm					
	101 to 250 mm	0 to +1.0 mm					
	251 to 630 mm	0 to +1.25 mm					
	631 to 1000 mm	0 to +1.4 mm					

Note) Refer to page 134 for definitions of terms related to pressure.

Standard Stroke

Bore size (mm)	Standard stroke (mm)
32	25 to 800
40	25 to 800
50	25 to 800
63	25 to 800
80	25 to 800
100	25 to 1000

Table 5 Characteristics

In the second table can be checked that a 80 or 100 mm cylinder allows a stroke up to 800 or 1000 mm respectively , the stroke required for our mechanism is 715 and for this reason this cylinder is good enough in order to be carried out.

The following calculations show the limits in the range of stroke for this cylinder.

First of all, it is mandatory to know that each position and joint of the cylinders change the requirements of stroke, in the graphic there are several curves for each kind of supports.
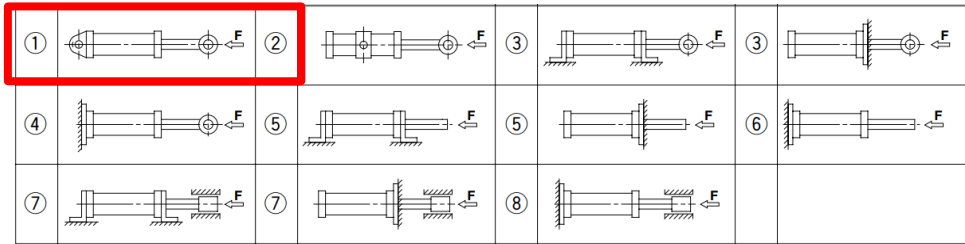
Pic.44 Supports of cylinder.

The supports that these cylinders have are the number one since each of the ends allows the rotation.
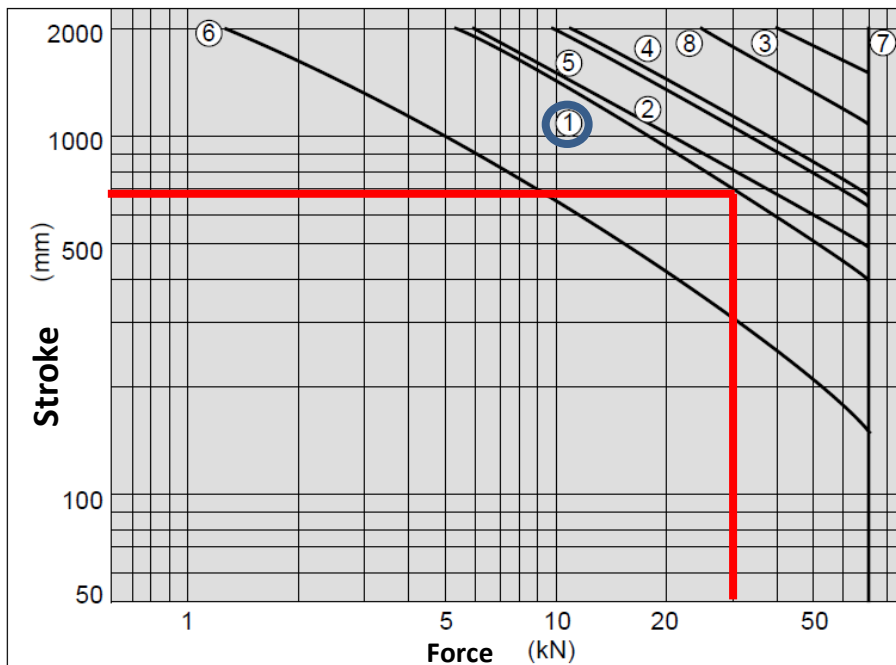
Pic.45 Graphic 80mm diameter size

As we can see in this graphic, a 80mm diameter cylinder would not be able to develop such a big force in order to raise the weight cause of the too much length of the stroke.

