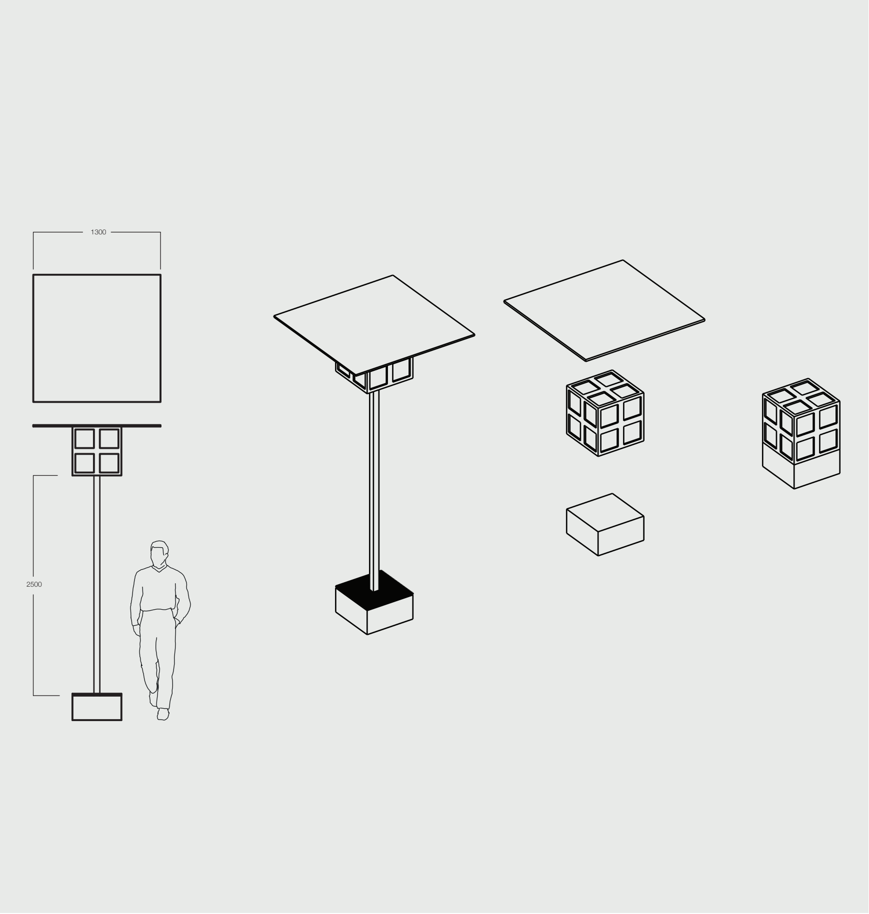
Illustration of the current lights in the park with their issues.

Characteristics of Original Design:

- Steak-holders of Garnethill park like the current lights' aesthetics and do not want to see them go but would like to see an improvement.
- The original design features a flat top with raised walls which traps the water, there is no consideration for drainage.
- People often use the top as an ash tray, they often get filled with rubbish.
- Since they are low down they are frequently the subject of vandalism.
- The materials used are not robust enough, the plastic often breaks and leaves the delicate bulb exposed (assume it is acrylic).
- Because they are frequently the subject of vandalism they are no longer used, the council has run out of resources given up maintaining them.



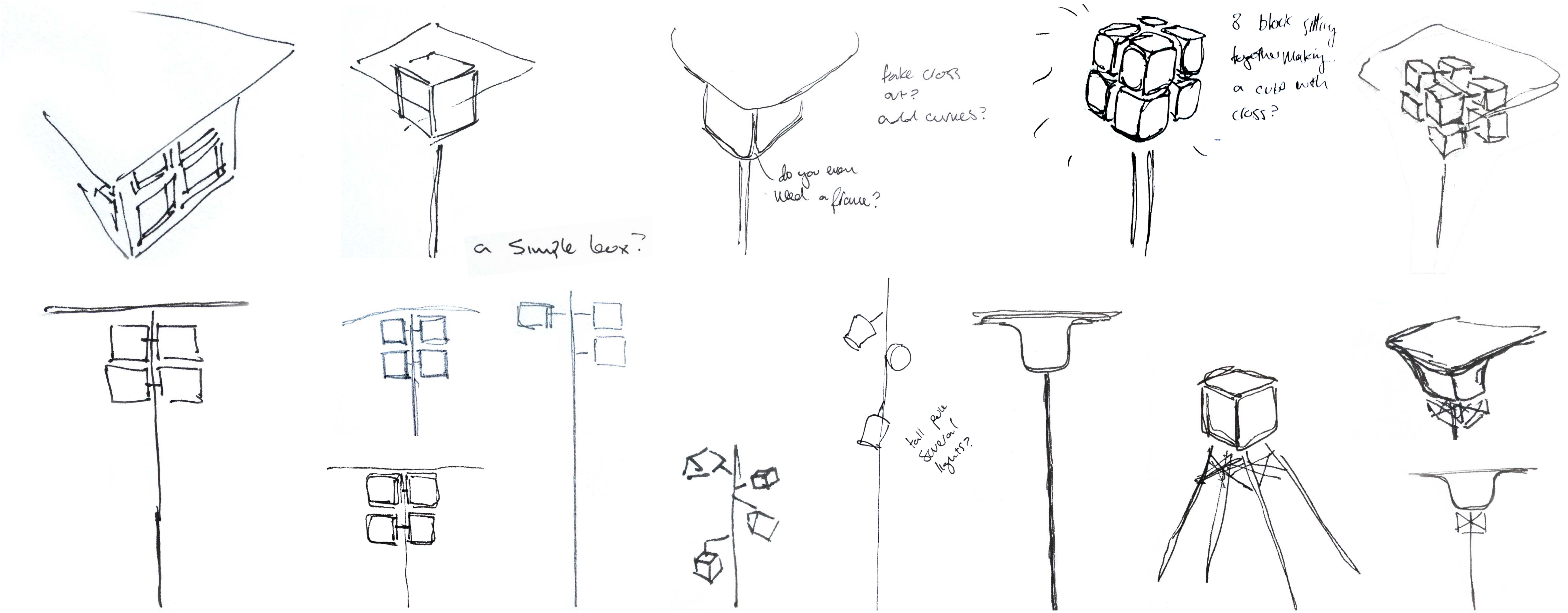
The original design is shown on the far right, the new proposal on the left.

New Design Specification:

- The new, replacement lighting must give due consideration to the steak-holders liking of the original design concept and there for must respect Dieter Magnus' vision for the lights and maintain the intended identity of the park.
- The new lights must run off the main grid (which may be supplemented by other means of power).
- They must be robust and not be easily vandalised.
- They must be structurally stable, the components should not buckle under the structures own weight plus the weight of 4 people with a factor of safety of around three.
- The lights must only be turned on when required (when it is dark).
- The internals of the lights must be easily accessible (for the council only) for maintenance purposes.
- The lights must take global and local light pollution into account, as in it must not bother residents with views of the park or contribute to the cities overall light pollution.
- The light produced must be soft with no glare.
- The lights should make the park feel safer.
- They must be IP56-protected, that is; it should have complete protection against contact and most dust as well as the entrance of moisture from a high pressure source (12.5mm diameter nozzle) from a distance of 3 meters for 3 minutes. This should protect the lamp from any vandals, weather or spray from a high pressure hose (for cleaning purposes or in case of accidental spray).
- The design of the light must take drainage into consideration.

Initial Ideas
Initial forms and thoughts

Raised



Selected drawing from initial brainstorm on form.

Variations on the form of the original design.

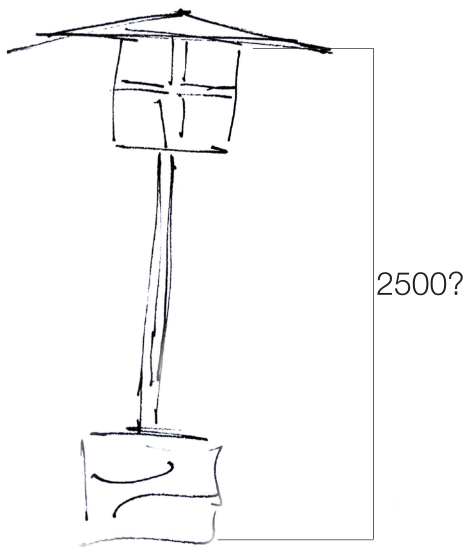
- An initial brainstorm exploring the form the light may take shows the exploration of various ideas such as reducing the detail on the face by removing the cross, curved corners were considered, the value of the frame questioned, perhaps it could be made up of a eight of cubes on arms to create another cube, or maybe the cubes are not arranged orthogonally, maybe they are not cubes, could it rest on more than one leg, how could the structure be secured in an aesthetic way?

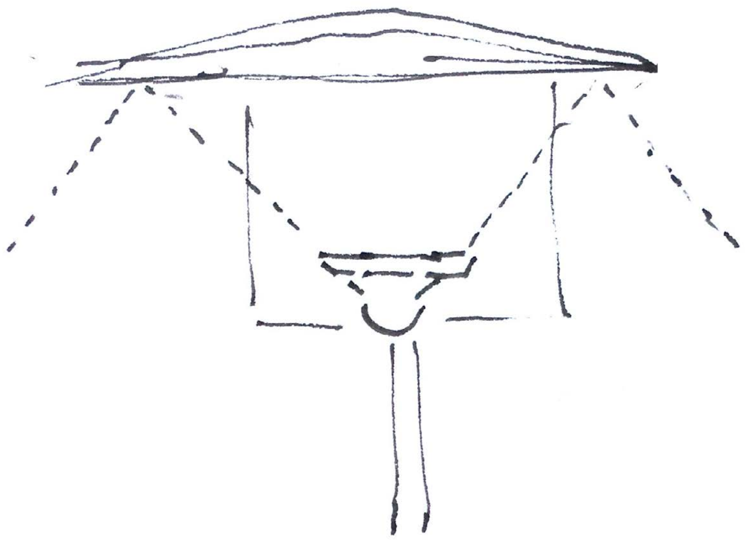
- Feedback from the community council suggests that it should be kept as simple as possible and retain the parks identity as most as possible so I will go with a simple cube with a cross.

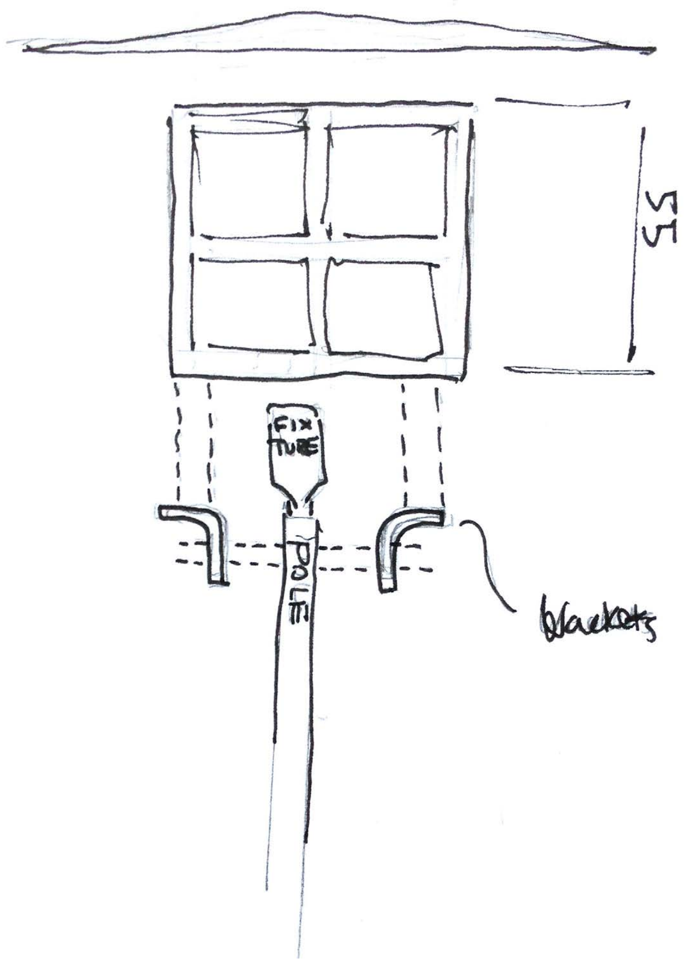
Raised

Initial Thoughts
Initial features and things for consideration

RAISED DIETER LIGHT
INITIAL IDEAS





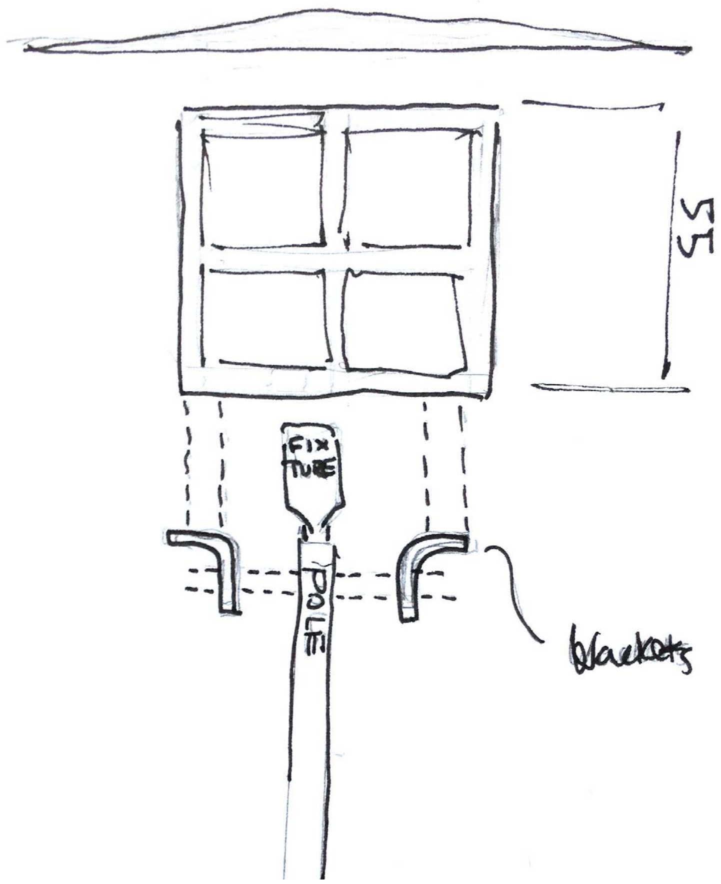


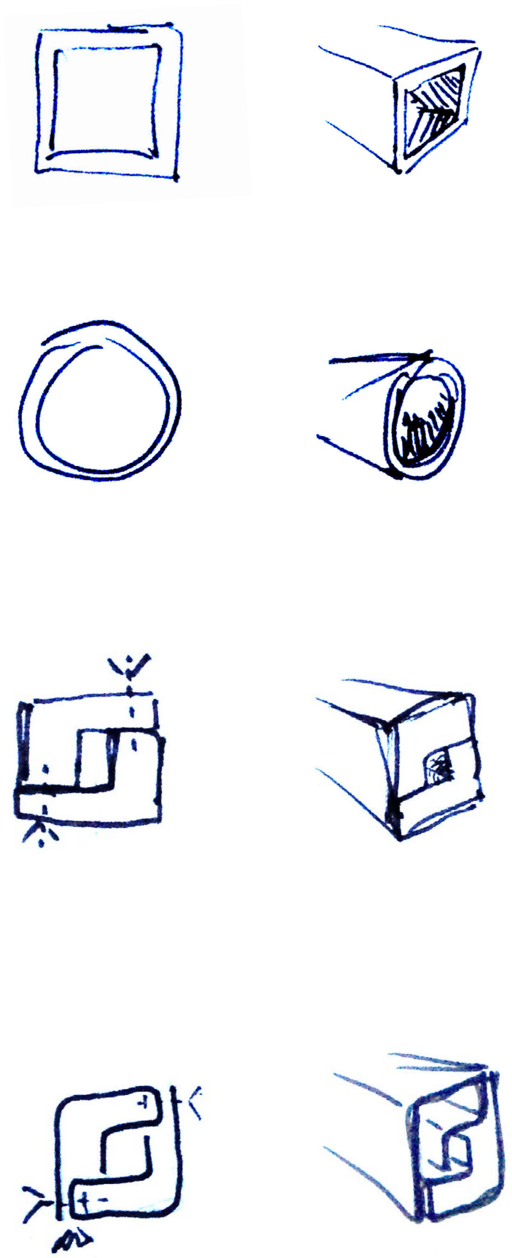
Drawings introducing general dimensions and the concept of the reflector.

Rough idea of proportions and concept of reflector.

- The light should be similar to before but raised a significant distance off the ground, around 2.5m.
- They will be placed in the same location as the original lights were, our aim is to restore the park with respect for the original design.
- The part on the top reflects the light in order to spread the light where it is required and not contribute to light pollution.
- The design can be split up into three sections, the shade, the pole and the roof/reflector. The light fixture will have to be considered as will the method of fixing the components, perhaps brackets can be used to fix the shade to the pole, welding would be another option. The design should also have similar dimension to the existing design, around about a 550mm cube.

Development
Considerations for the supporting column



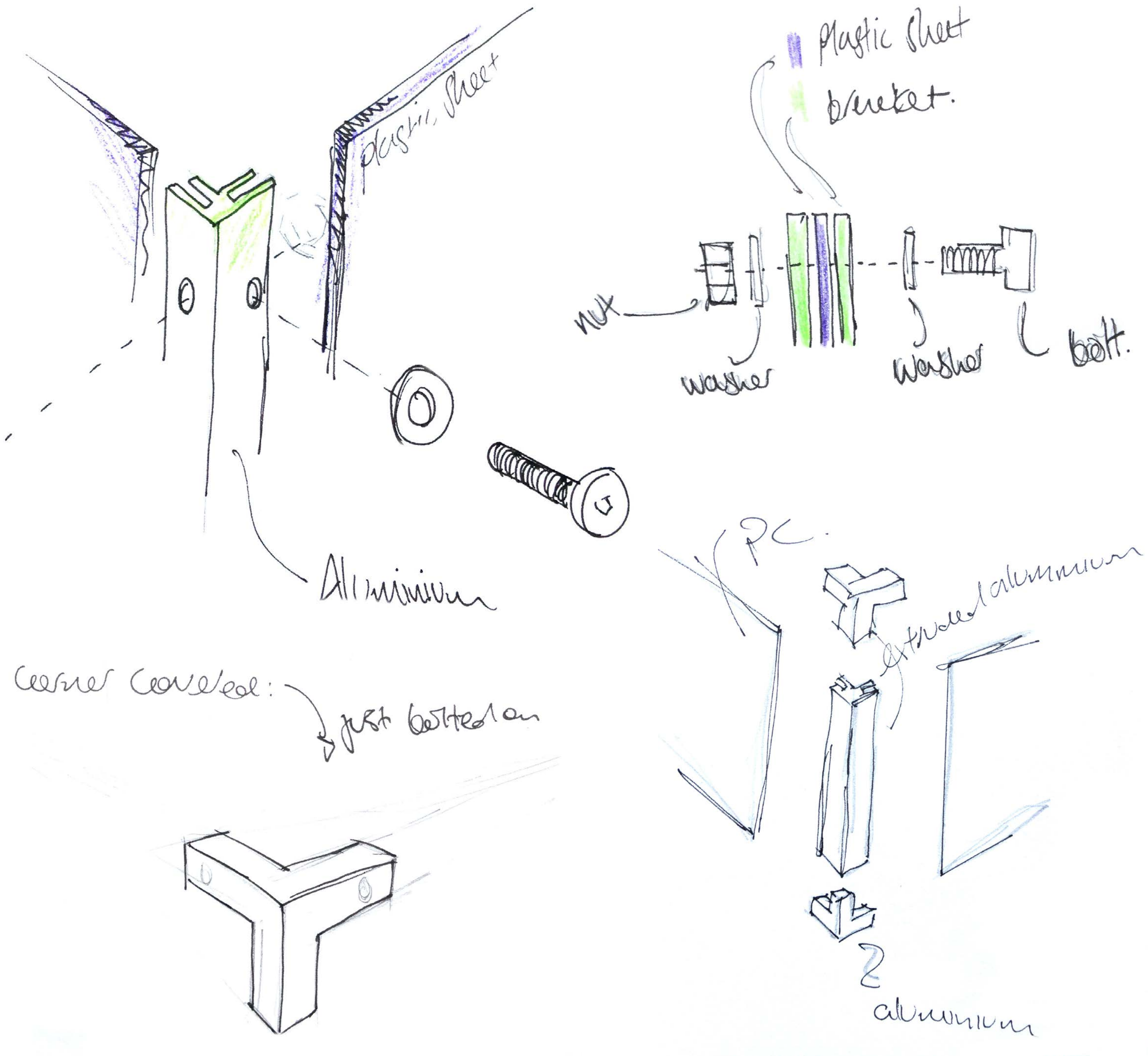


Drawings showing different methods of creating a column.

Material and production method for the column.

- The column must be hollow in the centre to house the cables for the LED.
- A hollow shape could be created through an extrusion. Hollow extrusions can be expensive because of the complex die shape however it should be possible to find a simple **standardized extrusion** to complete the job.
- An alternatives to extrusion maybe to route and treat two pieces of hardwood which come together with a hole in the centre for cables, this however would require heavy maintenance. This would require protection at the base to stop it from becoming damp and
- Perhaps two pieces of metal could be cold rolled into a shape similar to the routed hardwood and come together with a space for cables.
- Some criteria needs to be created to determine best possible material for the application. Either aluminium, or steel which has be galvanised or is stainless seem likely to be suitable for the job. Impact strength should be considered. Parameters effecting stiffness should be considered (shape, Young's Modulus) as this has an effect on how structurally stable the light is. Analysis will be completed in later stages.