The next step is checking if 100mm can be enough for it.
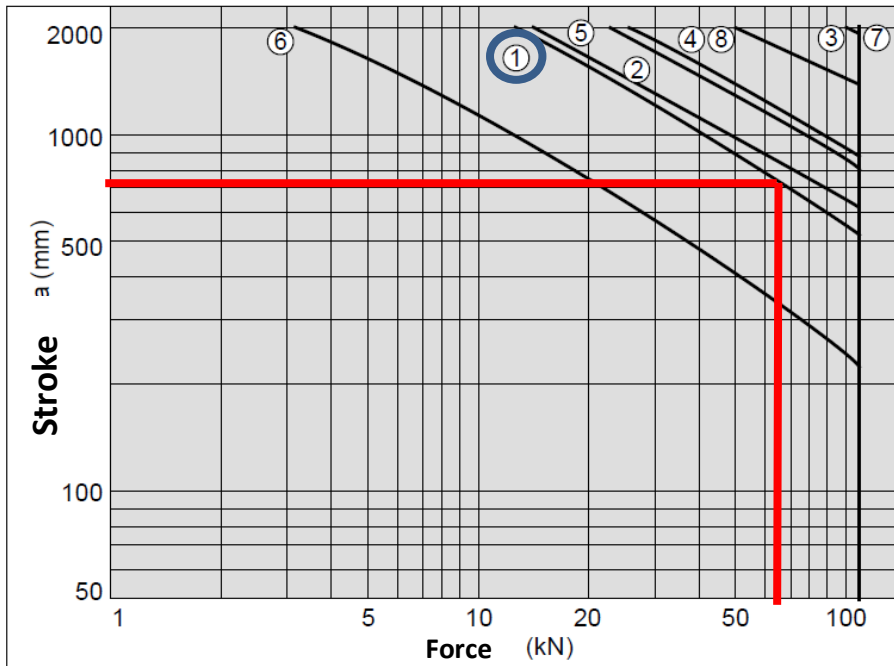
Pic.46 Graphic 100mm diameter size

As we can see in the preciously graphic, the values of stress which would be developed by the cylinder are lower than the values that it can support according to the graphic so we can assure that the cylinders will work without problems.

Indeed, the maximum force that will be working in the cylinders will be less than the force that is necessary in order to develop buckling with the measures chosen, the hydraulic cylinders for this design will have the following characteristics:

$$Plunger\ diameter = \ 56mm$$
$$Bore\ diameter = \ 100mm$$
$$Maximum\ Force = \mathbf{38446.77N}$$
$$Stroke = 715mm$$

Since we chose a 56mm rod cylinder, the bore size will be 100mm as the following table shows.

Theoretical Output

OUT | IN
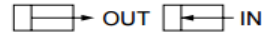
Unit: N

Bore size (mm)	Rod size (mm)	Operating direction	Piston area (mm²)	Operating pressure (MPa)			
				3.5	7	10	16
32	18	OUT	804	2814	5628	8040	12864
		IN	549	1922	3843	5490	8784
40	22	OUT	1256	4396	8792	12560	20096
		IN	876	3066	6132	8760	14016
50	28	OUT	1963	6871	13741	19630	31408
		IN	1347	4715	9429	13470	21552
63	36	OUT	3117	10910	21819	31170	49872
		IN	2099	7346	14693	20990	33584
80	45	OUT	5026	17591	35182	50260	80416
		IN	3436	12026	24052	34360	54976
100	56	OUT	7853	27486	54971	78530	125648
		IN	5390	18865	37730	53900	86240

Theoretical output (N) = Pressure (MPa) x Piston area (mm²)

Table 6 forces that the mechanism can develop

The previously table shows the forces that the cylinder would develop, since the piston area does not change, the force will be influenced by the operating pressure which one the hydraulic bomb is working.

Since this is a double effect cylinder, it will have a different force when it is rising and when it is lowering because the working areas are different. When it is rising the oil will work over all the bore area while when it is lowering it will work over the bore area without the rod or plunger area.

This system is valuable for our mechanism due to the fact that the biggest force must be done in the lifting movement since the containers will be full and the weight would be bigger.