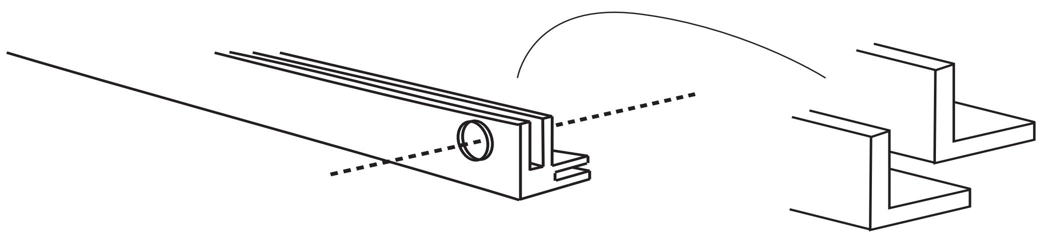
Development
Initial panel assembly

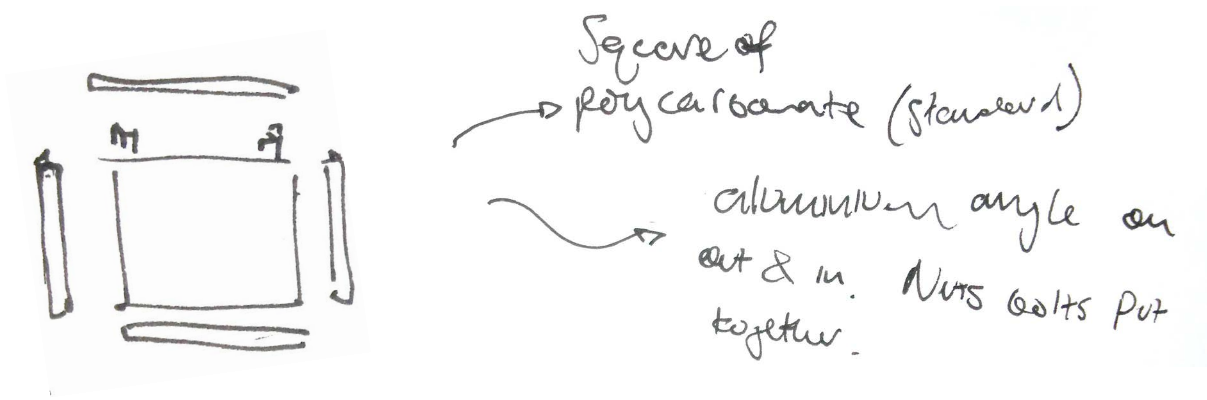


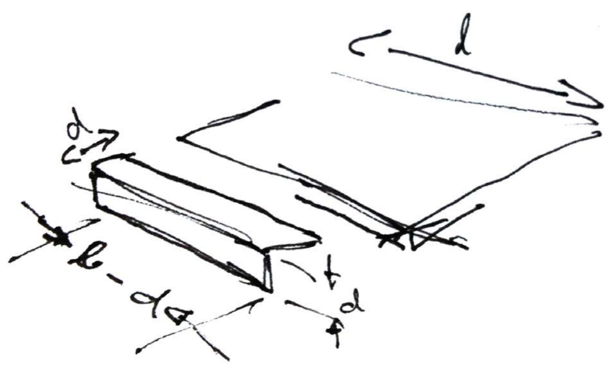
Extruded aluminium brackets holding plastic sheets in place.

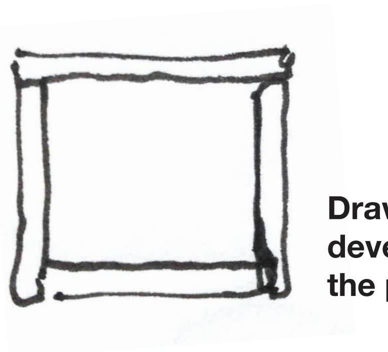
Materials choice and assembly methods.

- A cube could be assembled by using plastic sheets slotted into a bracket on the corner as shown.
- The plastic sheets could then be held in place with bolts, washers and nuts.
- The corners could be secured with the joint shown.
- The bracket could be made from aluminium because it has a high resistance to corrosion, it is low weight (the top should be minimal weight so as to reduce the chance of self excited oscillations as much as possible), it is strong and also recyclable. Aluminium will offer a long lasting solution with minimal maintenance (steel would require more maintenance to keep it from rusting and in good quality).
- Extrusion would be a suitable process because the bracket has a uniform profile.
- The plastic panels could be made from polycarbonate. PC can come with optical qualities for diffusing light or you can get a light diffusing film to apply. PC has a high stiffness to weight ratio and a high impact resistance.





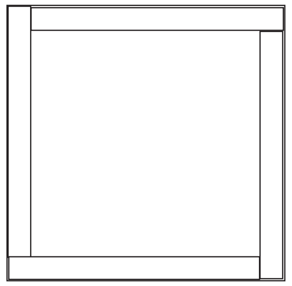


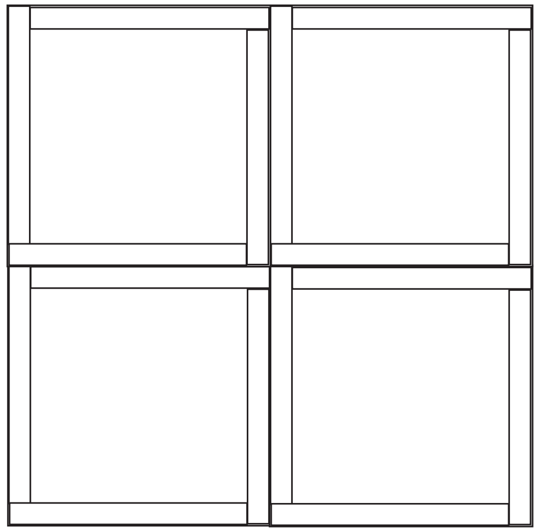


Drawings behind development of the panels frame.

Replacing the bespoke extruded frame with a standardised extrusion.

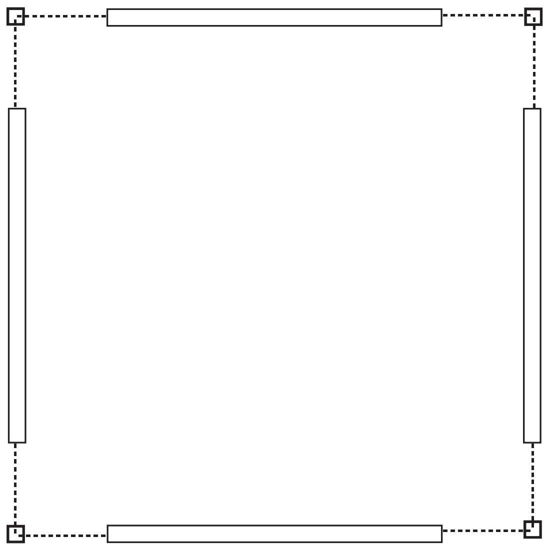
- Instead of using a bespoke extrusion to frame the PC panel you could use a standardised, off the shelf, extrusion instead. This would be much cheaper.
- You would simply use 8 aluminium angle extrusions, one on every edge of the PC on both faces, which could be bolted or welded together.
- If the length of the PC panel is l, and the width of the angle is d, then the length of each of the angles would be $(l - d)$.
- To reduce prefabrication efforts the angles could be assembled on the panel as shown, this would mean that the corners would not have to be cut at an angle and all the components would be the same size.





Assembling four panels to make a side and four sides to make part of the cube.

- Four panels, with their eight angles, would be able to be fixed together either though welding or by using nuts, bolts and washers. This would make up one face.
- Four faces would come together to create a cube without a top or a bottom. They would probably have to be welded to a column which would sit in the corner created by the panels.
- All the metal components on this part of the design will still be aluminium as it is an ideal material for outdoor use and there are many standard extrusions available.



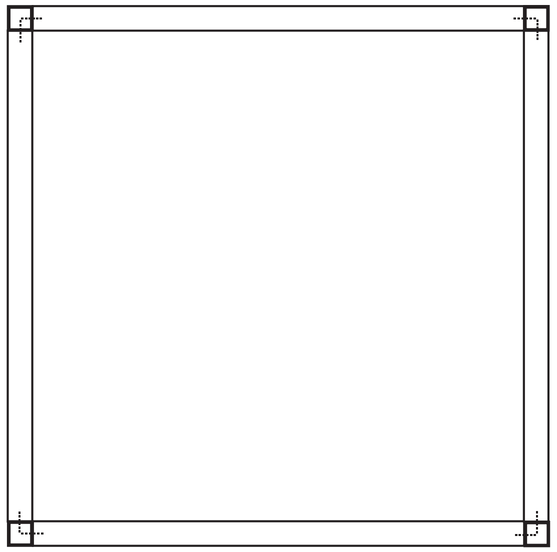
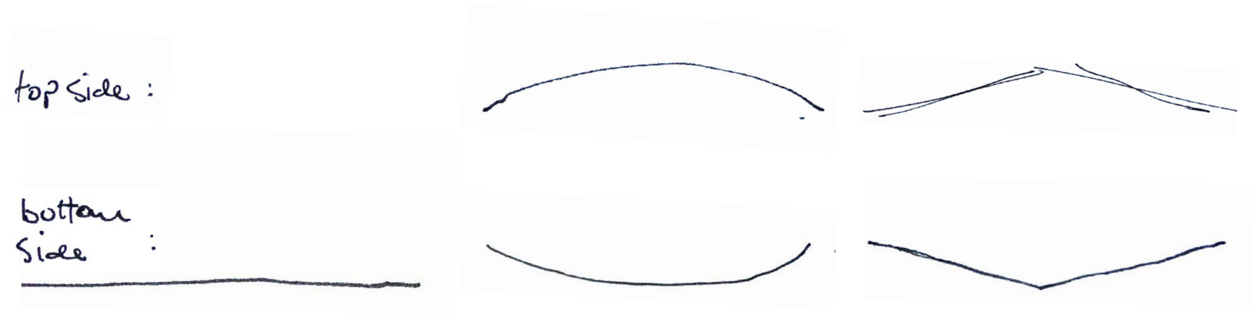
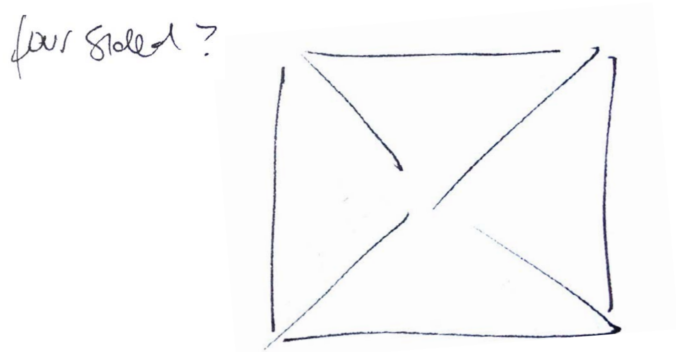
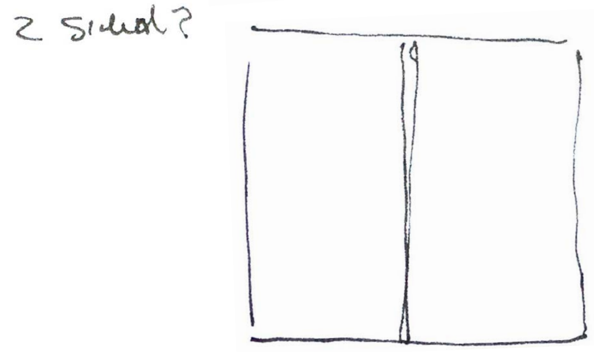


Illustration showing four panels assembled and four sides assembled





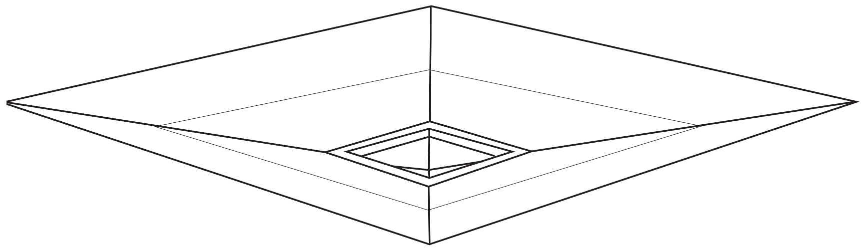


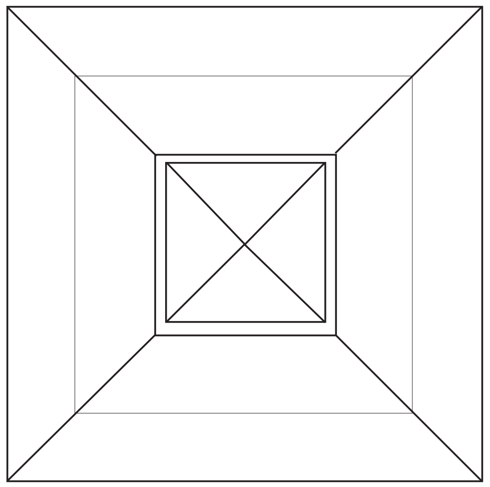
Drawings showing various roof and reflector shapes.

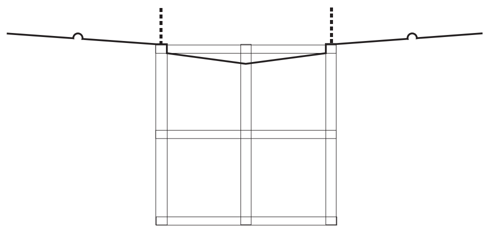
Considerations for the roof component.

- The top of the light will be made up of two components, the roof and a reflector.
- The roofs function is to provide a slope so that rainwater does not gather in the reflector. The reflector's function is to reduce light pollution by redirection and will be looked at next.
- The top side (the roof) needs to be a slope in order to allow for proper drainage. The profile could be curved or slanted.
- It cannot be a singular component. If it were one piece of sheet metal, in profile a straight line raised on a gradient, this would cause an uneven distribution of light.
- The bottom part (the reflector) could be flat or very slightly curved to encourage a wide distribution of light.
- The simplest solution would be to avoid the curved roof and go for one of the linear gradients. The easiest way will be to form the roof out of sheet metal, if curved this can cause residual stresses which can result in undesired deformation of the final shape. For the sake of symmetry, I will go with the four sided gradient.

Development
Considerations for the reflector







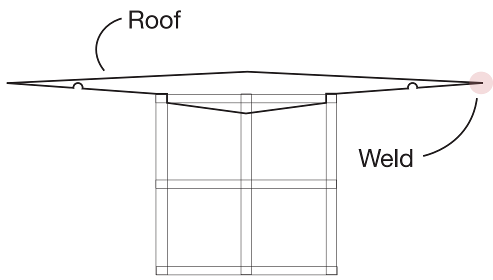
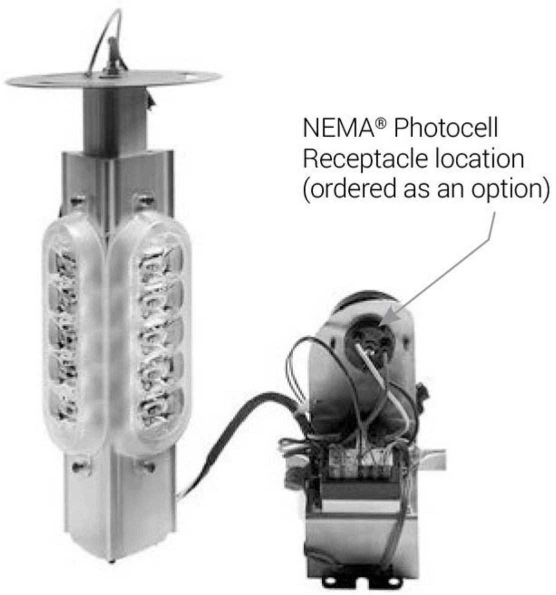
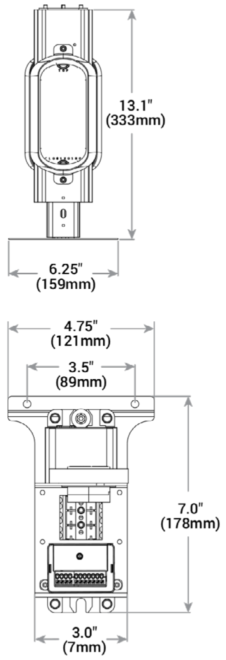


Illustration showing four panels assembled and four sides assembled

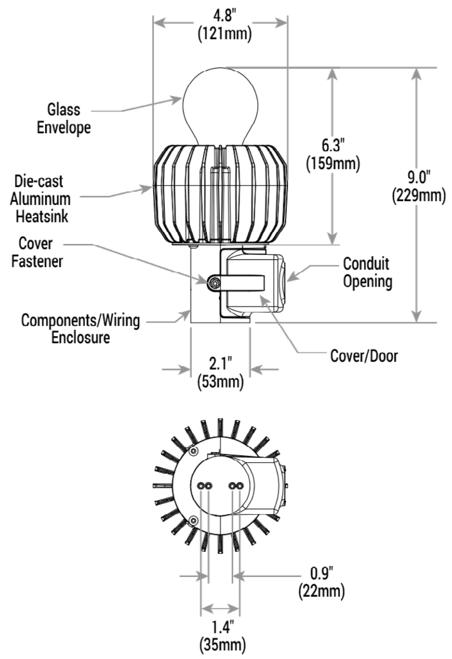
Considerations for the reflector component.

- The reflector is slanted in order to encourage a wide distribution of light (the angle will be looked into more later and a more rationalised approach taken to choosing the angle).
- There will be a bead shape running parallel with the sides to force any water running down the underside of the reflector to drip off before reaching the light.
- There is a flat square the size of the light so that it can easily be fixed to the flat top of the light either by welding or with bolts.
- Once inside the cube, the reflector continues to slope, this is because we do not want the majority of the light to go straight down, we want it spread out.
- A spherical shape would distribute the light inside more evenly however it is not important to us to light the corners (there is a frame covering the corners) so a square based pyramid optimises the distribution of light, lighting the faces as much as possible.
- For simplicity, at the moment, proportions are only based on the rule of thirds.





Cree Post-Top Upgrade Kit.



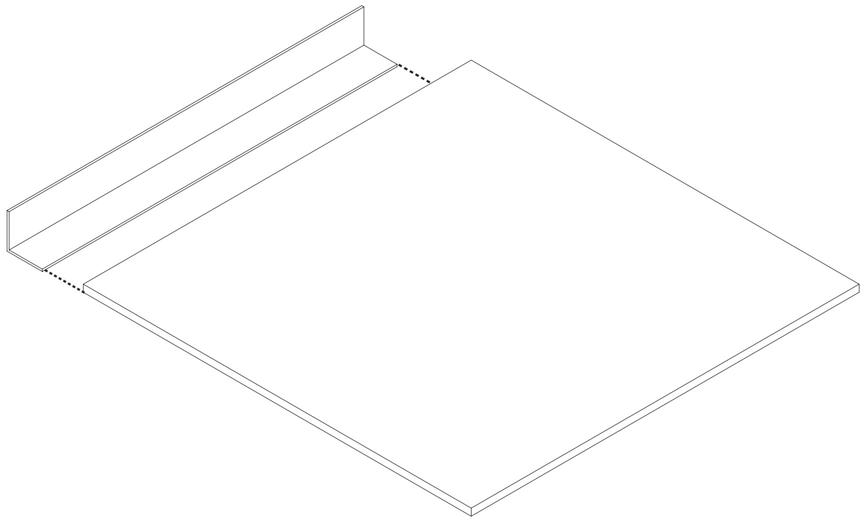
Cree DPT Series Decorative Street and Roadway.

Selection of lighting fixture type.

LED type selection.

- After completing research on various types of lighting fixtures and comparing their attributes it became apparent that LED's would be the most suited type of fixture for the application. LED's offer the highest ratio of lumen output to input power, that is to say, they are the most efficient. LED's are also a far longer term solution requiring much less maintenance.
- After looking at different LED modules the two on the left stood out because they allow for easy installation. The fixtures are designed for retrofitting older luminaire systems with LEDs or for completely new installations.
- A lighting engineer would look at the output lumen for each of the lights and their LMF (lumen maintenance factor) to predict their luminary value at the end of their life to design the quantity and brightness required, so at the beginning they would be brighter than required.
- The Cree Post-Top Upgrade Kit can yeild a possible output of 6400 L with an input wattage of 68 - 97W. The warmth of light produces can be between 2700 K (warm) and 4000 K (cold).
- The Cree DPT Series has a lower output of 3400 L and a lower input of 34W. The warmth of light produces can range from 3000 K (warm) to 4000 K (cold). This fixture seems to be satisfactory for the job but to determine correctly would need to consider the required lumen per meter^2.

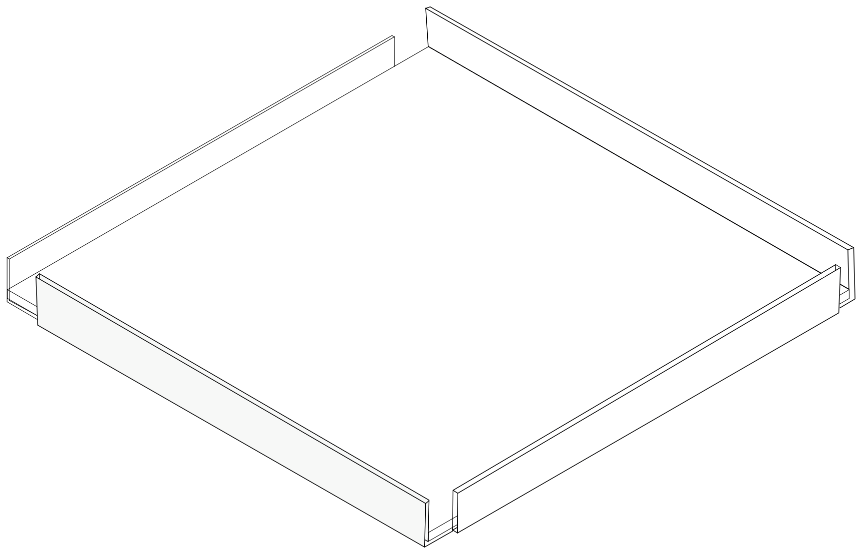
Assembly Instruction
Complete assembly instructions for V1



Polycarbonate
panel and
one equal
25x1.5x251.5
aluminium angle.