In this case the biggest force that the mechanism can develop will be limited because of the long stroke, since we have a 56mm rod and 715mm length of stroke, according with the graphic, the biggest force that the cylinder can support will be around 65000N, it is enough for our mechanism.

This is the pressure that is required for the maximum force.

$$P = \frac{F}{A} = \frac{38446}{\pi * 50^2} = \frac{4,89N}{mm^2} = 43.9 bares = 4.4 MPa$$

The maximum pressure that the cylinder can use is $16 MPa = 1600\frac{N}{cm^2}$

$$Proof\ pressure = 24 MPa = \frac{2400N}{cm^2}$$

Since 4.4Mpa is not a normalized pressure, it will be calculated what is the limit of pressure that it can support cause of the limit of the force of 65000N.

$$P = \frac{F}{A} = \frac{65000}{\pi * 50^2} = 8.27MPa$$

This means that the pressure that we will use is **7MPa**

As we can see in the table of the forces depending of the pressure, we have different values for both movements of the cylinder but both of them are suitable for our mechanism:

$$OUT = 54971N$$
$$IN = 37730N$$

3. Thickness of the cylinder

Now it is time to calculate the thickness of the cylinder, for this calculation we have to study the stress that is produced in the cylinder, for this topic we have to make the distinction between two assumptions, one is that the cylinder can be thin wall or thick wall since the stress are not the same in both cases.

- If the cylinder is thin wall, the relation should be the following one: e<d/40
- If the cylinder is thin wall, the relation should be the following one: e>d/40

Since the thickness is unknown, the process will be choose one of these assumptions as right one and check later if it is right, then we will have our cylinder, otherwise the right one is the other.

In the cylinder and pressurized elements, as can be the hydraulic cylinders that will be used in this system there are radial and tangential stresses with an intensity which depends of the radio of the element.

Once that the radial and tangential stresses are calculated, the longitudinal deformation is considered constant around the circumference of the cylinder, which means that the hypothesis that a straight section of the cylinder remains straight after the stress.
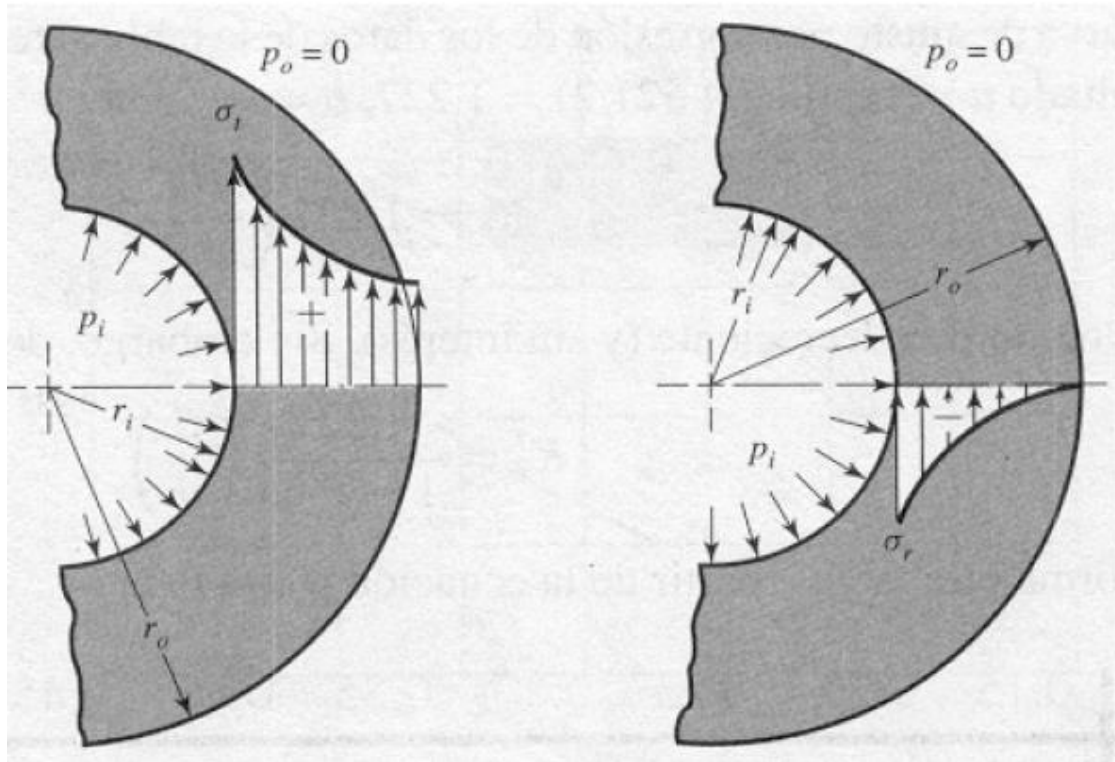
Pic.47 Distribution tangential and radial of the stresses.