Step 1.

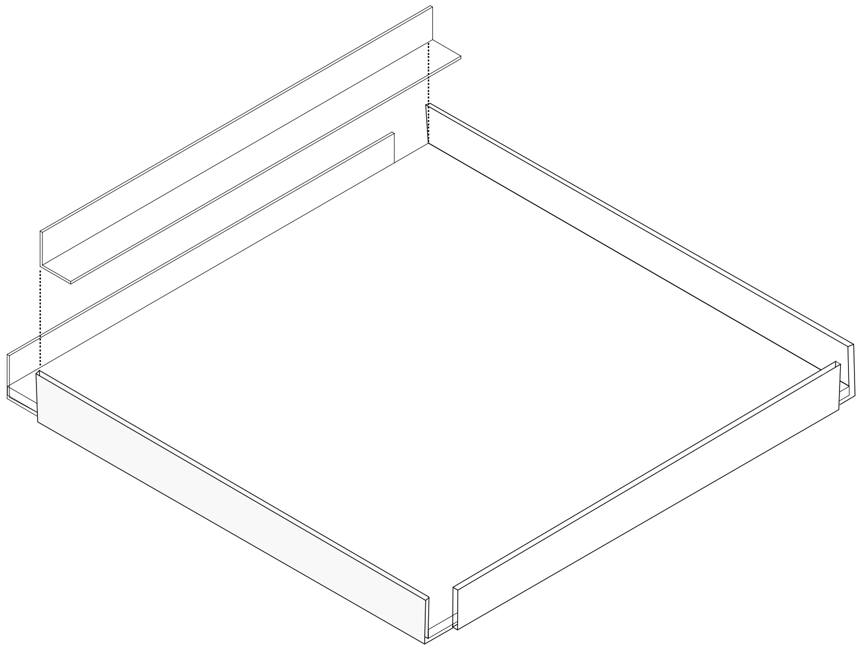
- Place one 25x1.5x255 aluminium angle under a polycarbonate panel.



Polycarbonate
panel and
four equal
25x1.5x251.5
aluminium angle.

Step 2.

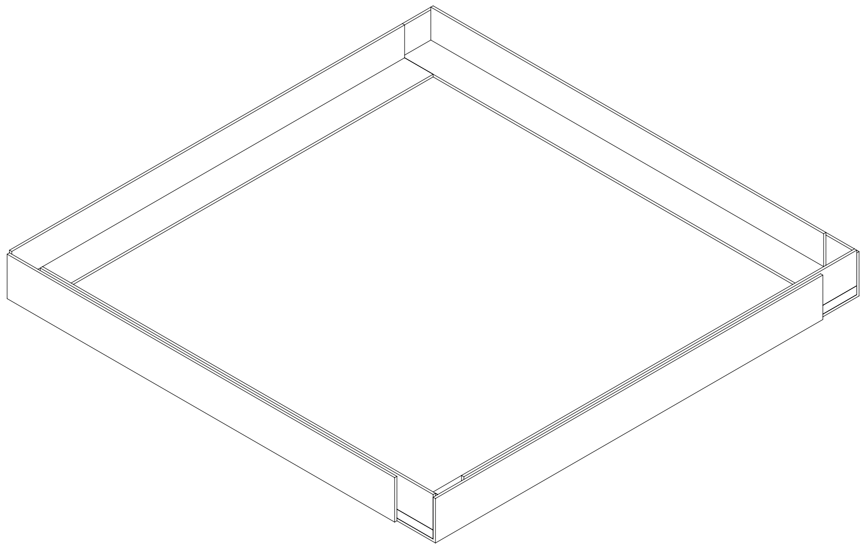
- Repeat step one for all edges, simply placing the aluminium angles under the polycarbonate in the pattern shown.



Addition of one 20x1.5x255 aluminium angle.

Step 3.

- Place one 20x1.5x255 aluminium angle on the other side of a polycarbonate panel. The aluminium angles on this face should leave a gap at the opposite end from the aluminium angles on the front face.



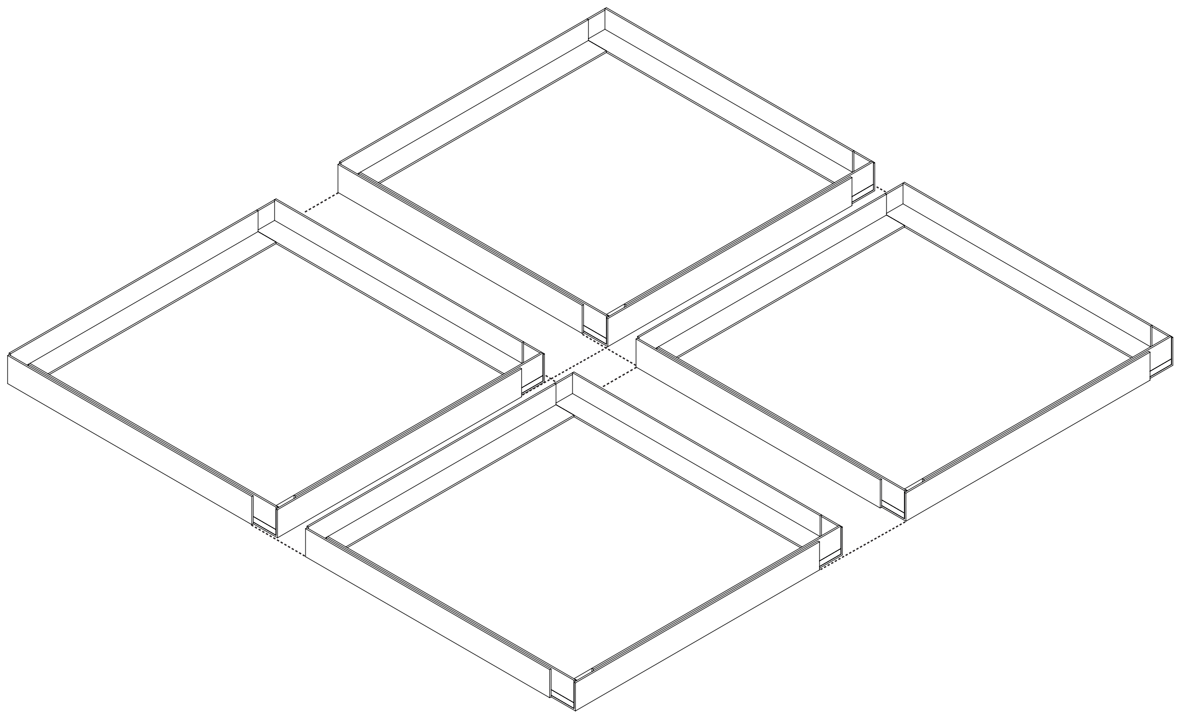
All the aluminium angles assembled on a PC panel.

Step 4.

- Repeat step three for all edges, simply placing the aluminium angles on top of the polycarbonate in the pattern shown.
- The angles should then be welded or bolted together holding the PC in place.
- This will have to be repeated on four panels for a face, there will be four faces like this per light and there are 25 lights, so it should be repeated 400 times.

Step 5.

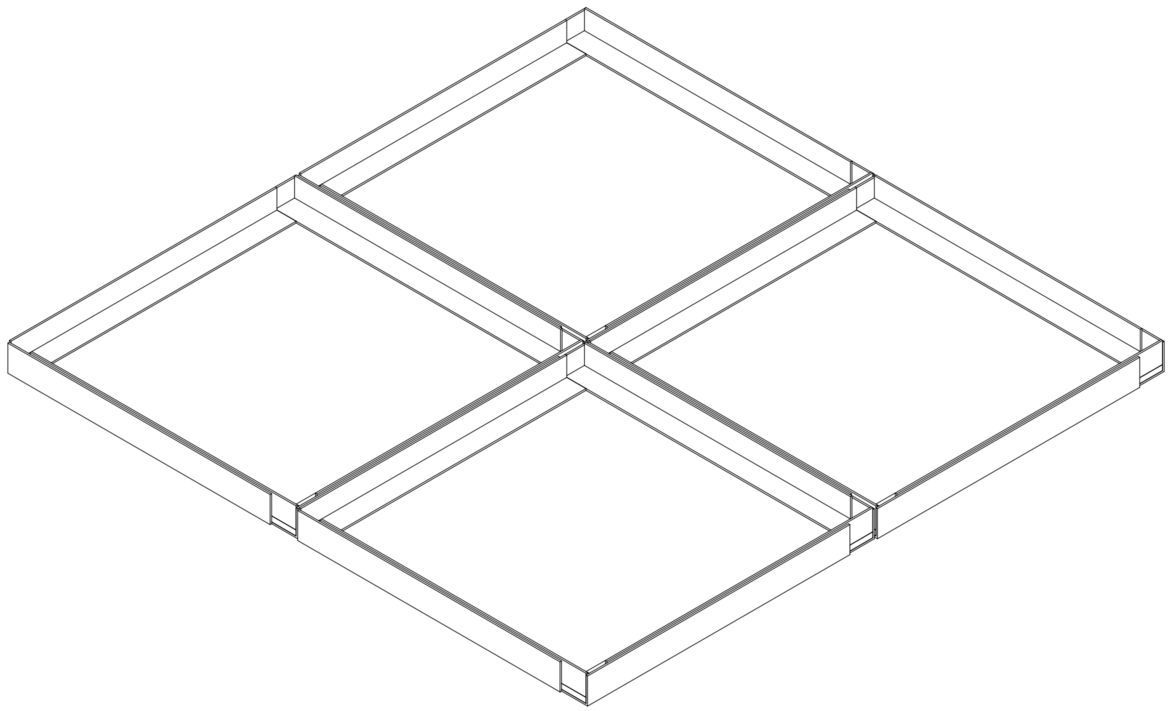
- Four panels can then be aligned as shown.



Arrangement of four PC panels.

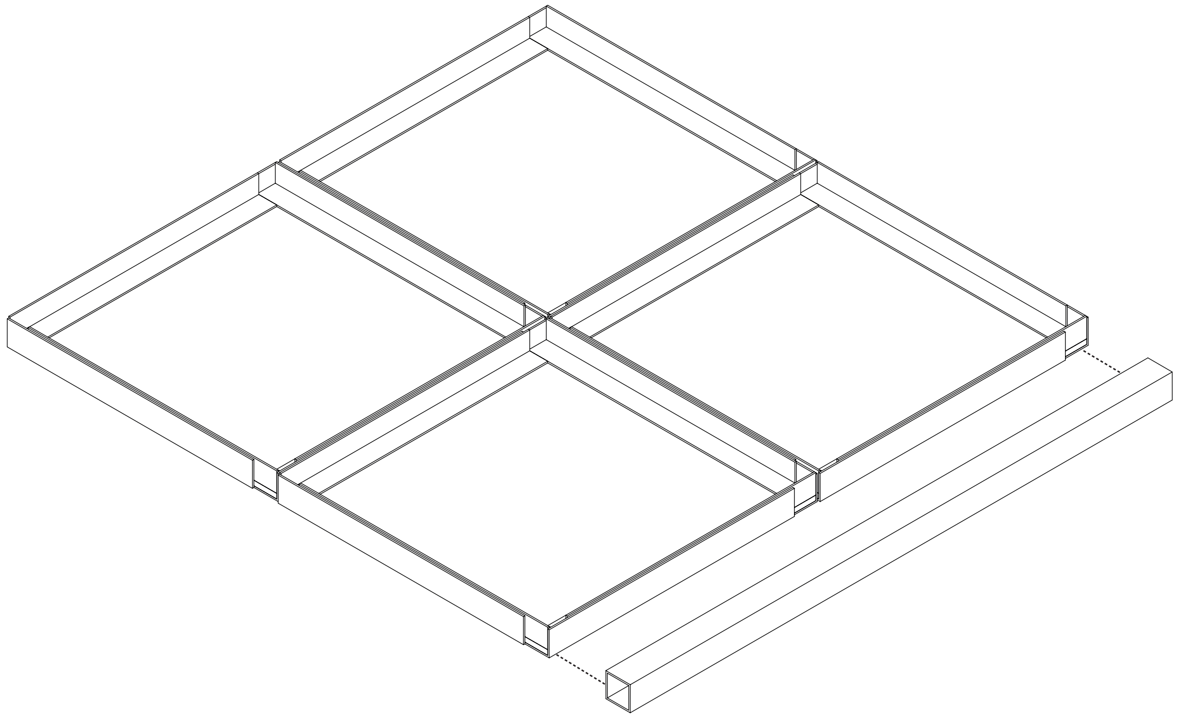
Step 6.

- The panels will then be fixed together again with either nuts and bolts or by welding.
- Aslan D160 Diffuser Film should be applied to the PC.
- This will have to be repeated 4 times per light, so a total of 100 times.



Four panels assembled to make a face.

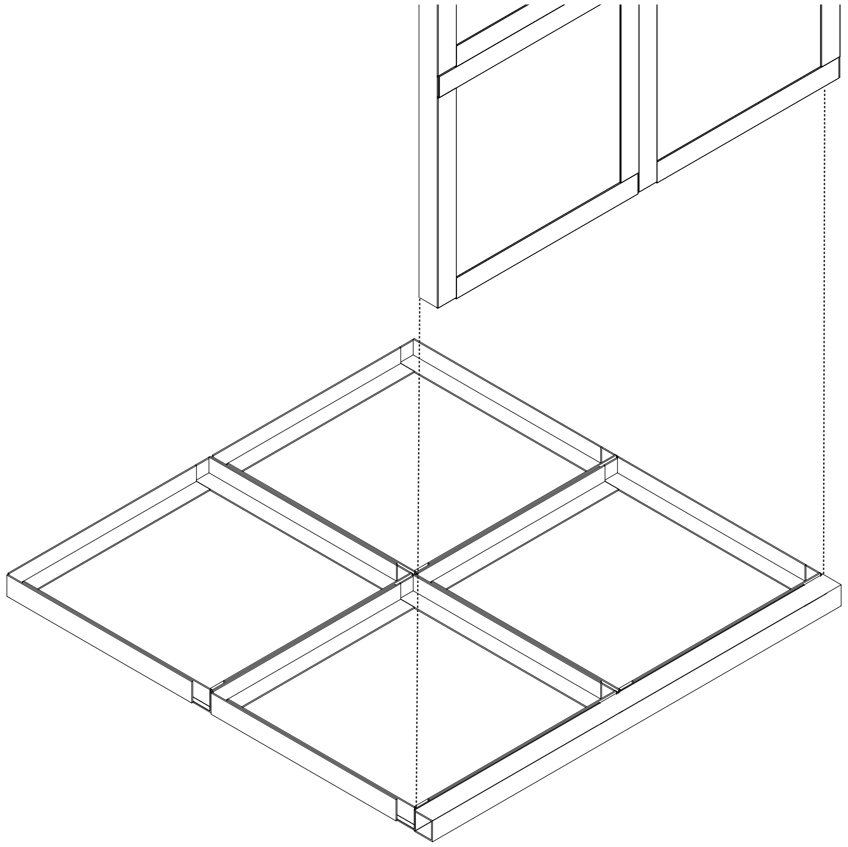
Raised



Placement of hollow box section and face

Step 7.

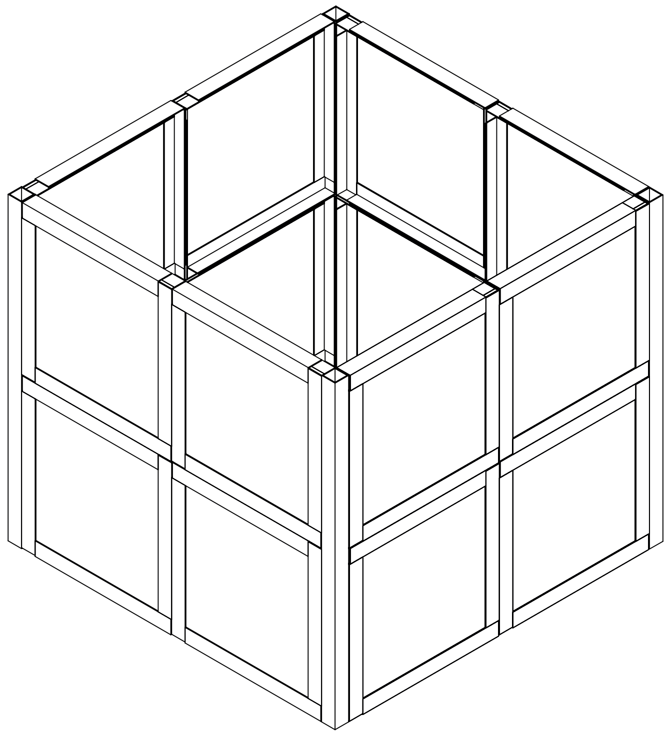
- Weld a 25x25 hollow aluminium box section to the side.



Placement of next face on box section.

Step 8.

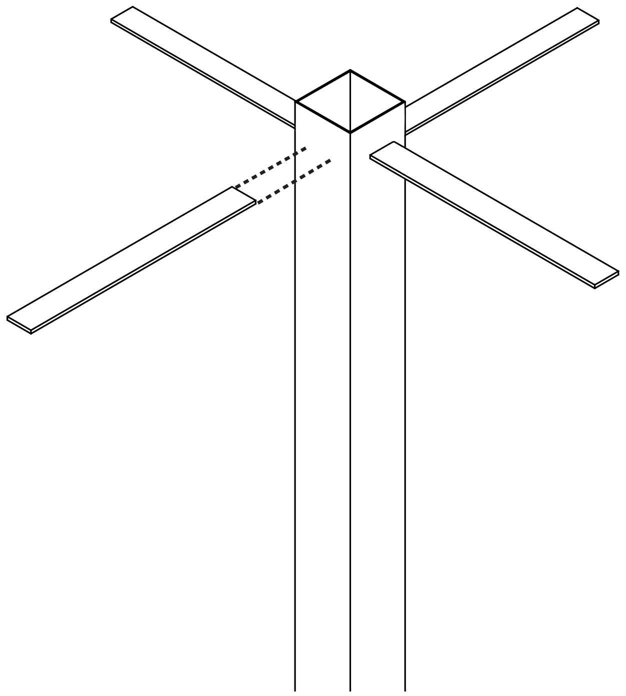
- Fix another assembled face to the side of the box section and repeat for four faces.



Four faces assembled.

Step 9.

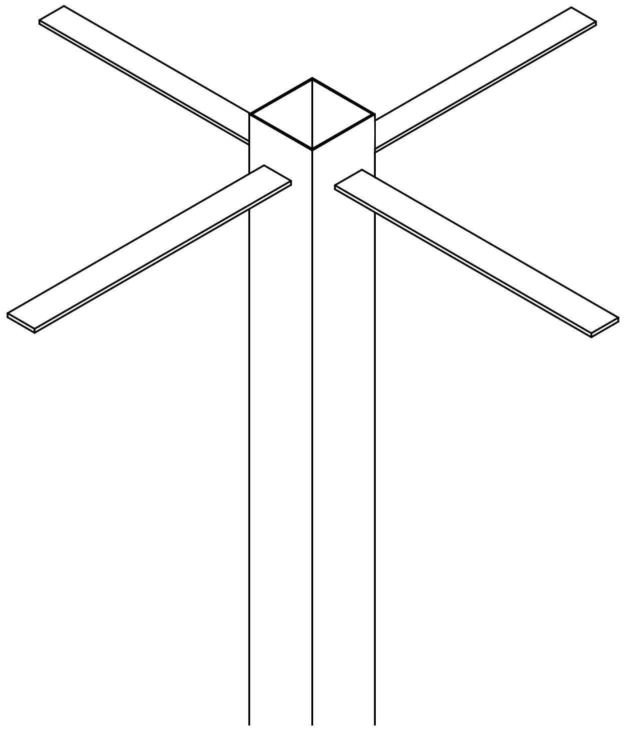
- The four faces assembled should look and sit like this.



Brackets on pole.

Step 10.

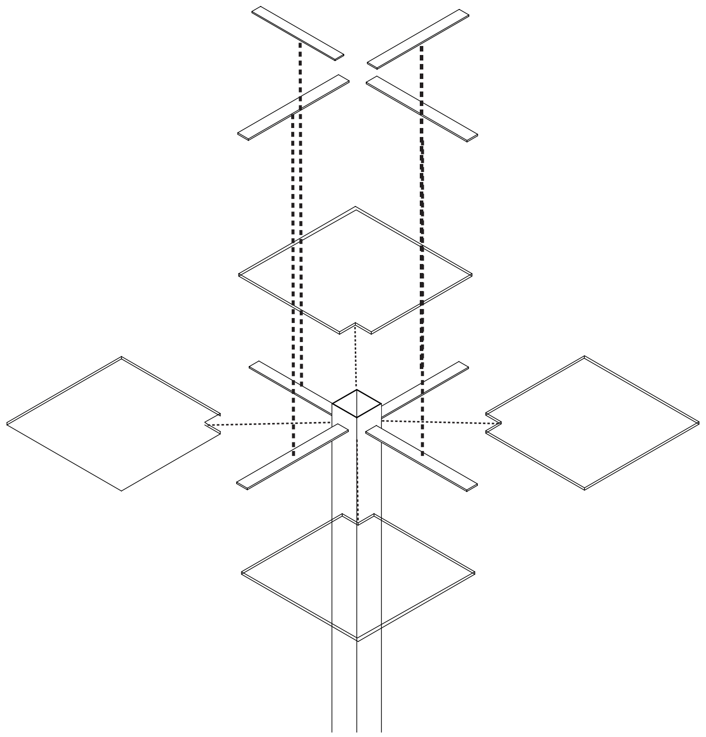
- Next, take the 25x3.2x200 aluminium bars and weld them to the 75x75x3000 hollow box section of Aluminium.



Brackets welded to pole.

Step 11.

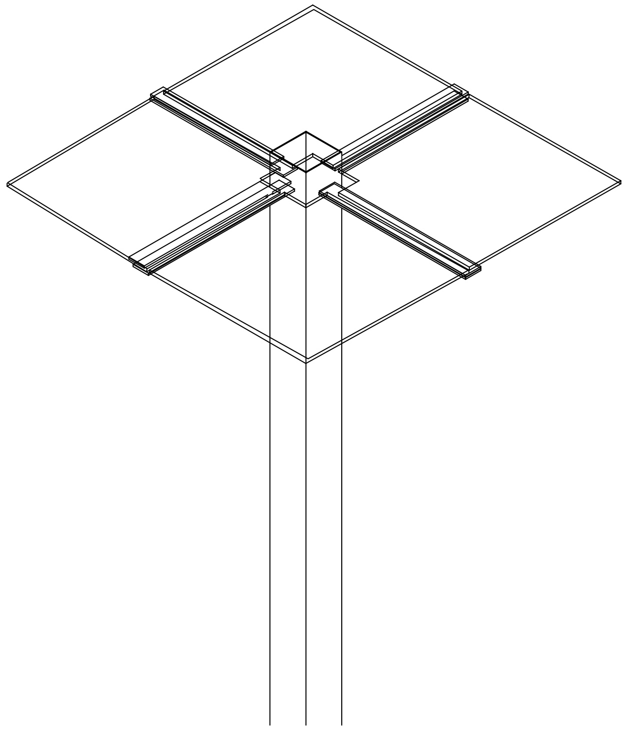
- The bars should be welded as shown at a distance of 60mm from the top of the pole.
- The weld thickness should be calculated later, it is very likely going to need extra support.



Arrangement of other bars and underside PC panels.

Step 12.

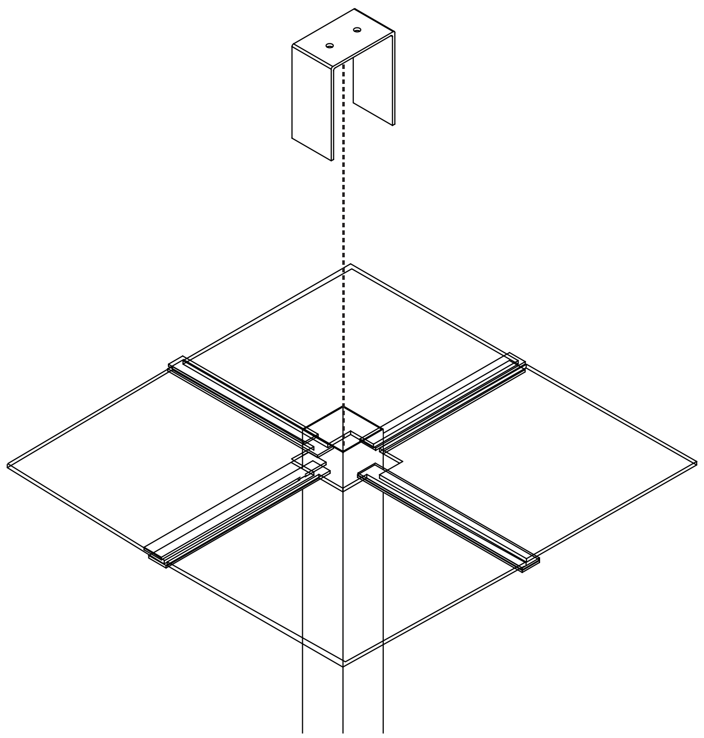
- Place the polycarbonate panels with a cut-off corner in between another set of bars and the original bars.



Step 13.

- The bars should be welded as shown at a distance of 60mm from the top of the pole.
- The weld thickness should be calculated later, it is very likely going to need extra support.

Bars welded to pole with PC sandwiched in between.

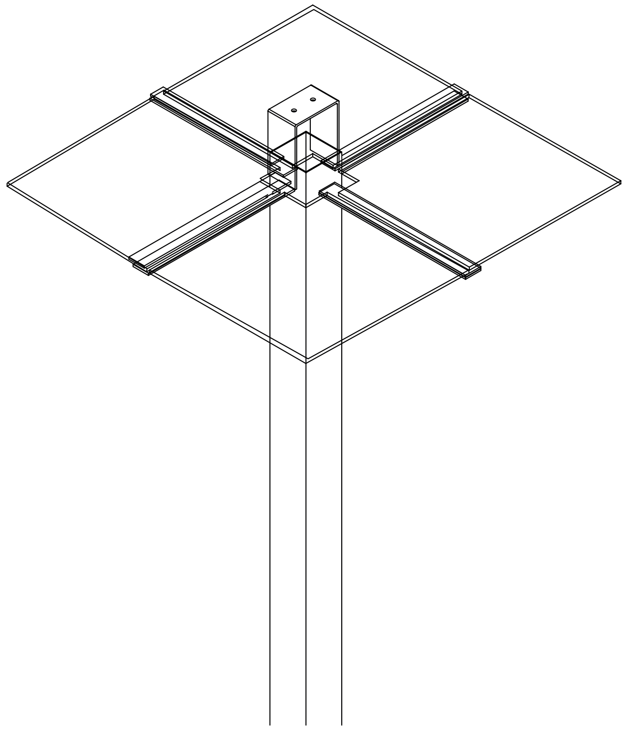


Step 14.

- The bracket for mounting the light fixture is now welded on the outside of the pole, again, weld thickness is yet to be calculated.

Positioning of bracket in respect to the pole.

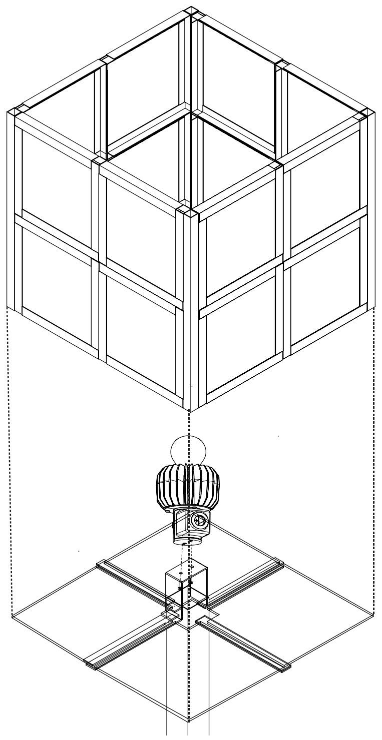
Raised



Bracket fixed to pole.

Step 15.

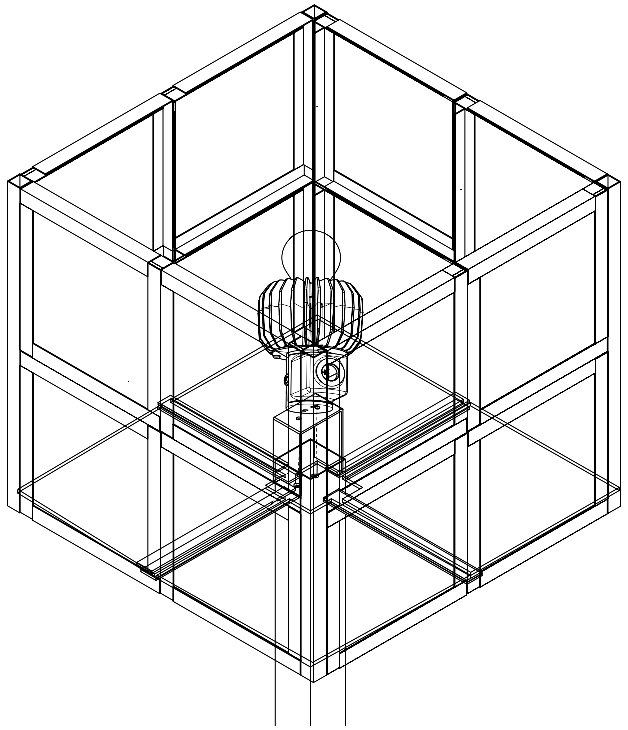
- The bracket for the light fixture should be fixed as shown.



Lighting fixture and four faces relative to base.

Step 16.

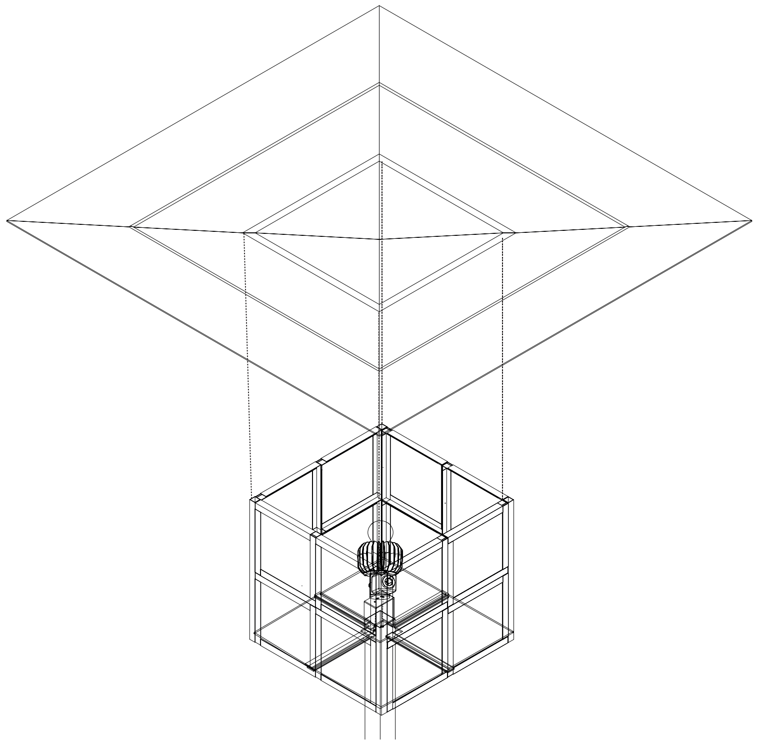
- The cables to the light fixture should be passed through the pole ready to be fixed to the LED.
- The light fixture should be screwed in place on the bracket and the cables connected, there are detailed instructions on how to install the fixture available from Cree's website.
- The four faces can be fixed to the aluminium bars now.



Pole, four face and base assembled with lighting fixture on bracket.

Step 17.

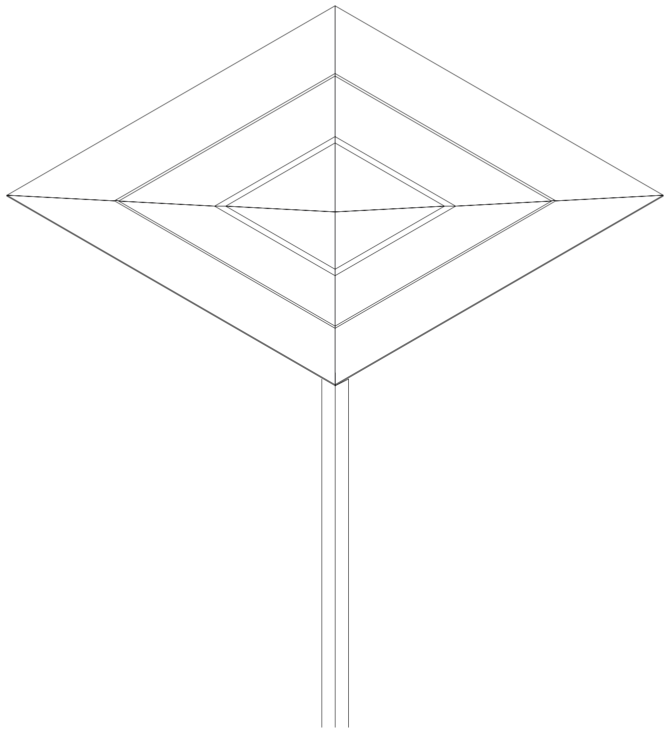
- The bracket for the light fixture should be fixed as shown.



Position of reflector on the four faces.

Step 18.

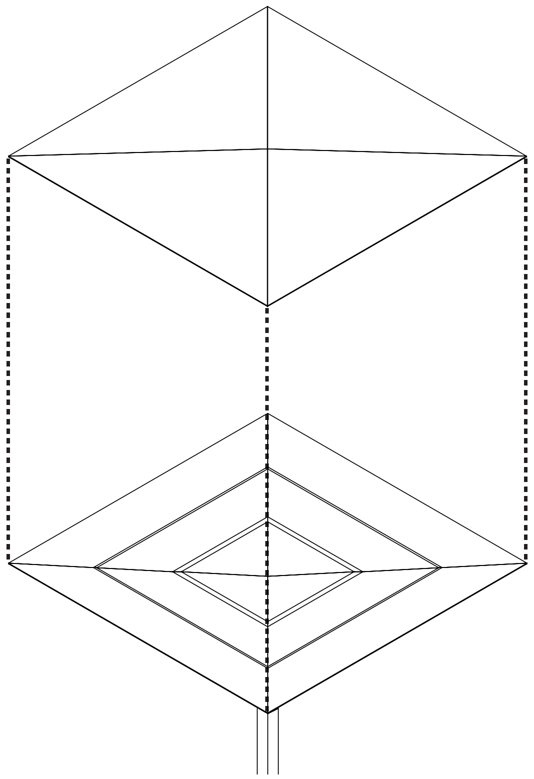
- The reflector can now be welded to the four faces.
- This method of assembly does not allow for access to the lighting fixture after construction so needs to be revised.



Reflector fixed on the structure.

Step 19.

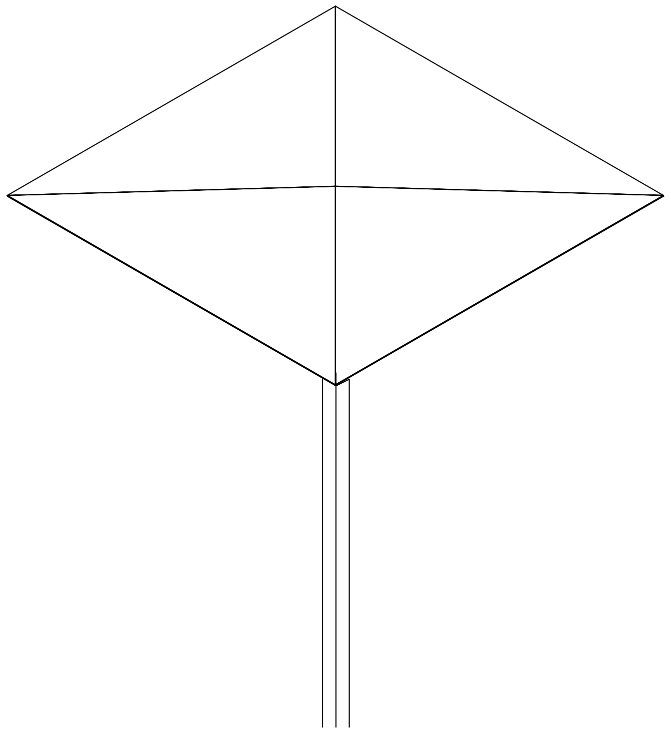
- The reflector should be fixed onto the structure as shown.



Position of roof on the reflector.

Step 20.

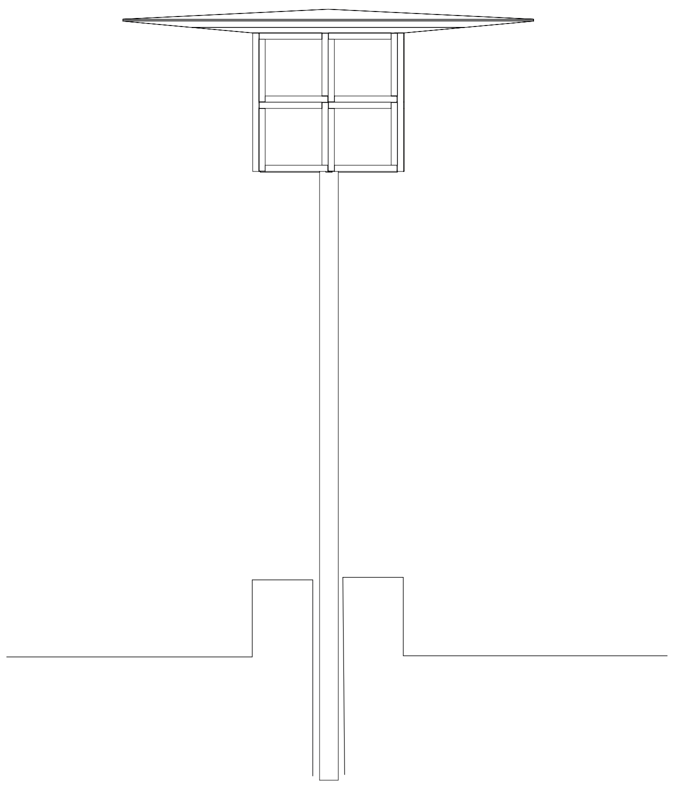
- The roof should now be positioned on the reflector as shown.



Roof fixed to the reflector.

Step 21.

- The roof should be welded onto the reflector as shown around the edge of the reflector.



Structure fixed into ground.

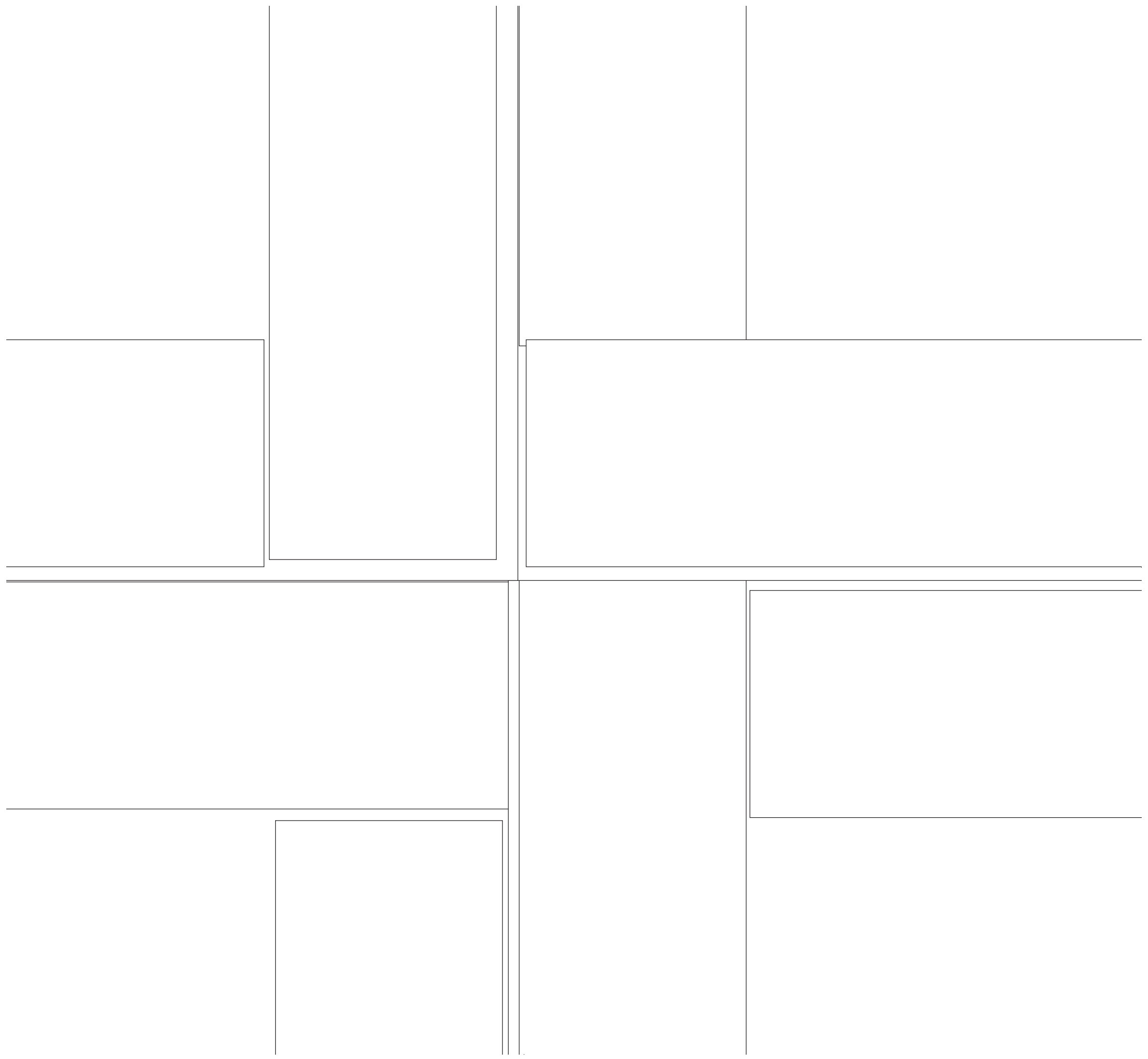
Step 22.

- The pole can now be cemented into the ground in the original positions defined by Dieter Magnus.

Render of Version One light.

Summary of system so far.

- The lights would be placed in the same places as defined by Dieter Magnus to try keep the identity he intended.
- The lights have been raised in order to keep them out of reach from vandals, they have also been made from more robust materials (ie polycarbonate instead of acrylic).
- The polycarbonate panels have a light diffusing film in order to provide an even, soft glow. These will need to be replaced every seven years.
- The design uses a reflector to minimize light pollution and optimise the distribution of light so that the paths are well illuminated.
- The LED used has a warranty of ten years so should require far less maintenance than the previous lighting system.