Since $P_0 = 0$ the distributions are the following ones:

$$\sigma_t = \frac{r_i^2 * p_i}{r_0^2 - r_i^2} * \left(1 + \frac{r_0^2}{r^2}\right)$$

$$\sigma_r = \frac{r_i^2 * p_i}{r_0^2 - r_i^2} * \left(1 - \frac{r_0^2}{r^2}\right)$$

The longitudinal stress when the piston absorbers the reaction in the ends cause of the internal pressure is:

$$\sigma_l = \frac{r_i^2 * p_i}{r_0^2 - r_i^2}$$

Considering that the cylinder is a thin wall item with $e =\leq \frac{r}{20}$, in these cases the radial stress will be so small if we compare it with the tangential stress, it is the radial stress which supports the force that tries to split the two halves of the cylinder acting over all the stress area.

$$(\sigma_t) máx = \frac{p * (d_i + t)}{2 * t}$$

The longitudinal stress is supposed uniformly distributed as well:

$$\sigma_l = \frac{p * d_i}{4 * t}$$

$$\sigma_\theta = (\sigma_t)máx = \frac{p * d}{2 * t} = \frac{4.38 * 100}{2 * t} = \frac{219}{t}$$

$$\sigma_z = \sigma_l = \frac{p * d}{4 * t} = \frac{4.38 * 60}{4 * t} = \frac{65.7}{t}$$

$$\sigma_r = 0$$

Now we calculate the Von Mises stresses.

$$\sigma_\theta = \sigma_1 = \frac{219}{t}$$

$$\sigma_z = \sigma_2 = \frac{65.7}{t}$$

$$\sigma_r = \sigma_3 = 0$$

$$\sigma_{VON\ MISES} = \sqrt{\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}} = \frac{\mathbf{275.27}}{\mathbf{t\sqrt{2}}}$$

Now we pose the following equation:

$$\sigma_{VON\ MISES} = \frac{yield\ stress}{security\ coeficcient} = \frac{310MPa}{3} = 103.3\frac{N}{mm^2}$$

$$103.3\frac{N}{mm^2} = \frac{275.27}{t\sqrt{2}} \rightarrow t = \mathbf{1.88}$$

$$t < \frac{d}{40} => 1.88 < \frac{100}{40} = 2.5$$

Since $.88 < 2.5$, it is not necessary to develop the other theory, it means that with a thickness of 1.88mm it is enough in order to support these stress.

4. Flow calculations

First of all, knowing that the maximum speed allowed for the cylinder is 500mm/s the flow that the cylinder requires will be calculated following the next equation;

$$Q = s * A$$

$$A_{Piston} = \frac{\pi}{4} * D^2 = \frac{\pi}{4} * 10^2 = \mathbf{78.53 cm^2}$$

$$A_{rod} = \frac{\pi}{4} * (D_{piston}^2 - D_{rod}^2) = \frac{\pi}{4} * (10^2 - 5.6^2) = \mathbf{53.9 cm^2}$$

Since the flow depends of the area, there will be two different flow cause of the areas which are different when the rod is going up and when it goes down. This is due to the fact that the surfaces are different, and the fluid will make a different force.