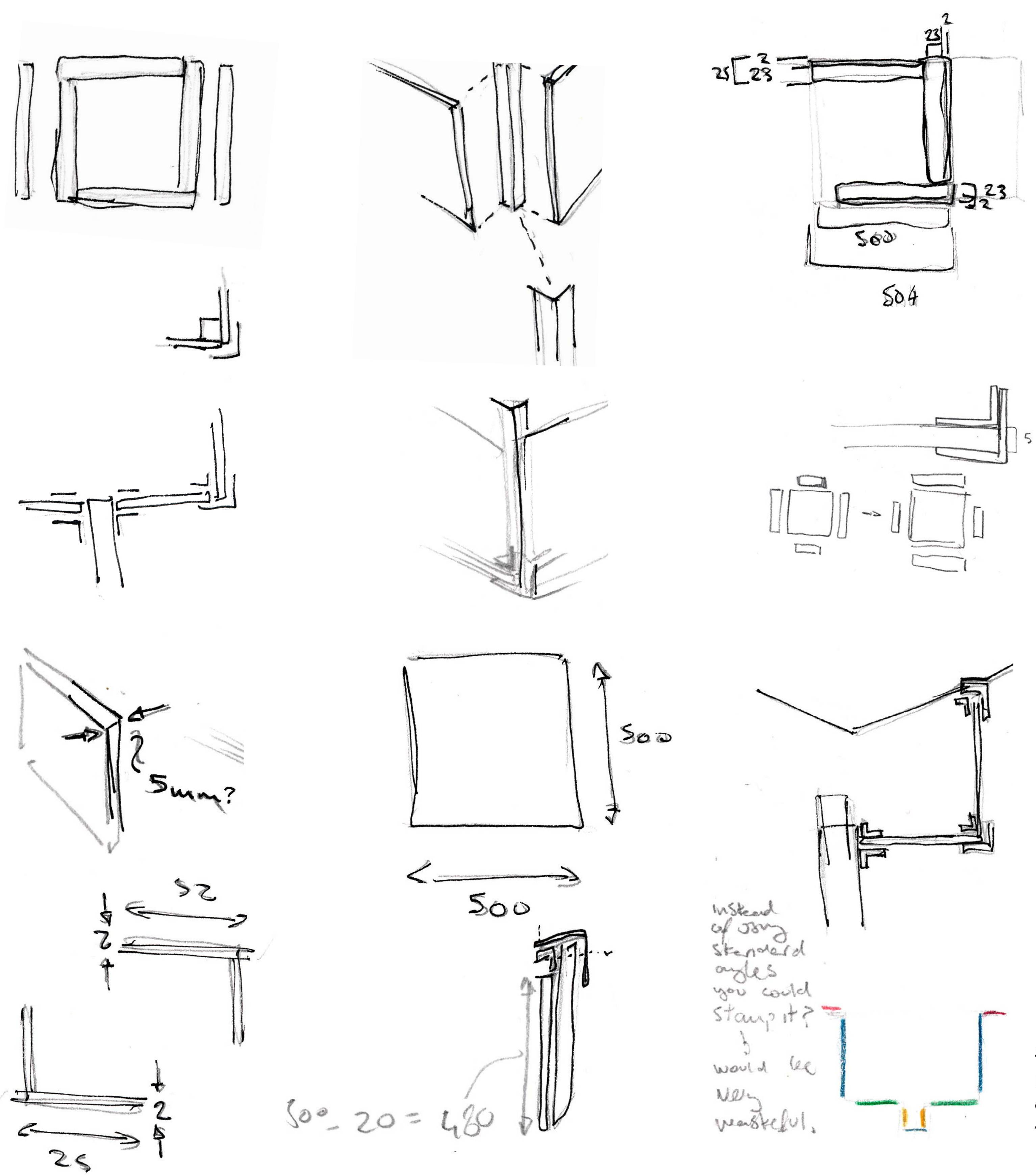
Close up diagram of Version One's face.

Issues with Version One to be addressed in Version Two.

There are a number of issues inherent with Version One of the design. These points can act as a PDS to shape the next version of the design. The points discussed come from peer and internal evaluation.

- Because of the geometry, there is a gap in the face that must be filled or it will not be IP36 protected.
- The assembly process is very long, having to assemble 400 panels.
- There is no access to the light once built.
- Structural integrity needs to be determined.
- The size of the deflector needs to be rationalised.
- It needs to be visualised at night.
- A systems diagram must be developed showing any electronic modules and touch points for interaction.

Development:
New frame ideas



Sketches from notebook when deveolping a new frame.

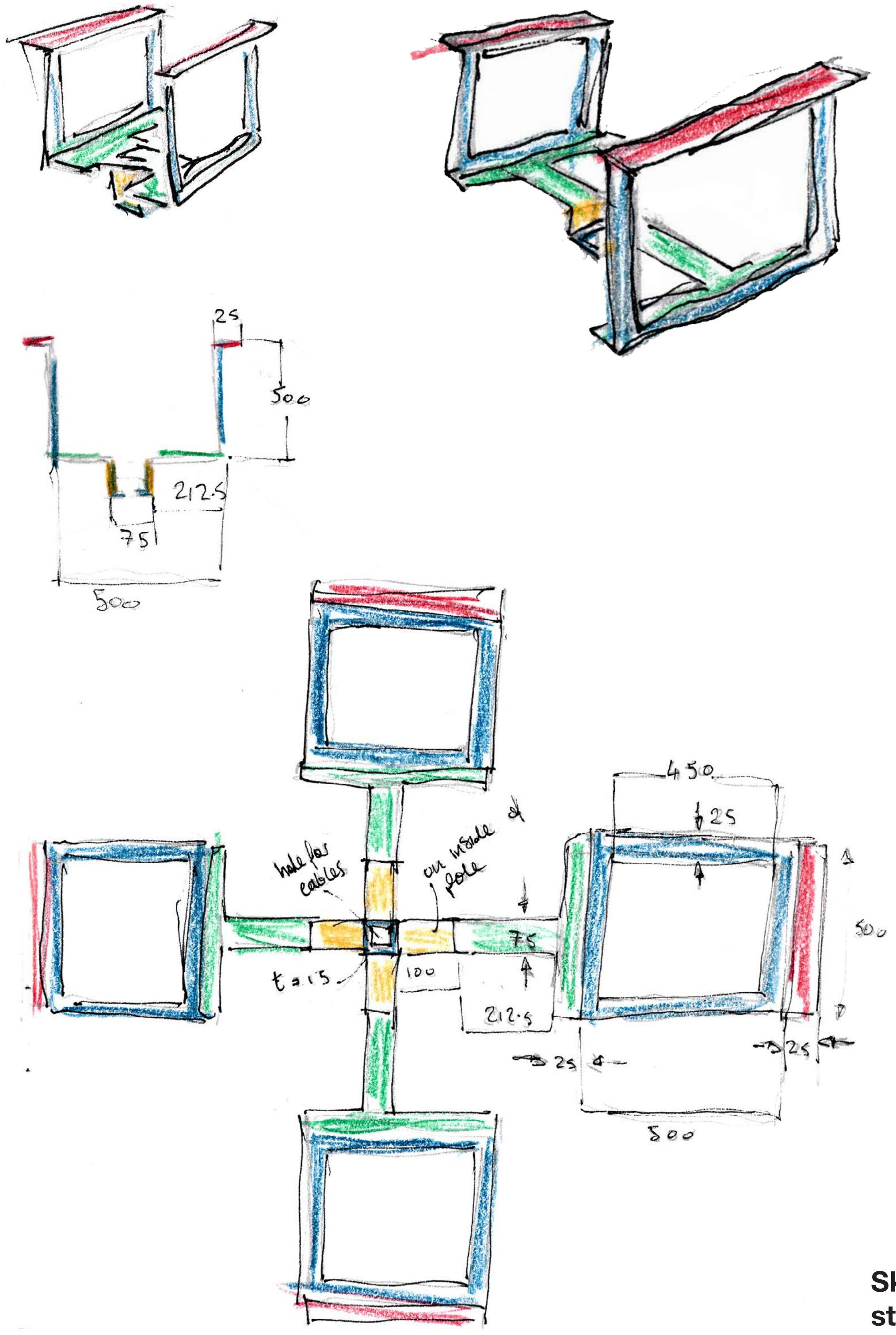
Developing a new frame to increase IP rating and reduce assembly process.

- Since the light is not water tight and has a long assembly process because of the frame, a new simplified version should be developed. The sketches on the left show the beginning of this process.

- I began by reducing the number of polycarbonate panels per face and thinking of different ways in which to frame it, mostly using standard aluminium extrusions. However this technique did not yield great results, it narrowed the possibilities down too much.

- In order to think of the problem in a different way, instead of using standard aluminium extrusions I thought about how you may solve the problem through stamping and forming sheet metal, this is discussed on the next page.

Development:
New frame, stamped concept



Sketches for a stamped frame.

How a stamped frame may or may not work.

- Although a stamped frame would be an incredibly inefficient solution, due to the large quantity of waste material (the negative space), it did provide me with an alternative way of thinking and allowed me to come up with a form that could be replicated using standard extrusions shown on page****.
- The folds for different planes are highlighted in different colours.
- The small blue pat in the centre would be inside the pole and would be horizontal, it has a whole in it to allow cables to be passed through.
- The yellow part would be vertical and mostly in the pole, the pole and frame could be fixed together here using nuts and bolts.
- The green part would be horizontal and make up the base of the cube.
- The blue part would be the vertical faces of the cub, if desired they could contain a cross. The requirement of a cross should be investigated soon.
- The top red layer would be horizontal and would provide a surface for fixing the reflector and roof.

Photos showing construction of 1:10 scale model.

1:10 Scale model.

- Constructing a 1:10 scale model aloud me to understand the form better and gave me the opportunity to think about how you may gain access for maintenance.
- Although stamping and forming the frame would not be very efficient, you could make a similar structure out of standard components which is what I moved onto doing. This model helped me figure it out.
- I also made three different roofs which had various dimensions in order to figure out, proportionally, what might look good. The results are come later after the results of a variation on the profile (one with a cross and one without).

Development:
Figuring out the shape.

1:2 scale cardboard prototype of one side of frame.

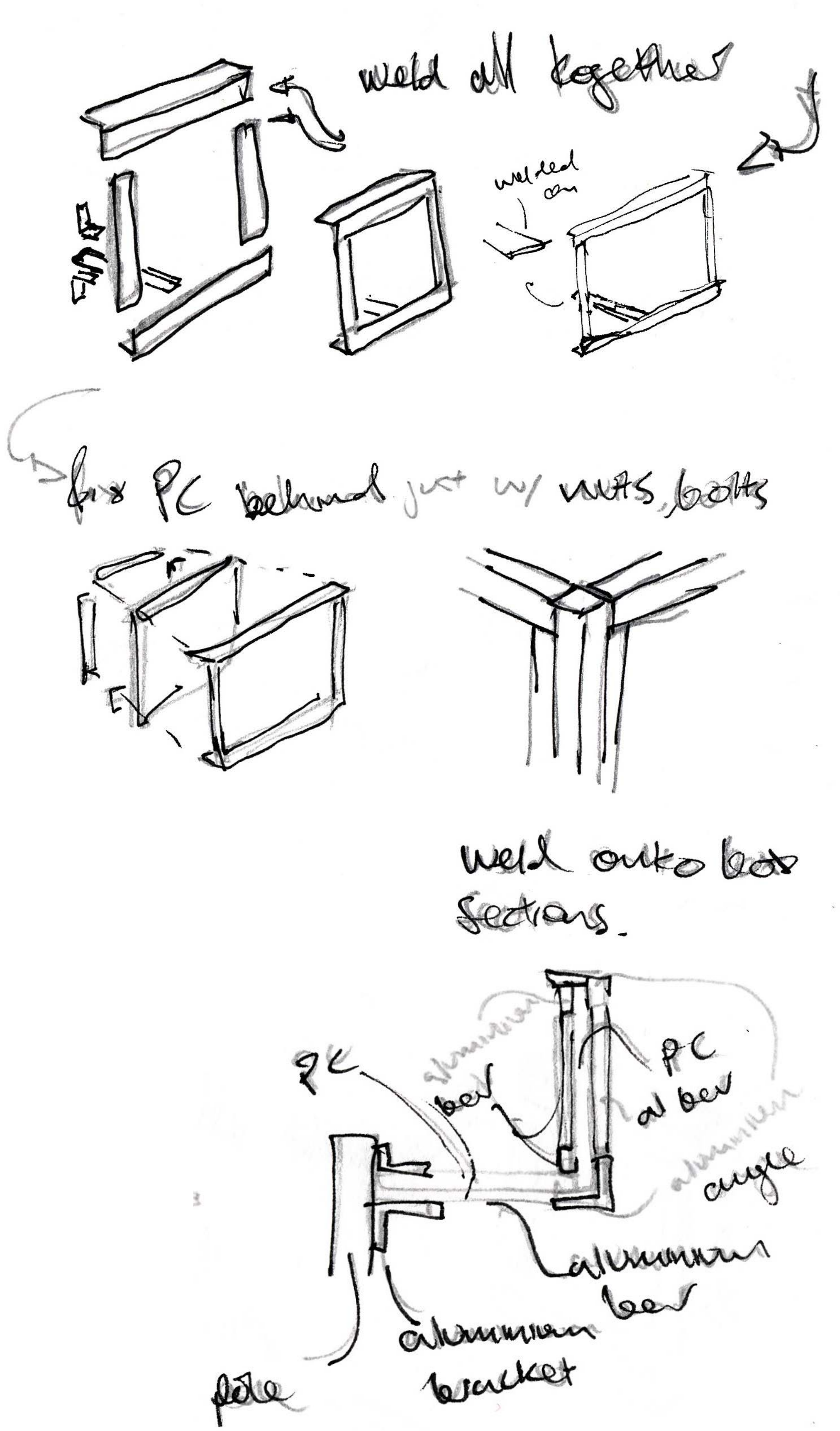
1:2 scale model to help understand the form.

- I was finding it quite hard to visualise the 3d shape in my head so I made a 1:2 scale model out of cardboard, this helped me understand the form in my head and helped me figure out how it goes together.

- I was able to identify where components would be welded.

- It also helped me think about how you would have to adjust it to be a door, you would just not weld it to the reflector or to bottom L angle to the cantilever coming from the post. Hinges would need to be fixed somewhere.

- It also made me realise that although its convenient for the shape to have the L sections horizontal they would offer more structural integrity if the were vertical.



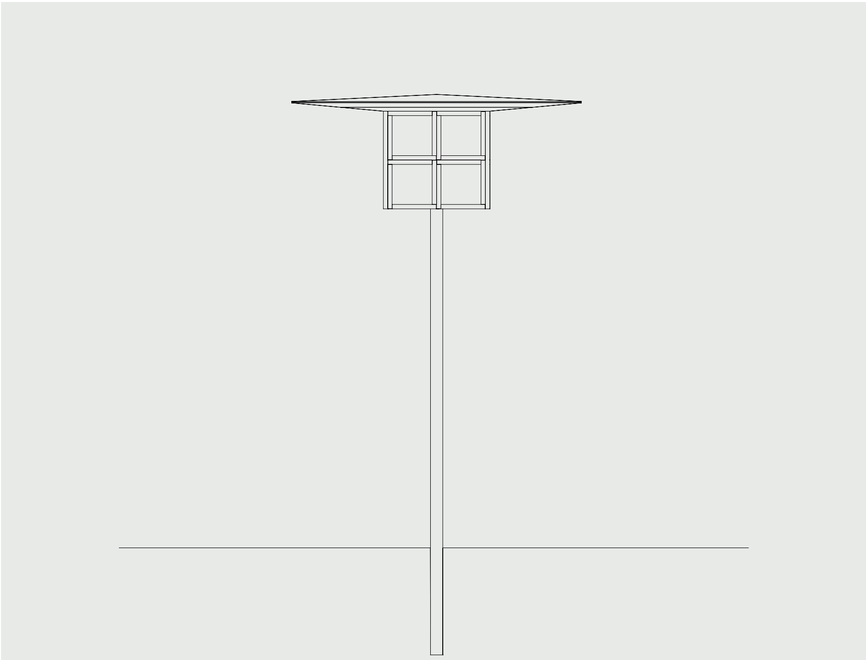
Drawings showing how the new frame could come together.

How the new frame could change the profile.

- Instead of stamping and forming the frame with a huge amount of waste material you could make a similar shape but from standard extrusions cut to the required length as pictured.
- Two angles would be used as the horizontal borders of the frame and two bars would be used for the vertical borders. A bar would connect the structure to the pole.
- You would have to be careful with where you specify what type of weld so that the PC panel can sit flush against the frame without a bump from a weld causing a gap where water could get in.
- Once four sides were constructed they could be fixed at the corners with a box section like in the previous version.

Raised

Original Profile

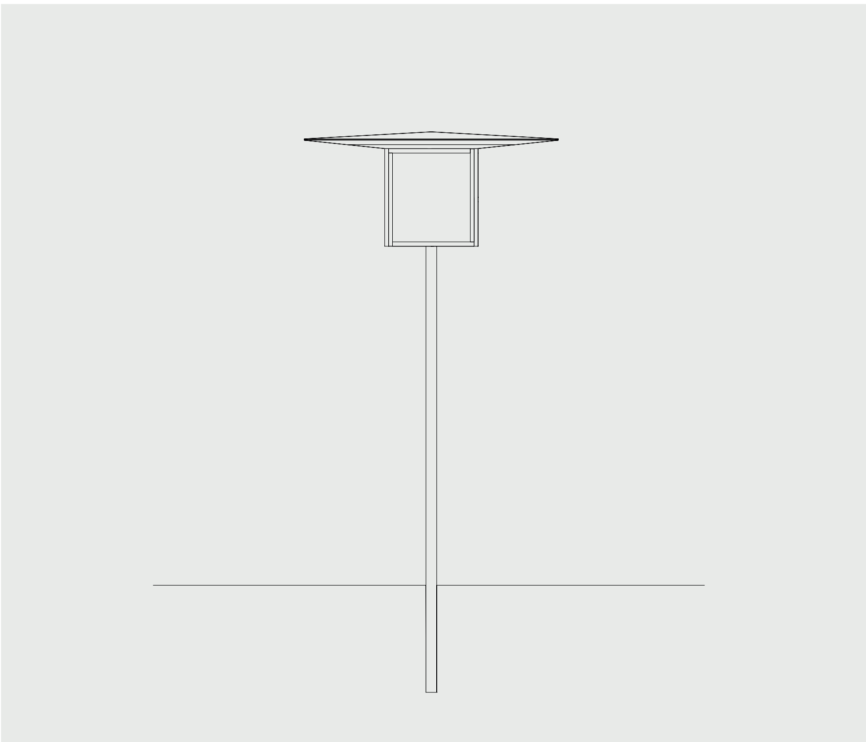


Section of original profile.

- The original profile I designed uses four polycarbonate panels with aluminium angles fixed around their edges on either side to hold it together, four of these panels would then make up one side. This would be an unnecessarily long assembly process for something that does not provide any function.

- The design should be kept as simple as possible. The original design only uses the four panels to make up one side to create a cross effect, so it is purely aesthetic yet does even look very nice. A more efficient and functional solution should be found instead.

Developed profile

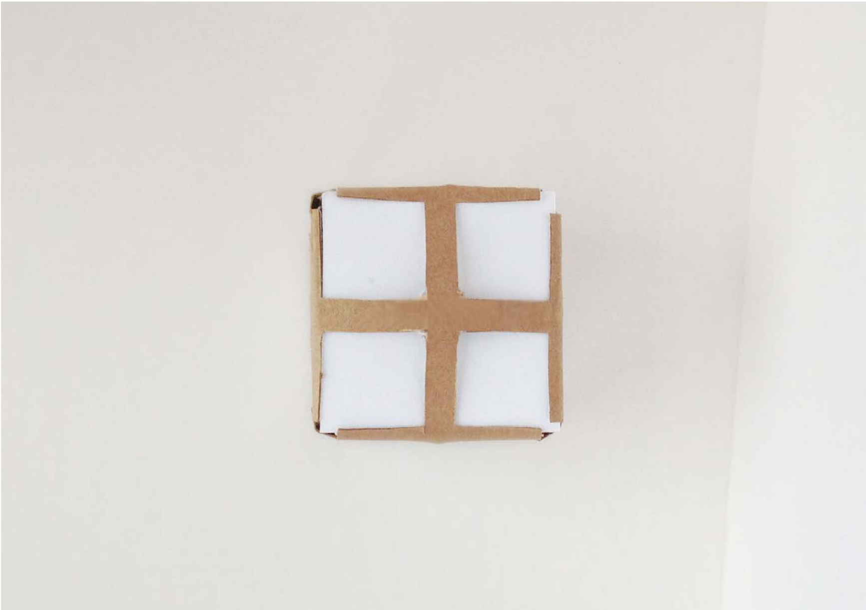


Section view of an iteration of the profile

- This iteration uses only one sheet of polycarbonate per panel. It would be the same as the smaller panels on the original profile but four times larger, taking up an entire face. It would be constructed as described on the previous page. The fewer the components, the less to go wrong, the fewer gaps for fluid to leak through, the faster and easier the assembly.

- The steak-holders should be consulted on the decision of altering the aesthetic to see which they prefer. Even if they prefer the original frame with a cross, a cross could easily be added to the new frame and it still maintain the advantages.

User feedback:
Art School Steak-Holder feedback on Profile Iteration and Roof Size.



1:10 model showing original profile

Original Profile

- When students of the Art School were presented with the two prototypes shown, the majority, although quite evenly split, said that they liked the cross with the resemblance to Macintosh because of the boxy sort of detailing, they actually preferred the simpler, more straight forward design without a cross.
- After explaining that the resemblance to Macintosh was most likely coincidental (Magnus uses similar designs in German parks), the students felt more for the more simpler design.

1:10 model showing profile Iteration

Profile Iteration

- The more simplistic design will mean a quicker and easier assembly process.
- Not having a third vertical column for holding up the roof will mean that the columns at the side must take more of the force and therefore will have to have a larger cross sectional area for spreading the stress and also to increase the stiffness to reduce likeliness of buckling.

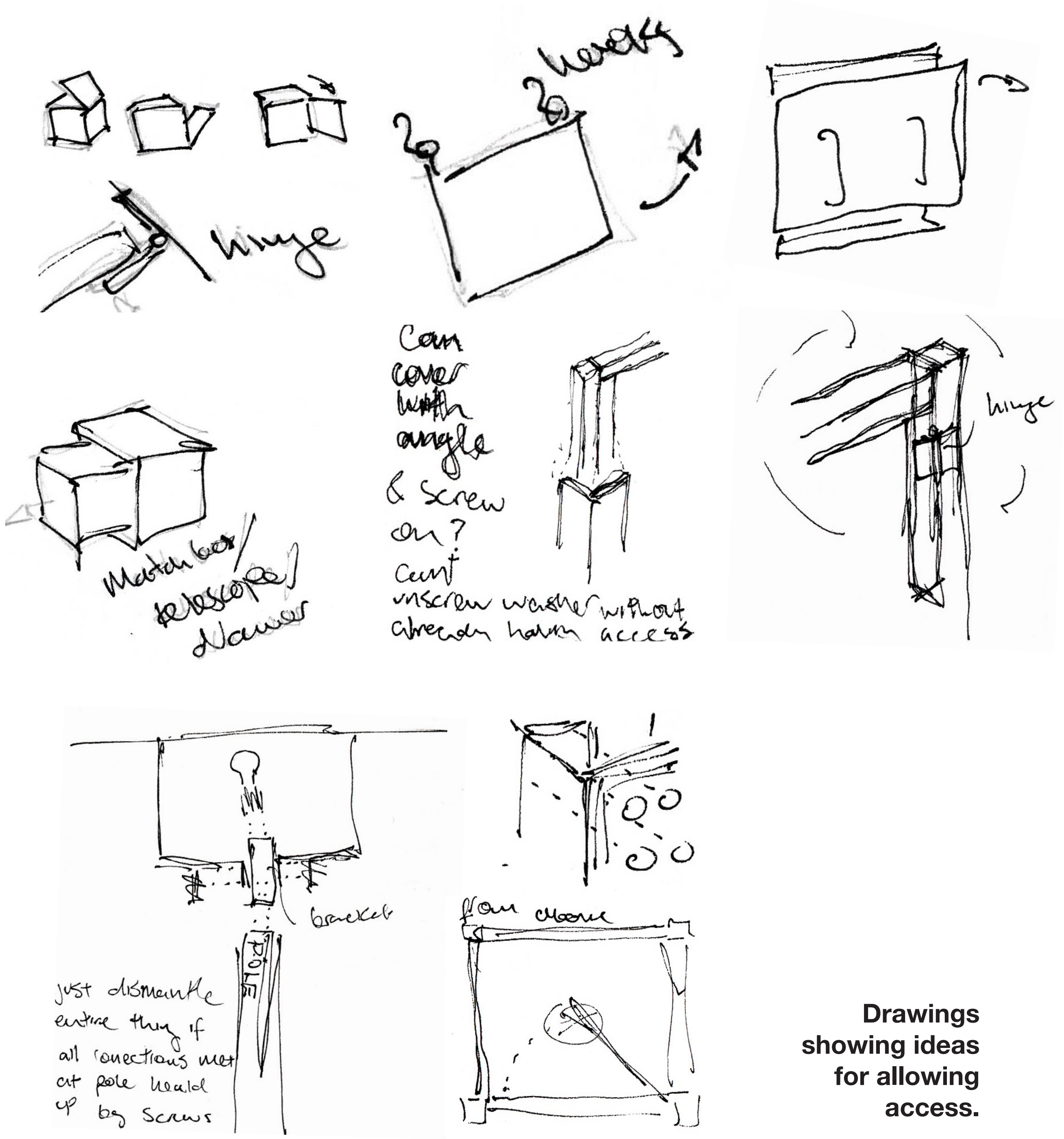
User feedback:
Art School Steak-Holder feedback on Profile Iteration and Roof Size.

1:10 showing proportions of various roof sizes

Roof Iterations

- When students from the Art School were asked about the proportions of the reflector and roof the majority said that they preferred the smaller roof.
- They were presented with the options of having a ratio of box width (w_{Box}) (hight and width are equal) to overhang (w_{Roof}) to be 1:3 in the top picture, 1:2.5 in the middle picture and 1:2 in the bottom picture.
- One student explained “It should be small as small as possible while still retaining its function”, in practice this would be difficult to achieve because I do not have access to the lighting fixture or materials of reflector, however, in theory this could be experimentally determined or with the appropriate experience and correctly equipped CAD package the distance could be found. I will look into one of these methods later.
- Ideally I would have shown the prototypes to more people from different focus groups to gain a better understanding of what the community as a whole want, however, for the time being, the art school alone will have to do.

Development:
Access for maintenance



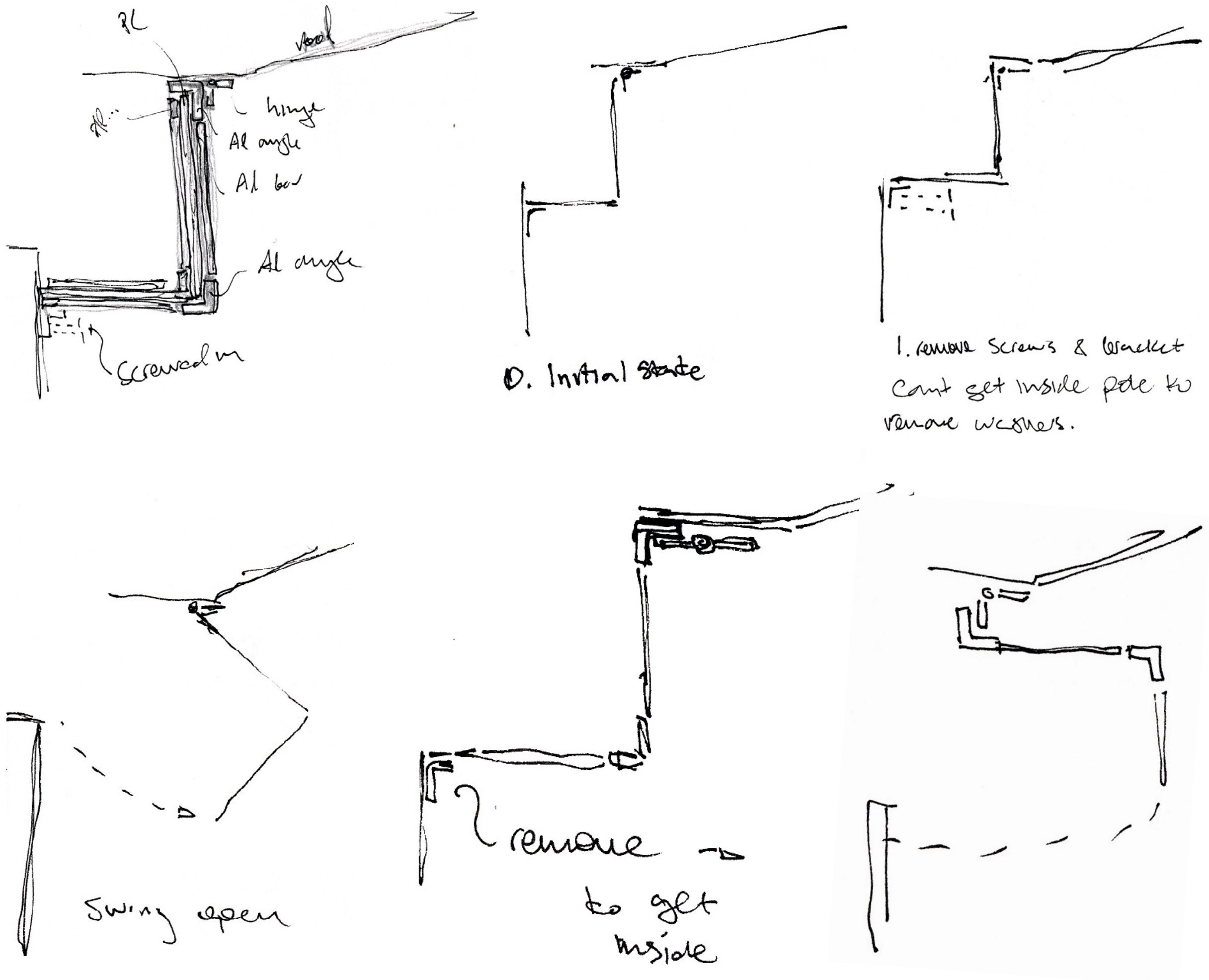
Drawings showing ideas for allowing access.

How to allow access for maintenance.

- Access needs to be gained to the internals of the light for maintenance purposes, although most of the components (PC panels, LED) should not require maintenance for around 10 years.
- Various techniques for opening things were considered in the brainstorm.
- I thought of using a hinge, different sides to put the hinge on, maybe it swings on hooks or lifts straight off, it could work like a drawer, the face could be attached only with screws that can be removed (this is not possible because there are no two parts which meet where you have access to both sides, they would have to protrude which would be unsightly), I thought if it all came together at the pole you could unscrew it and just dismantle the thing but again you do not have access to the inside of the pole.
- The most straight forward solution seems to be a hinge, which I will look into next.

Development:
Access for maintenance

Raised

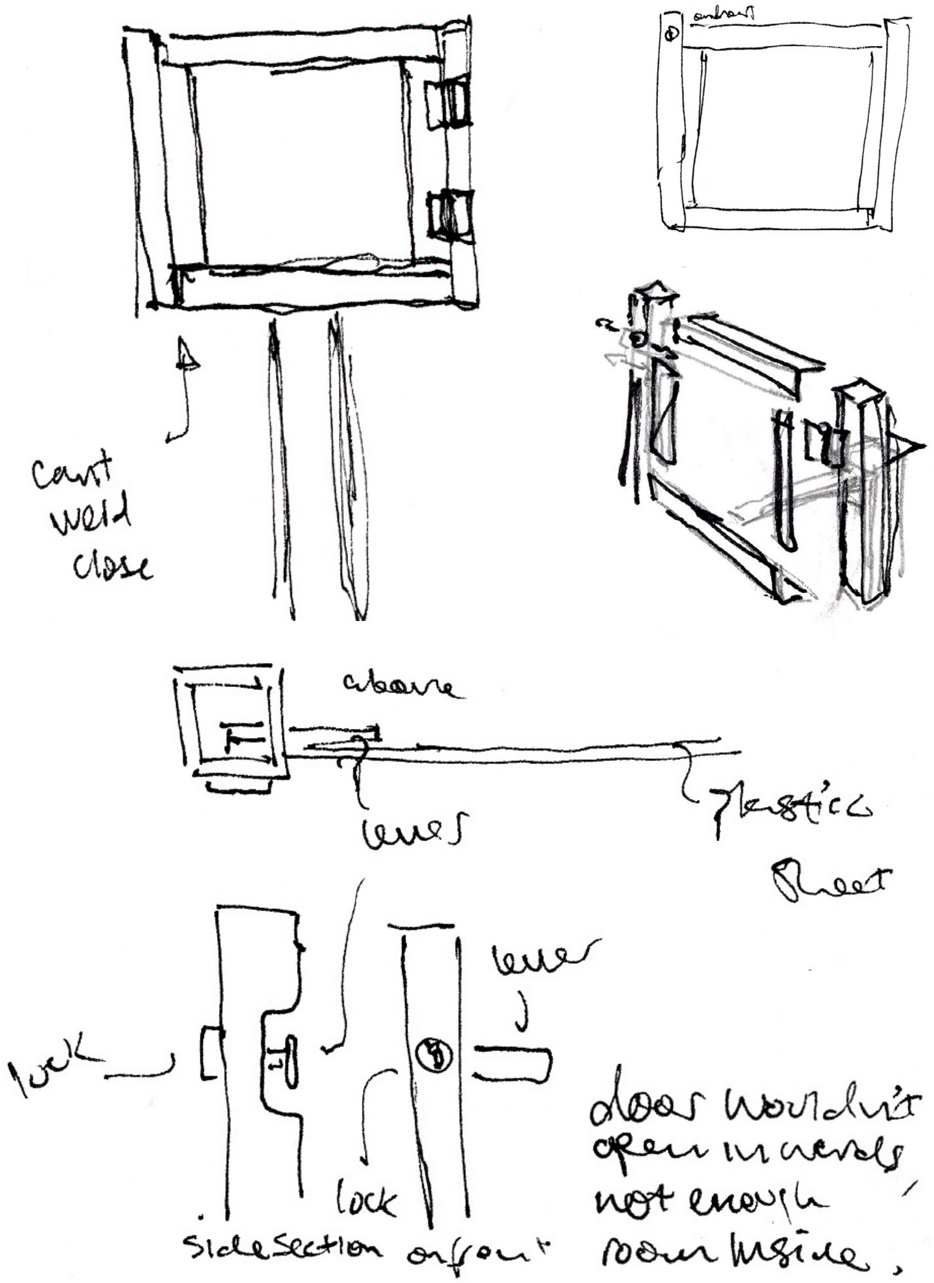


Drawings showing access with a hinge.

Access with a hinge on the roof.

- A lock or maybe just a bracket which can be unscrewed could connect to the pole, on the other end of the cube a hinge joins it to the roof, so it pivots on a horizontal axis.
- This would be difficult top open because it is high up, it might be heavy. It will be in an awkward position most likely with the person standing directly on front of it so they'd have to move out the way, duck under it and hold it up while trying to carry out maintenance unless there was a hook on the roof which held it out the way.
- Other solutions still need to be explored.

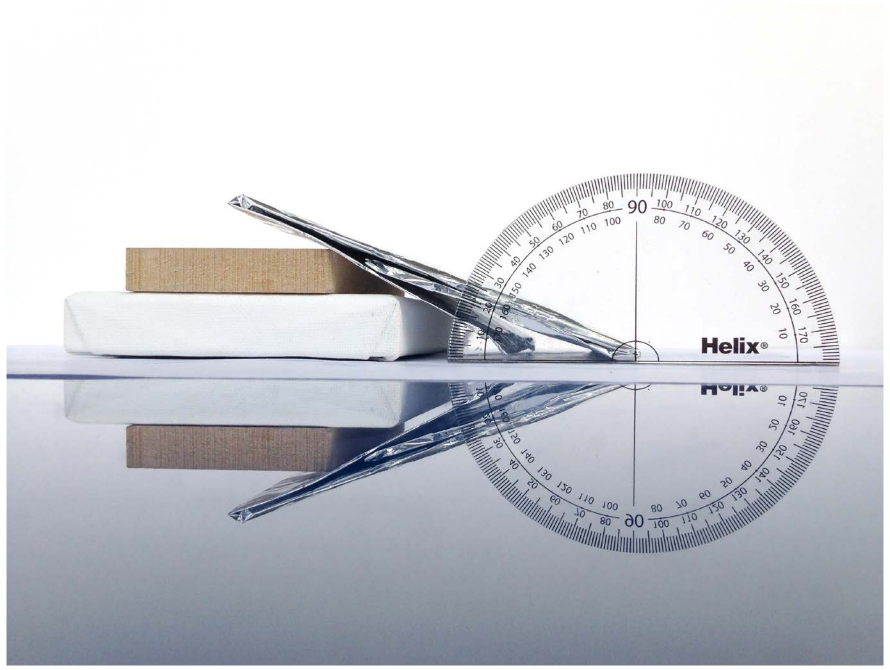
Development:
Access for maintenance



Drawings showing access with a hinge and lock.

Access with hinge and lock on front face.

- If there were hinges between the box section and the main frame then this may be able to provide access easily.
- A lock would be on he opposite side of the hinges in the box section and on the edge of the frame. It would not protrude out onto the PC or it would ruin the aesthetic.
- You would have to be careful not to weld the door closed like on the other faces. There would be no weld on the base of the cube or on the hollow box sections. The hollow box sections would have to be welded to the roof/reflector and would have to support the weight of the door.



Roughly finished aluminium foil slop.

Smoothly finished aluminium slope.

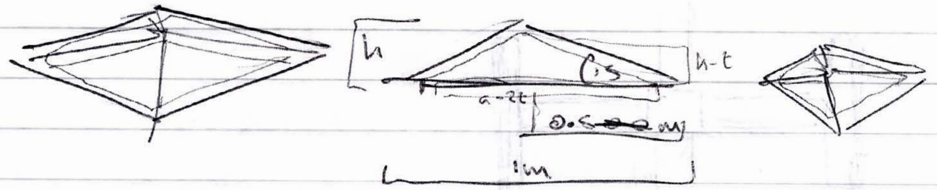
Results from slope with a roughly finished aluminium.

- By placing a droplet of water, from various heights, on aluminium foil resting at various angles, I was able to determine an estimate of the angle the roof is required to sit at in order to ensure water droplets do not rest on the metal.
- At 10° a small or large water droplet shows no sign of movement.
- At 15° a large droplet of water moved slowly while a smaller droplet moved very slowly.
- At 20° both droplets moved down the slope at a medium rate.

Results from slope with smoothly finished aluminium.

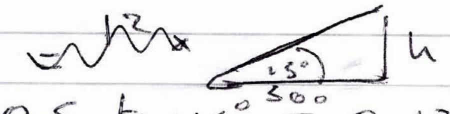
- At an angle of 10° on a smoothly finished aluminium surface a small water droplet which is gently placed down does not move, a larger droplet moves slowly.
- At an angle of 15°, when gently placed down, a small water droplet moves slowly, a larger water droplet moves faster. In the video on drop box you can see a water droplet increasing with speed as it gains mass from picking up smaller water droplets on the way down.
- At 20° all sized water droplets move with a relatively high velocity.
- A typical sheet of aluminium will be somewhere between the bumpy roufh sheet of aluminium foil and the smoothly finished aluminium arm. For this reason I will specify an angle of 15°.

Structural Analysis
Rationalise dimensions



roof is a hollow square based pyramid

$$V_{roof} = \frac{a^2 \times h}{3} - \frac{(a-2t)^2(h-t)}{3}$$



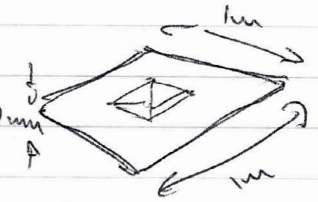
$$h = 0.5 \tan 15^\circ = 0.134 \text{ m.}$$

$$V_{roof} = \frac{1^2 \times 0.134}{3} - \frac{(1-2\times 0.9\times10^{-3})^2(0.134 - 0.9\times10^{-3})}{3}$$

$$= 0.0447 - 0.0442$$

$$= 0.5 \times 10^{-3} \text{ m}^3$$

$$V_{ref} \approx 0.9\times10^{-3} \text{ m}^3$$



$$m_{ref+roof} = \rho_{Al}(V_{ref} + V_{roof})$$

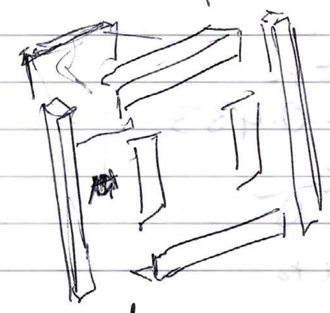
$$= 2712 \times (0.9\times10^{-3} + 0.5\times10^{-3})$$

$$\boxed{= 3.8 \text{ Kg}}$$

$$m_{person} = \boxed{70 \text{ kg}}$$

Calculations for mass of roof and reflector.

Mass of door:



$$M_{pc} = V_{pc} \times \rho_{pc}$$

$$0.5\times0.5\times3\times10^{-3}$$

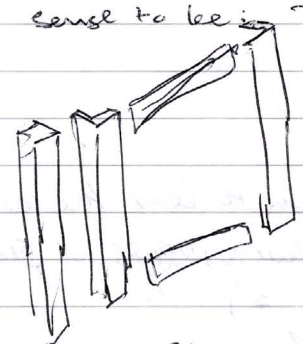
$$\approx (0.75\times10^{-3}) \times (577)$$

$$= 0.433 \text{ kg}$$

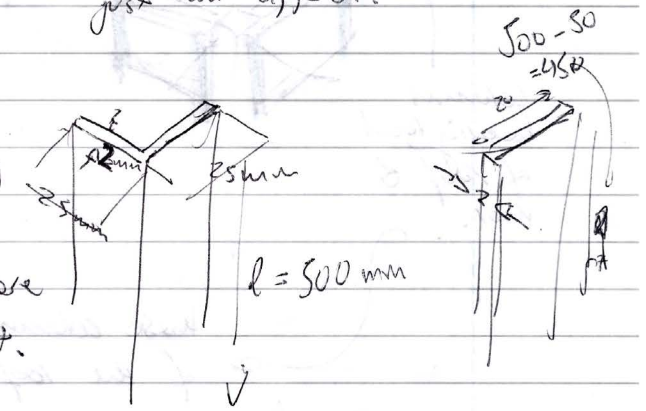
approx!

↳ figuring out sizes now! this is just an approx.

Would Make more sense to be:

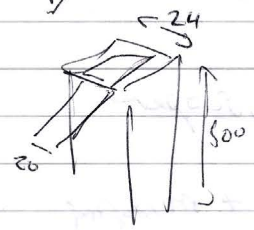


vertical angle offers more support.



$$V_{angle} = ((25\times10^{-3})^2 - (23\times10^{-3})^2) \times 0.5$$

$$= 0.048\times10^{-3} \text{ m}^3$$



$$V_{bar} = 20\times10^{-3} \times 2\times10^{-3} \times 450\times10^{-3}$$

$$= 1.8\times10^{-5} \text{ m}^3$$

$$V_{box} = ((24\times10^{-3})^2 - (20\times10^{-3})^2) \times 500\times10^{-3}$$

$$= 8.8\times10^{-5} \text{ m}^3$$

$$M_{al\,door} = \rho_{Al}(2V_{angle} + 2V_{box} + 2V_{bar})$$

$$= 2\times2712\,(0.048\times10^{-3} + 1.8\times10^{-5} + 8.8\times10^{-5})$$

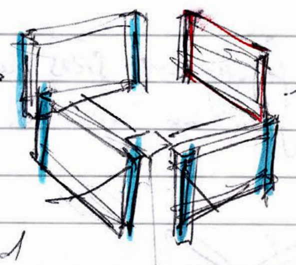
$$= 0.835 \text{ Kg}$$

Mass of one face.