When we calculate the flow, we have to know that if 500mm/s is used as speed, the flow will be so huge so it is better to avoid this problem and use such a quite smaller speed in order to get smaller flow which allow the mechanism lifts properly and fast as well without the costs of the other one.

The speed chosen is: 150mm/s

$$Q_{up} = A * s = 78.53 cm^2 * \frac{150mm}{s} * \frac{6}{1000} = \mathbf{\frac{70.667 l}{min}}$$

$$Q_{down} = A * s = 53.9 cm^2 * \frac{150mm}{s} * \frac{6}{1000} = \mathbf{\frac{48.51 l}{min}}$$

After studying the prices of the pumps, there are 4 options to evaluate:

1. Two 70 litres/min flow pumps = 2x 935,92= 1871.84€
2. One 140litres/min flow pump, one way. = > not possible cause of dangerous limit of flow.
3. **One 164litres/min flow pump, one way => 1489.60 €**
4. One 71-71 litres/min flow pump, two ways. = 1971.86€

The final decision is a 160litres/min pump since it is the cheapest one and beside of this, using one, the probability of breakdown in the mechanism is less than using two.

Pic.48 Properties of the pump

$$Caudal = 164 \; l/min$$

$$Speed = 1200pm$$

Oil used: FLUID DRIVE HM − 22

Highly refined hydraulic fluids for stringent working conditions.

They contain anti-wear, anticorrosive, antioxidant and antifoaming additives. Meet the ISO 6743 standard HM class and DIN 51524 Part 2, HLP class.

ISO grade = 22

Flash point = 180ºC

Pour point = -33ºC

Density = 0.88g/ml

Viscosity Index = 100

6. Economics Calculations

First of all we should have in mind that this project is an improvement of one public service that it is already working, what it means that the investment that is required in it will be part of the improvement of the city´s quality.

However this technology must be implanted in the European cities before the deadline so there is no impediment for avoiding this system; anyways the budget has to be fully adjusted in order to be afforded by the town where it is going to be implanted, beside of this, this project does not seek a huge benefit since it is preferred the improvement in the quality of life and environment.

1. Direct costs

1. Personal costs

In the personal costs are included those costs related with the work of everyone who is carrying out this project. It is reflected by hours of work and the cost depending of each range of worker.

The project can be designed by one engineer who was the responsible of the design, study and viability of the mechanism,, one secretary who helped him in the paperwork and the workers who build the mechanism and all the other parts.

First of all, it will be established a monthly salary as reference for the different workers and after that it will be calculated the brute salary.

ENGINEER COST	
Net monthly salary	1200€
Social security (33% net salary)	396€
Total monthly cost	1596€
Total annual cost	19152€

Table 7 Engineer´s cost

SECRETARY COST	
Net monthly salary	500€
Social security (33% net salary)	150€
Total monthly cost	650€
Total annual cost	7800€

Table 8 Secretary´s cost

WORKERS COST	
Net monthly salary	450
Social security (33% net salary)	150€
Total monthly cost	600€
Total annual cost	7200€

Table 9 Wokers´ Cost

The next step is knowing how many hours will work each of them during the development of the project.

WORK DAYS OF THE YEAR	
YEAR	365 days
WEEKS IN THE YEAR	52
SATURDAYS AND SUNDAYS/WEEK	104 days
HOLIDAYS	15 days
PUBLIC HOLIDAYS	14 days
TOTAL DAYS	232 days

Table 10 Working days

If we have in mind that the engineer works 8 hours per day:

HOURS WORK PER DAY	8
HOURS WORK PER YEAR (232 days)	1856
COST PER HOUR (Engineer)	10.32€
HOURS WORK PER DAY	8
HOURS WORK PER YEAR (232 days)	1856
COST PER HOUR (Secretary)	4.20€
HOURS WORK PER DAY	8
HOURS WORK PER YEAR (232 days)	1856
COST PER HOUR (Workers)	3.88€