Structural Analysis
Rationalise dimensions

mass of door:

$$m_{door} = m_{Al} + m_{pc}$$
$$= 0.835 + 0.433$$
$$= \underline{1.268\ Kg}$$



door fixed to roof.

columns bearing load of roof & door.

these columns may have to bear the load of the roof, the door & perhaps a person (climbing? maintaining?)

Total mass the columns need to support

$$m_{allowable} = 4 \times m_{person} + m_{door} + m_{roof\ tarf}$$
$$= 70 + 3.8 + 1.3\cancel{4}$$
$$= 75\ Kg.$$

285 | for 4 people

→ factor of safety should be somewhere about 2 or 3

Calculations for allowable mass on frame's columns.

$$F_{allowable} = 3 \times m_{allowable} \times g$$

8553 N

$$= 3 \times 75 \times \cancel{9.81}^{10} = \underline{\underline{2.25\ KN}}$$

This load, ~~as~~ however, is split across the 6 columns so for each column, the $F_{allowable}$ is just ~~750N~~.

2851 round to 3 ~~3~~ 1.5KN

$$\rightarrow F_{allowable} = 750\ N$$

0.375 KN

Euler's buckling rule states

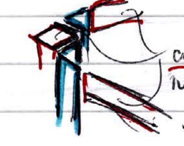
$$F_{allowable} = \frac{n\pi^2 EI}{L^2}$$

→ find required I & compare with that of standard extrusions.

~~If we find I & compare with that of standard components can find~~

$$\rightarrow I = \frac{F L^2}{n \pi^2 E}, \quad F = 750\ N, \quad L = 0.5, \quad E = 69 \times 10^9\ N/m^2$$

$n = 4$ since both ends are built in/fixed



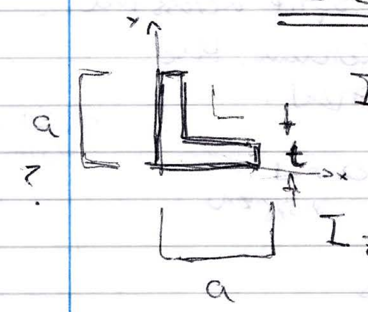
act to fix load bearing columns in place. ~~The additional mass~~ ~~forgot to add across~~ mass is negligible compared to the ~~eff~~ stiffening effect they produce. Since they will be welded along the side they will help carry much of the load compared to the mass they add.

Calculations for allowable load on frame's columns.

$$I = \frac{750 \times 0.5^2}{4 \times \pi^2 \times 69 \times 10^9}$$

2.75×10^{-10}

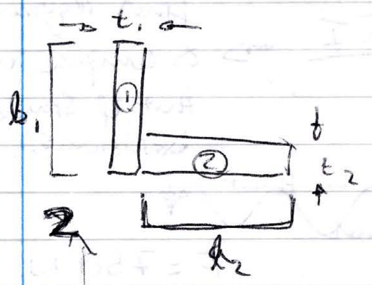
$$= 6.883 \times 10^{-11} \, m^4$$



I_{zz} for an equal angle section is

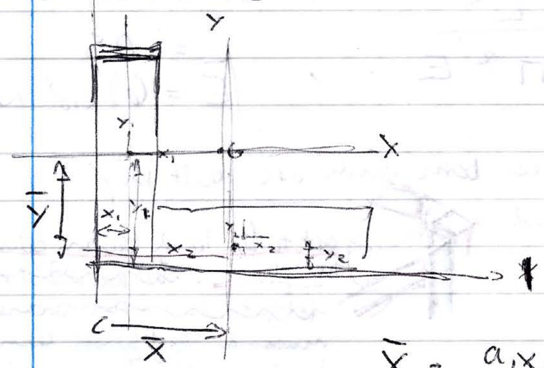
?

$$I_{zz} = \frac{2}{3}\left[t y^3 + a(a-y)^3 - (a-t)(a-y-t)^3\right]$$



$$a_1 = t_1 \times l_1$$

$$a_2 = t_2 \times l_2$$



$$x_1 = t_1/2$$

$$x_2 = \frac{l_2}{2} + t_1$$

$$y_1 = l_1/2$$

$$y_2 = t_2/2$$

$$\bar{X} = \frac{a_1 x_1 + a_2 x_2}{a_1 + a_2}$$

$$= \frac{(t_1 l_1)(t_1/2) + (t_2 \times l_2)(\frac{l_2}{2} + t_1)}{a_1 + a_2}$$

Calculating and deriving general formula for inertia.

$$\bar{X} = \left(\frac{t_1^2 l_1}{2} + \frac{t_2 l_2^2}{2} + t_2 l_2 t_1\right) \div (t_1 l_1 + t_2 l_2)$$

$$= \frac{\left(\frac{2t_1^2 l_1 + 2t_2 l_2^2}{4} + t_2 l_2 t_1\right)}{t_1 l_1 + t_2 l_2}$$

$$= \frac{\left(\frac{2t_1^2 l_1 + 2t_2 l_2^2 + 4t_2 l_2 t_1}{4}\right)}{t_1 l_1 + t_2 l_2}$$

$$= \frac{\left(\frac{1}{2}t_1^2 l_1 + \frac{1}{2}t_2 l_2^2 + t_2 l_2 t_1\right)}{t_1 l_1 + t_2 l_2}$$

$$\bar{Y} = \frac{a_1 y_1 + a_2 y_2}{a_1 + a_2}$$

$$= \frac{(t_1 l_1)(l_1/2) + (t_2 \times l_2)(t_2/2)}{t_1 l_1 + t_2 l_2}$$

$$= \frac{\frac{1}{2}t_1 l_1^2 + \frac{1}{2}l_2 t_2^2}{t_1 l_1 + t_2 l_2} = \frac{1}{2}\left(\frac{t_1 l_1^2 + l_2 t_2^2}{t_1 l_1 + t_2 l_2}\right)$$

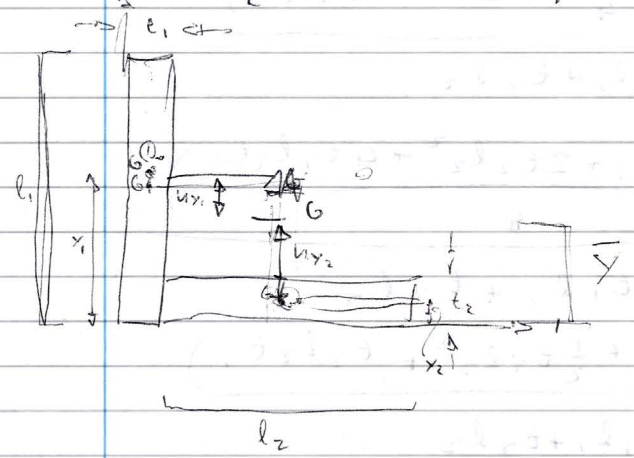
Deriving general formula for inertia of frame supporting column.

Structural Analysis
Rationalise dimensions

Raised

$$h_{y_1} = y_1 - \bar{y} = l_1/2 - \bar{y}$$

$$h_{y_2} = \bar{y} - y_2 = \bar{y} - t_2/2$$



$$I_1 = \frac{b_1 d_1^3}{12} + a_1 h_{y_1}^2$$

$$= \frac{t_1 l_1^3}{12} + (t_1 l_1)\left(l_1/2 - \bar{y}\right)^2$$

$$I_2 = \frac{b_2 d_2^3}{12} + a_2 h_{y_2}^2$$

$$= \frac{l_2 t_2^3}{12} + (t_2 l_2)\left(\bar{y} - t_2/2\right)^2$$

$$I = I_1 + I_2$$

$$I = \frac{t_1 l_1^3}{12} + (t_1 l_1)\left(\frac{l_1}{2} - \frac{1}{2}\left(\frac{t_1 l_1^2 + t_2^2 l_2}{t_1 l_1 + t_2 l_2}\right)\right)^2 +$$

$$+ \frac{l_2 t_2^3}{12} + (t_2 l_2)\left(\frac{1}{2}\left(\frac{t_1 l_1^2 + t_2^2 l_2}{t_1 l_1 + t_2 l_2}\right) - \frac{t_2}{2}\right)^2$$

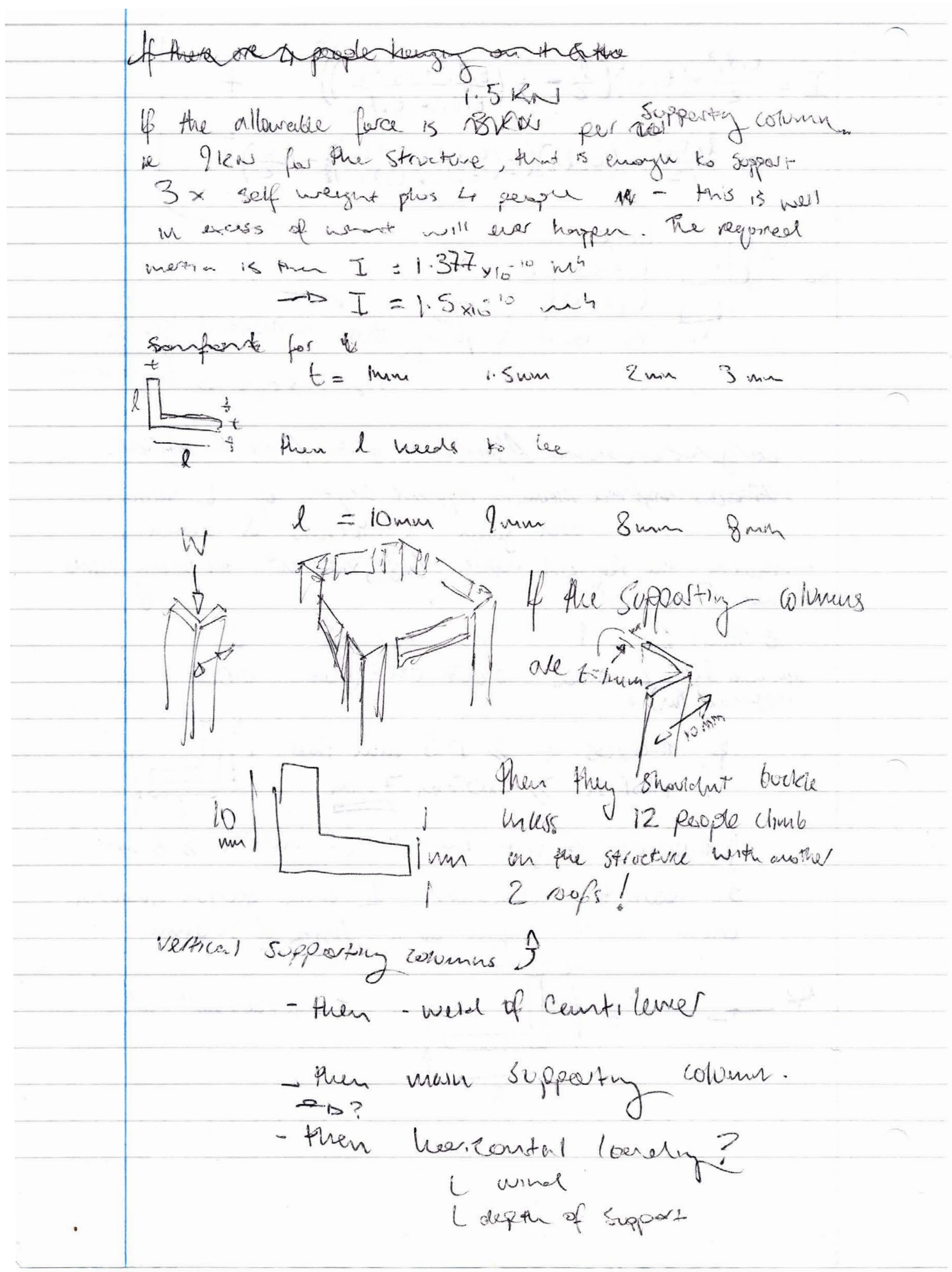
Deriving formula for frames supporting columns.

Using an algorithm to determine minimum required dimensions of supporting column.

- Using Matlab to create a script (shown below) which cycles through values for the length of the arms on an L section with various thickness's and calculates the second moment of inertia I was able to determine the minimum size required so that it would not buckle under a given load (using Euler's buckling theorem).

```
%algorithm for finding length of arm of L section given thickness and moment of inertia
%written for standard SI units
clc, clear

requiredInertia = 1.5*(10^-10); %Can work out from Euler's bukcling load
specifiedThickness = 1*(10^-3); %check availability

    for n = 1*(10^-6):1*(10^-3):1 %limits for checking lengths -ie between 1 micrometer to 1 meter in steps of 1mm

        %lengths and thickness of L section (assume t=1.5, loop lengths)
        t1=specifiedThickness;  %thickness of verticle arm if sitting like L
        t2=t1;                  %thickness of horizontal arm
        l1 = n;                 %length of verticle arm - loop to check minimum requiremned
        l2 = n;                 %length of horizontal arm - an equel L section

        %correct legnth
        l2 = l2-t1;

        %verticle distance of centroidal axis from global co-ordinate system
        ybar = 0.5*((t1*(l1^2)+l2*(t2^2))/(t1*l1 + t2*l2));

        %Inertia of individual rectangle components
        I1 = t1*(l1^3)/12 + (t1*l1)*(((l1/2)-ybar)^2);
        I2 = l2*(t2^3)/12 + (t2*l2)*((ybar - (t2/2))^2);

        %Inertia of complete L section
        I = I1 + I2;

        %Check to see if it meet required length
        if I >= requiredInertia
            fprintf('For an equel angle section with thickness 1.5mm the required lenth of arms are:\n')
            n
            break %breaks for loop at first instance of required inertia being met
        end
    end
```

Raised


~~If there are 4 people hanging on the~~
1.5 kN
If the allowable force is ~~8kN~~ per ~~rod~~ supporting column
ie 9kN for the structure, that is enough to support
3 x self weight plus 4 people – this is well
in excess of what will ever happen. The required
inertia is then $I = 1.377 \times 10^{-10}$ m⁴
$\rightarrow I = 1.5 \times 10^{-10}$ m⁴
~~Sunfords~~ for t
t = 1mm 1.5mm 2mm 3mm
then l needs to be
l = 10mm 9mm 8mm 8mm
W
If the supporting columns are t=1mm
10 mm
10 mm
1mm
Then they shouldn't buckle unless 12 people climb on the structure with another 2 roofs!
vertical supporting columns
- then - weld of cantilever
- then main supporting column.
- then horizontal loading?
wind
depth of support

Results from Matlab script.

Selecting an appropriate section for supporting column in frame.

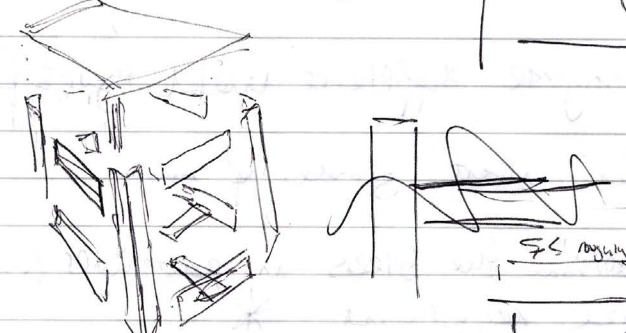
- The Matlab script returned the values for the length of the arms on an L shaped section in order for it not to buckle under a given load when a thickness is specified. The results are shown on the left.
- Capalex supply an equal L section with dimensions 10x10x1mm available in several alloys which would support the roof with four people hanging off it with a factor of saftey of 3 (so actually it could hold 12 people and three extra roofs).

Structural Analysis
Rationalise dimensions

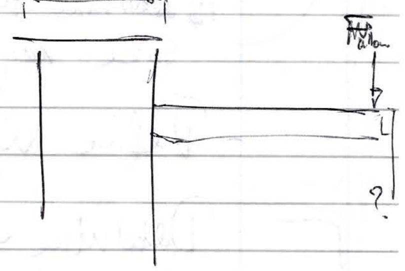
Raised

Speak to Colin Well

* Need to choose right type of Al 6xxx series?

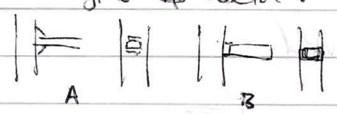


55 roughly



F allow

What type of weld?



A B

?

$F_{allow} = M_{allow}\, g$

factors of safety

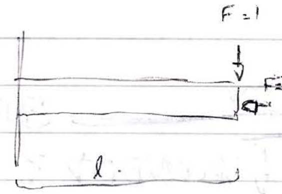
$M_{allow} = \left(\frac{M_{roof} + M_{ref} + 4M_{person} + M_{door}}{3} + M_{face} \right) \times 3$

assume its spread between 3 forces evenly

$= \left(\frac{3.8 + 4\times 70 + 1.263}{3} + 1.263 \right) \times 3 = 96.3\,kg$ $\times 3 = 288.87 \approx 300$

$F_{allow} = mg \Rightarrow 1\,KN \to 3\,KN$ *

F=1



F=1's length depends on width of supporting column which can be taken as 75mm at the moment.

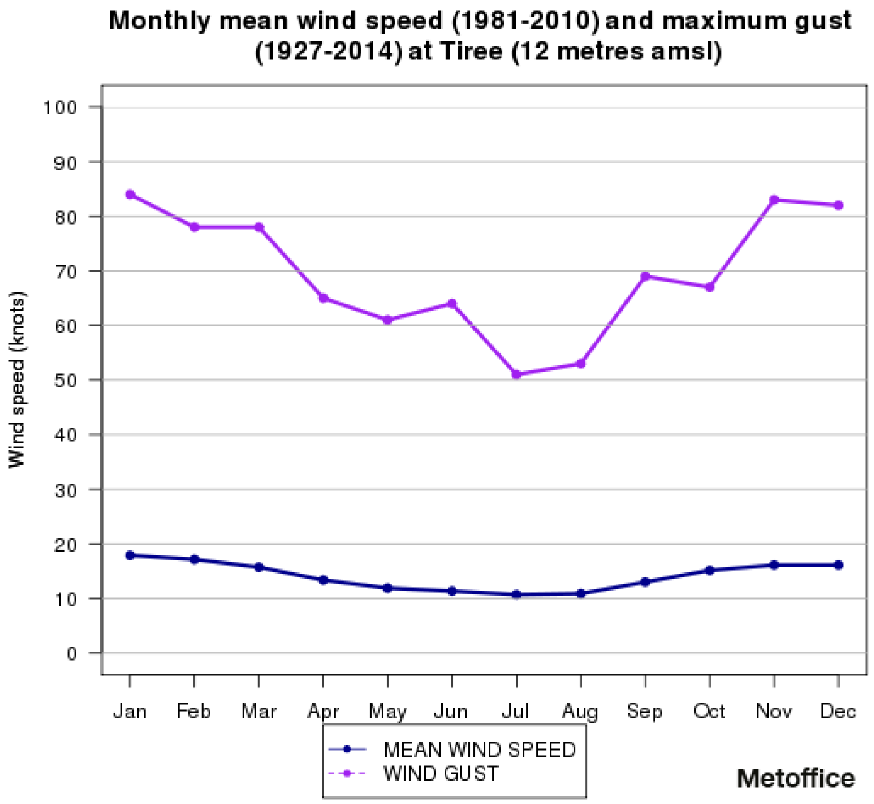
$l = \frac{500 - W_p}{2} = \frac{500 - 75}{2} = 0.21\,M$

* this is in y direction, will have horizontal loading from wind forces. The highest average windspeed in windiest month between 1981 - 2010 on Tiree (way windier than Glasgow) was is around 85 knots. → 85 knots = 43.73 m/s

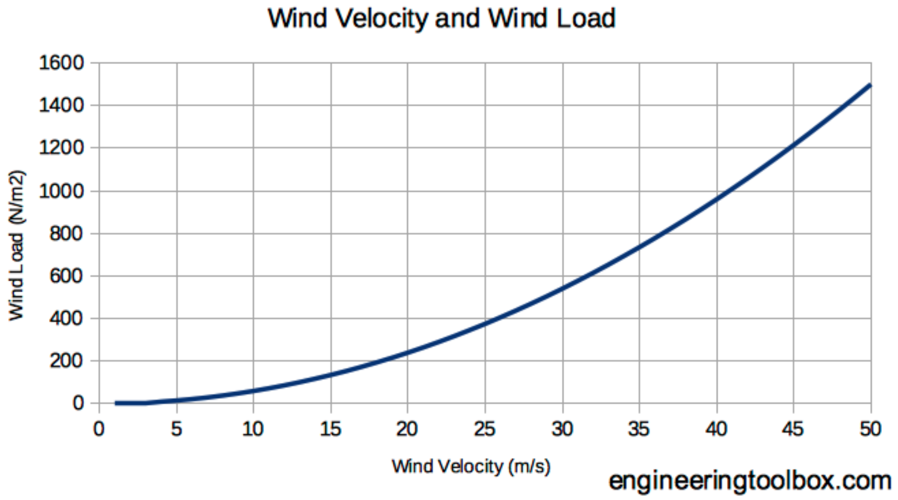
from the graph this gives a pressure of $P_{wind} = 1162\ N/m^2$

The majority of this load will be on the 0.5 m² face so $F_{wind} = 1162 \times 0.5 = 581\ N$

FOS would bring this to about 1.5 KN. *



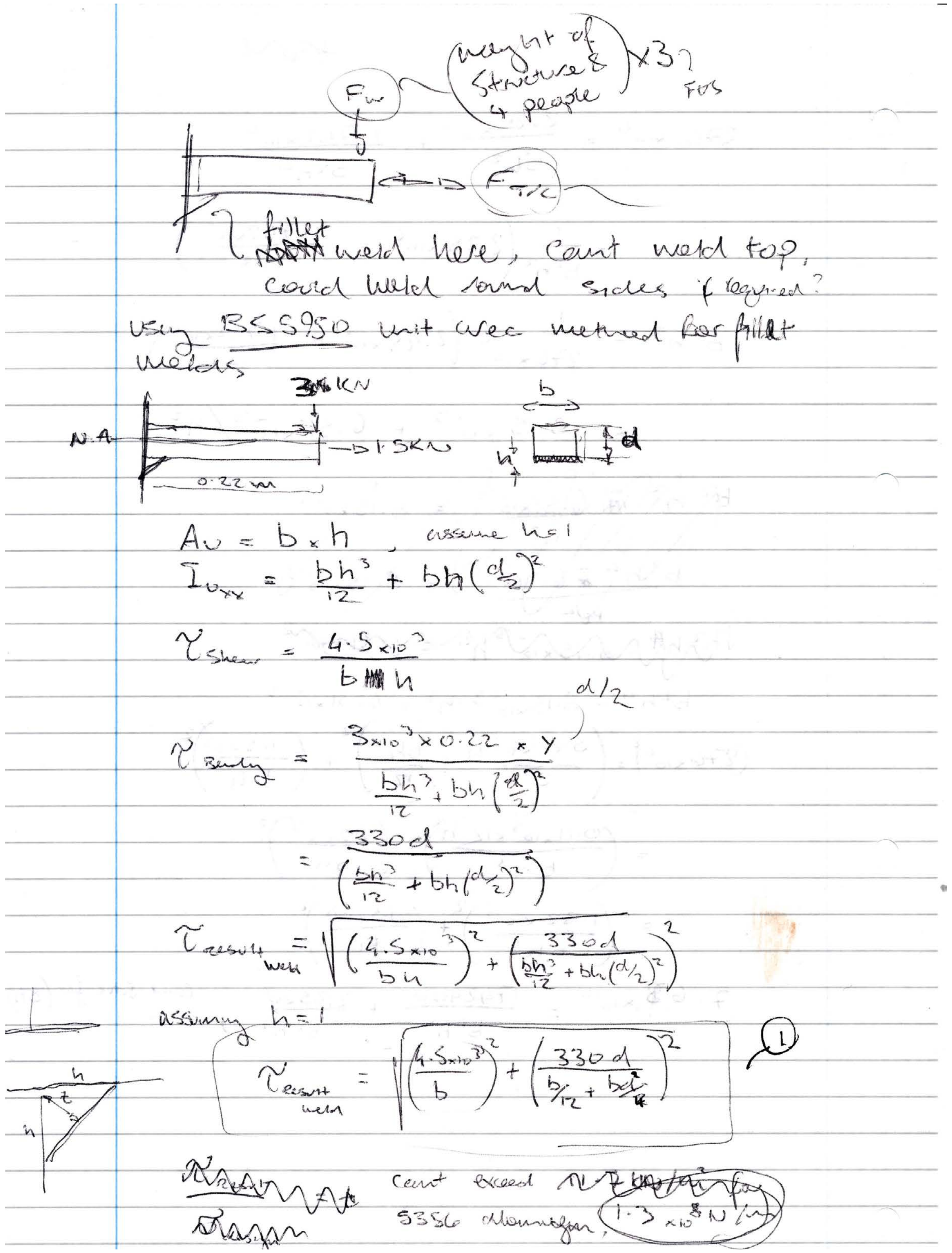
Metoffice



engineeringtoolbox.com

Calculations for defining allowable load the frames cantilever support.