Table 11 Costs per hour

So the costs related with the personal are the following ones:

- Engineer cost:10.32€/hour
- Secretary cost: 4.20€/hour
- Workers cost: 11.64€/hour

WORK TIME DISTRIBUTION (Engineer and Secretary – Workers)

Study of the project and alternatives	120 hours
Chosen the properly materials	30 hours
Calculations	100 hours
Writing of documents	100 hours
Drawings	50 hours
Writing of the final documentation	150 hours
Assembly of the mechanism	80 hours
Building of the project	60 hours

Table 12 Hours of working

Engineer and secretary hours: 550 *hours*

Workers (3)*hours*: 140 *hours*

$$Engineer\ cost = 550\ hours * \frac{10.32€}{hour} = \mathbf{5676}€$$

$$Secretary\ cost = 550\ hours * \frac{4.20€}{hour} = \mathbf{2310}€$$

$$Workers\ cost = 140\ hours * \frac{11.64€}{hour}(3\ workers) = \mathbf{4888}€$$

$$Total\ direct\ personal = 5676€ + 2310€ + 4888€ = \mathbf{12874.8}€$$

2. **Software costs**

Software	Price 1 year License
Working Model	300€
CATIA V5-6R2014	8828€+1324€(Maintenance)
Microsoft Office 2016	539€
TOTAL	**10991€**

Table 13 Software costs

Knowing that these softwares will be used during 1856 hours per year.

The price per hour is:

$$\frac{10991€\ year}{1856\ hours\ year} = \frac{\mathbf{5.92}€}{\mathbf{hour}}$$

Since for this project 550 hours will be used:

$$550\ hours * 5.92€ = \mathbf{3257}€$$

3. Material costs

Part	Units	Cost (1)	Total
Concrete H-25 (Precast)	4.8m3	265€	1272€
Cylinders Steel Sheet 750x450x6mm	2	78€	156€
Bottom Steel Sheet	1	584€	584€
Wheels Profile (206x87x12)	4	330.50€	1322€
Hitch	8	56€	448€
Bar	8	336€	2688€
Wheel	8	43€	344€
ISO4016 BOLT M10x80 GRADE C HEXAGON HEAD	8	0.85€	6.8€
ISO 4034 NUT M10 GRADE C HEXAGON HEAD	8	0.10€	0.80€
ISO7089 WASHER10x20 GRADE A PLAIN NORMAL	16	0.05€	0.80€
ISO 8738 WASHER 10 GRADE A PLAIN WASHER	16	0.06€	0.96€
Long Cross Profile 60x40x4x1660mm	4	105€	420€
Short Cross Profile 60x40x4x1614mm	4	94€	376€
Reinforcement of cylinders profile 60x60x3x925mm	4	63€	252€
Support	6	11€	66€
Stop	8	5.63€	45.04€
ISO 2341 CLEVIS PIN 16x50 WITH HEAD TYPE B WITH SPLIT PIN HOLE	4	1.2€	4.8€
ISO7089 WASHER16x30 GRADE A PLAIN NORMAL	12	0.07€	0.84€
ISO 4014 BOLT M3x20 GRADE A HEXAGON HEAD	4	0.26€	1.04€
ISO 4032 NUT M3 GRADE A HEXAGON	4	0.04€	0.16€
ISO4016 BOLT M10x100 GRADE C HEXAGON HEAD	8	0.95€	7.6€
ISO 7089 WASHER 10x20 GRADE A PLAIN NORMAL	32	0.05€	1.6€
ISO 4032 NUT M10 GRADE A HEXAGON	8	0.10€	0.80€
Welding Sheet 2600x116x3	2	60.2€	120.4€
Structure (Total of all profiles)	1	3904€	3904€
Hitch Sheet 400x220x5	4	45.92€	183.7€
Container Sheet 1900x1490x6 (Without Corners)	4	480€	1920€
Container 2600l	4	896€	3584€
Telescopic Regulation cylinders	6	57€	342€
Boxes Platform	1	965€	965€
Garbage Box	4	178€	712€
Cylinder Hitch	2	48€	96€
ISO 4014 BOLT M30x220 GRADE B HEXAGON HEAD	2	2.70€	5.40€
ISO 4032 NUT M30 STEEL GRADE A HEXAGON	4	0.55€	2.2€
Rod Hitch	2	39€	78€
ISO 4014 BOLT M30x110 GRADE B HEXAGON HEAD	2	2.25€	5.50€
Hydraulic system (disaggregated)	1	2795€	2795€
Oil Tank	1	162€	162€

Table 14 Material costs

Hydraulic system

Part	Cost
Cylinder (2)	412x2=824€
Hydraulic Pump	1489€
Fork eyelet (2)	98x2=196€
Distribution(pipes and valves)	286€
Total	**2795€**

Table 15 Hydraulic costs

Container Structure:

Part	Units	Cost (1)	Total
Profile 60x60x3x1780	5	106€	530€
Profile 60x60x3x1590	10	96€	960€
Profile 60x60x3x1400	4	84€	336€
Profile 60x40x3x5900	4	204€	816€
Profile 60x40x3x1900	4	107€	428€
Profile 60x40x3x1780	8	97€	776€
Profile 60x40x3x280	4	14.50€	58€
Total	-	-	**3904€**

Table 16 Structure costs

Summary of material costs:

Material Costs	
Mechanism and auxiliary parts	**10.776**
Structure	**3.904 €**
Containers	**3.584 €**
Hydraulic	**2.795 €**
Concrete (Precast)	**1.272 €**
Screws	**39 €**
TOTAL	**21705.44 €**

Table 17 Summary material costs

Direct Costs	
Personal	**12874.8 €**
Software	**3257 €**
Material	**21705.44 €**
TOTAL	**37837.24**

Table 18 Direct costs

$$Total\ direct\ costs = Personal + Software + Material =$$
$$= 12874.8 + 3257 + 21705.44 = \mathbf{37837.24}€$$

2. Indirect costs

The indirect costs are cause of the activity required for the making of the project and which can not be included in any other topic of the direct costs.

In this part the following costs are included:

- Electricity and phone costs

The cost of the electricity used by the informatics computers and the amount of cost in the phone bill can be calculated as the 1% of the direct costs that the project will have, this is a rule that can be assumed when these values are too difficult to be calculated without knowing previously values.

$$Cost\ of\ electricity\ and\ phone = 37837 * 0.01 = \mathbf{378.37}€$$

- License of normative use and updates

Using the rules that must keep the development of the industrial activity and the updates of the normative suppose a fee that must be had in mind when the project´s budget is going to be calculated.

$$Licenses\ cost = \mathbf{2500}€$$

- Liability insurance

This insurance is mandatory in order to cover the necessities that can require incidents during the using of the project. This cost suppose the 40% of the engineer´s cost.

$$Liability\ insurance = 5676 * 0.4 = \mathbf{2270.4}€$$

$$\textbf{\textit{Indirect costs}} = 378.7€ + 2500€ + 2270.4€ = \mathbf{5149.1}€$$

3. Other costs

There are other concepts related with the different kind of administrative fees that are not included in any of the other two previously concepts however these must be have in mind because they are implicit costs in the development of any engineering project that is going to be carried out.

The fees which must be considered are:

- Administrative procedures
- Rates
- Visa at the College of Industrial Engineers.

A generic value for all these amounts of 5% of the total direct expenses will be taken.

$$Other\ costs = 37837.24€ * 0.05 = \mathbf{1891.86€}$$

4. Final cost of the project

The final cost of the project can be calculated with

CONCEPT	AMOUNT
DIRECT COSTS	37837.24 €
INDIRECT COSTS	5149.10 €
OTHER COSTS	1891.86 €
TOTAL	**44878.2€**

Table 19 Total costs

$$Total\ Cost = \mathbf{44878.2€}$$

7. Environmental and safety study

Everybody knows that every building, traffic light and even a sewer cause kind of environmental effect however when this project is developed, the environmental effect is going to decrease cause of the undergrounding of the containers.

When the cities are implanting this technology, the appearance of them is much more modern, clean and innovative because all the garbage is under the ground, otherwise if the containers are over the ground there will not be possibility of avoid the bad and awful smell that the garbage provokes.

Beside of the smell, the containers might cause an unpleasant visual appearance since they interfere in the city, especially if they are located in the old town or in places near to the monuments of the city.

Using this technology we can avoid both problems, on the one hand the underground containers makes a more beautiful city since the hidden garbage and on the other hand it avoid the smell problems, it is important to have in mind that this technology will be mandatory in the following years cause of an European law what it means that there is no excuse in order not to avoid the installation of these systems.

Maybe the mechanism can cause such a bad appearance while it is working and the containers rise to the surface of the street, however this period is too short since lifting the mechanism takes around 5 seconds plus the time that the containers are picked up and the time of get down as well, so it is an unimportant time if you compare this with the time that the mechanism is going to be under the ground.

So the conclusion about the environmental study is that the problems that there are with the currently technology are bigger than the problems that the mechanism can generate, only some random breakdowns can be worse than the benefits that it causes in which is related with the appearance and the smell problems.

Studying the safety of this technology, we can assure that this technology is more safe than the currently technology of picking up garbage. This system has several advantages in which respects with the safety.

It is important to know that since the containers are underground, these cannot suffer vandalism or the deterioration caused by the cold or the frozen water that they can contain when the weather is extreme.

Beside of the benefits of safety that the underground containers avoid, they can also be useful in which respects with the human safety since some people can think that it is possible to fell down in the hole that they have, but this is such an impossible case since during the period that the mechanism is being lifted and there would be a chance for the people to fell down inside the hole, this process is being supervised then this can not happen.

During the rest position of the mechanism, it is impossible to access to the hole since the steel plate that covers all the mechanism is going to be over it so there is no chance in order to access to the inside structure.

Thanks to the underground containers, the garbage can not be taken out from it what avoid that the animals which look for food inside the containers can take it out.

In conclusion about the safety in this system, this technology is safer than the currently technology for different reasons:

- There is no chance of accessing to the inside mechanism during the rest position when the containers are underground.
- During the up position, the supervision of the dustmen avoid that somebody could fell down as accident.
- This technology avoids the animals that usually are in the surroundings looking for food, these animals sometimes can have some kind of sickness that should be better to avoid.
- This underground system will avoid that different factors can provoke the moving of the normal containers what it means that if someone goes to throw the garbage and the container is not there, it can cause that the garbage will be thrown in other place.
- The huge capacity of this system makes that the times that the garbage must be collect are lower than in other systems, what it means less problems with the neighbors since the collecting usually is at night.

Conclusion

The current project has been carried out in order to develop the current technologies that are being implanted in the cities, these technologies have several fails and there are 2 topics that can be improved in a huge way, the time of lifting and the load that the system can support can be improved in which respect to dimensions and power of the cylinders.

Once that the objectives are fixed, the construction calculations have given me the requirements that should be used in order to build the mechanism and the platform that is used in this projects, the hydraulic system is designed according to the characteristics that are gotten in the hydraulic calculations.

When the designed is finished, it is time to study the costs that this project will have, in case that the costs are extremely high, it would require a new design cause of the impossibility to afford it. Since these are not so high, it can be proved that these expenses make the project to be able to be carried out.

The 3D design was made with the software Catia V5, this software presents variety of chances in which respect with the mechanical engineering, many options as can be the Von Mises stress study or the drawing of each part and assembly can be made with this software, so it has been the mainstay of this project.

Due to the fact that the calculations resulted right and the economic expenses were acceptable as well, this project could be carried out in any city that would like to improve its appearance since once that this technology is implanted, the city seems more modern and in an increasing way of life.

Finally I can say that while I was writing and designing this project, several ideas and improvements came across in the design, one example of this is the possibility of use a load detector which would be able to where the trash should be thrown and also when it should be picked up.

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