- If average maximum gust between 1981 and 2010 on Tiree (which is a lot windier than Glasgow) is 85 knots, then the wind pressure exerted on the structure is around 1162N/m² then the force is about 500N so with a factor of saftey of three the design load should be 1.5 KN.



weight of Structure & 4 people ×3? FOS

F_w

$F_{T/C}$

fillet weld here, can't weld top, could weld round sides if required?

Using BS5950 unit wee method for fillet welds

3kN

N.A

1.5kN

0.22m

b h d

$A_w = b \times h$, assume h=1

$I_{xx} = \frac{bh^3}{12} + bh\left(\frac{d}{2}\right)^2$

$\tau_{shear} = \frac{4.5\times10^3}{bh}$

$\tau_{Bending} = \frac{3\times10^3 \times 0.22 \times y}{\frac{bh^3}{12} + bh\left(\frac{d}{2}\right)^2}$, $y = d/2$

$= \frac{330d}{\left(\frac{bh^3}{12} + bh\left(\frac{d}{2}\right)^2\right)}$

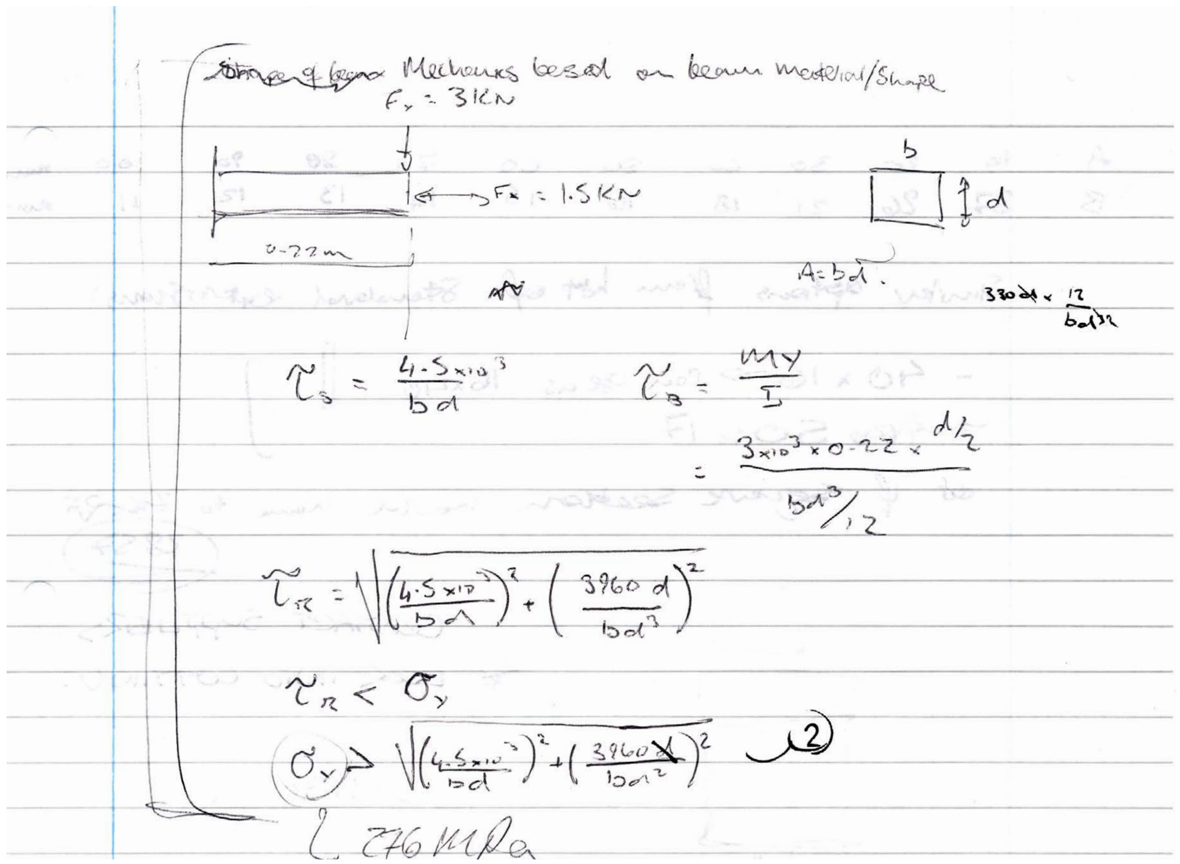
$\tau_{result\,weld} = \sqrt{\left(\frac{4.5\times10^3}{bh}\right)^2 + \left(\frac{330d}{\frac{bh^3}{12} + bh\left(\frac{d}{2}\right)^2}\right)^2}$

assuming h=1

$\boxed{\tau_{result\,weld} = \sqrt{\left(\frac{4.5\times10^3}{b}\right)^2 + \left(\frac{330d}{\frac{b}{12} + \frac{bd^2}{4}}\right)^2}}$ (1)

can't exceed 5356 newton, $1.3\times10^8\ N/m$

Stresses in weld due to shear and bending.



Mechanics based on beam material/Shape

$F_y = 3kN$

$F_x = 1.5kN$

0.22m

b d

$A = bd$

$\tau_s = \frac{4.5\times10^3}{bd}$ $\tau_B = \frac{My}{I} = \frac{3\times10^3 \times 0.22 \times d/2}{bd^3/12}$

$\tau_R = \sqrt{\left(\frac{4.5\times10^3}{bd}\right)^2 + \left(\frac{3960d}{bd^3}\right)^2}$

$\tau_R < \sigma_y$

$\sigma_y > \sqrt{\left(\frac{4.5\times10^3}{bd}\right)^2 + \left(\frac{3960}{bd^2}\right)^2}$ (2)

≥ 276 MPa

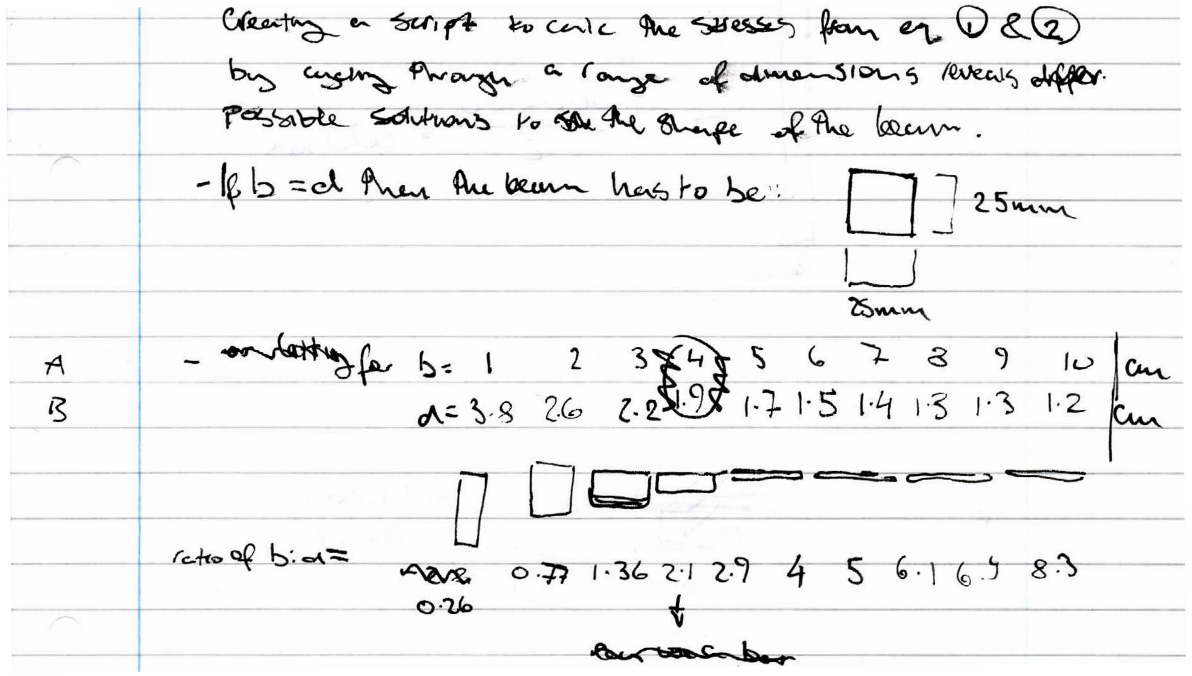
Stresses in cantilever beam.

Derivation of relationship between stresses (in beam and weld) and dimensions.

- The formula's for stress in the beam and the weld can be solved in Matlab with various dimensions in order to identify which component yields first and what shape the section should be.

```
%Script to calculate required d of bar given b and load
clc, clear

for b = 1E-2:1E-2:10E-2

    for n = 1E-3:1E-3:9000
        %cycles through depths starting at 9999mm, decrementing 1mm
        d = 1 - n;

        %calc stress in weld
        Sw = ( (4.5E3/b)^2 + (330*d/((b/12)+(b*d/2)))^2 )^0.5;

        %calc sress in beam (found analytically given the loading)
        Sb1 = (4.5E3/b*d);           %shear
        Sb2 = ((3960)/(b*(d^2)));    %bending
        Sb = ((Sb1^2)+(Sb2^2))^0.5;  %resultant


        %check to see if stresses have exceeded limit

        %weld stresses
        if Sw >= 1.3E8

            fprintf('stesses in weld exceeded yield first \n')
            b
            d
            break
        end

        %beam stresses
        if Sb >=276E6

            fprintf('stresses in beam exceeded yield first \n')
            b
            d
            break
        end
    end
end
```

Matlab script to calculate stresses in weld and beam for various dimensions.



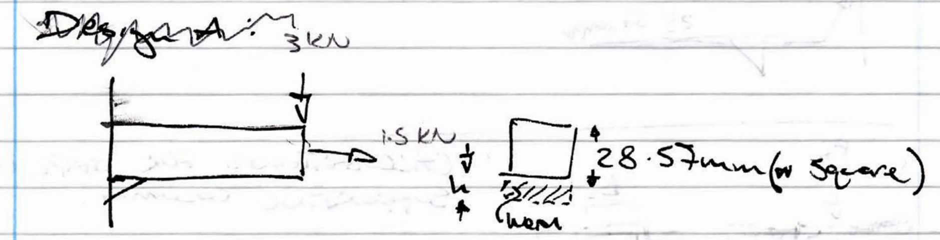
Dimensions returned by Matlab.

Required dimensions of cantilever support in frame.

- The Matlab script calculates the stresses in the beam and in the weld for various dimensions and identifies which yields first and then returns the sections dimensions.
- The cheapest bar available for the job (to hold four people and self weight with a factor of safety of 3) is square and can be supplied by Aalco, it is available in 6082 which is an appropriate alloy.

Weld size:
The unit area method of BS5950 for fillet welds:

Diagram:



$A_u = b \times h = 28.57\ mm^2$ assuming $h = 1$,

$I_{xx} = \frac{bh^3}{12} + A_u \bar{y}^2$

$= \frac{28.57 \times 10^{-3}}{12} + (28.57 \times 10^{-3})\left(\frac{28.57}{2}^2\right)$

$= 2.4 \times 10^{-3}\ m^4$

Shear:
$\tau_s = \frac{4.5 \times 10^3}{A_u} = 157.5\ KN/m^2$

bending:
$\tau_B = \frac{My}{I} = \frac{3 \times 10^3 \times 0.22 \times \frac{28.57 \times 10^{-3}}{2}}{2.4 \times 10^{-3}} = 3.93\ KN/m^2$

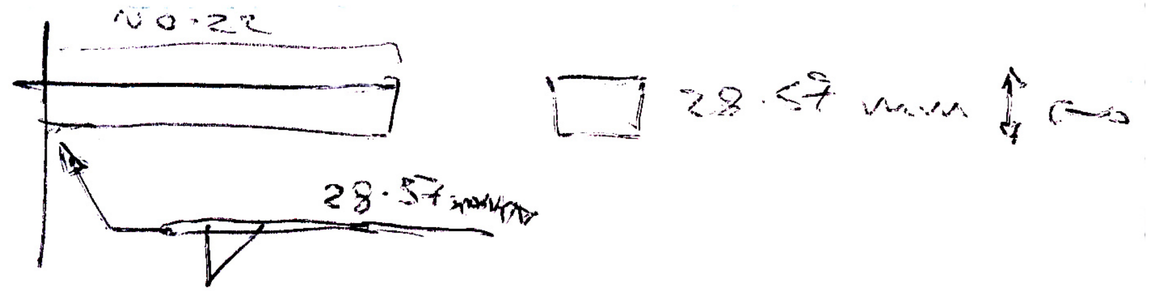
resultant:
$\tau_R = \sqrt{(157.5)^2 + (3.93)^2} = 157.5\ KN/m^2$

$t = \frac{\tau_R}{\sigma_d}$ the design stress is the yield

$= \frac{157.5 \times 10^3}{1.5 \times 10^2} = 1.2\ mm$

$h = \sqrt{2} \cdot t = 1.7\ mm$

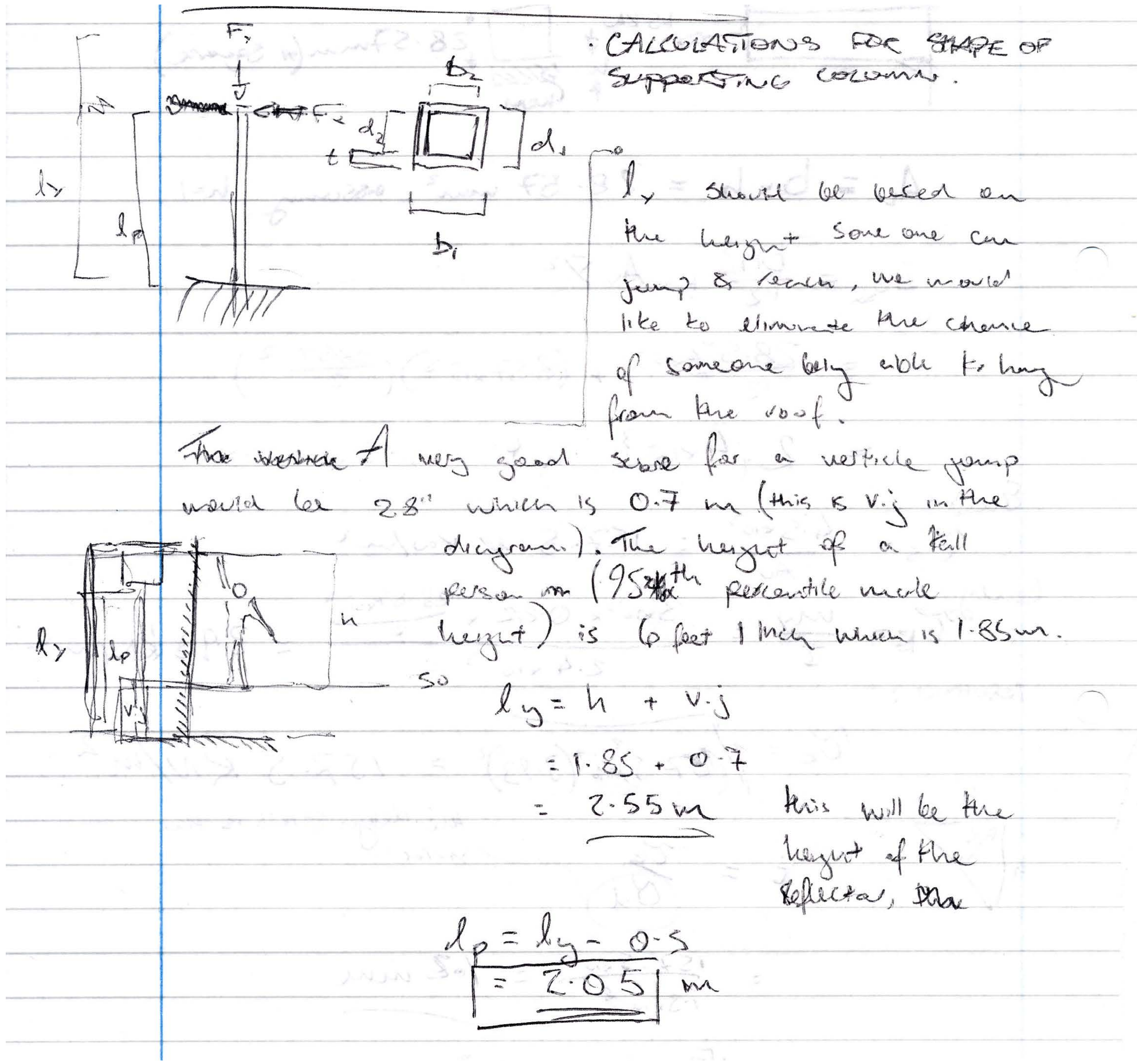
Calculations for weld throat and height.



Unit area method of BS590 for fillet weld.

- Using the unit area method of BS590 I was able to specify the required dimensions of the weld in order to support self weight with four people and wind loading with a factor of safety of three.

Raised


· Calculations for shape of supporting column.

l_y should be based on the height some one can jump & reach, we would like to eliminate the chance of someone being able to hang from the roof.

A very good score for a vertical jump would be 28" which is 0.7 m (this is v.j in the diagram). The height of a tall person (95th percentile male height) is 6 feet 1 inch which is 1.85m.

so $l_y = h + v.j$

$= 1.85 + 0.7$

$= 2.55\,m$ this will be the height of the reflector, thus

$l_p = l_y - 0.5$

$\boxed{= 2.05}\ m$

Calculations for pole height.

Required height to keep out of reach from vandals.

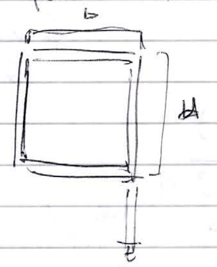
- The roof and reflector for the light would offer a perfect platform for somebody to hang and swing from, to prevent this the lamp can be designed so that any surface that can be gripped is out of reach.
- A very good vertical jump (diagram shown on left of page) is 0.7m, the 95th percentile males height is 1.85m. If the height of the reflector/ roof is the sum of these then it will be out of reach for the majority of the population. Based on this, the height of the pole out of the ground should be 2.05m.

Raised

Required dimensions of main supporting column.

- By knowing what force the structure must withstand and the material used the required inertia of the section can be calculated using Euler's buckling theorem.
- Since we know the required inertia, if we derive a general formula for the second moment of inertia for a square tubular section in terms of width and thickness, we can then check available thickness's from suppliers and solve for width to see what section is most appropriate.

The Shape of the pole must be hollow to allow for the passing of cables, so it's section must be:



It makes the maths easier & is more aesthetic for it to be square so let

$A = b = d$

The inertia will be:

$$I = \frac{bd^3}{12} - \frac{(b-2t)(d-2t)^3}{12}$$

$$= \frac{A^4}{12} - \frac{(A-2t)(A-2t)^3}{12}$$

$$= \frac{A^4}{12} - \frac{(A-2t)^4}{12}$$

1
1 1
1 2 1
1 3 3 1
1 4 6 4 1

$$= \frac{1}{12}\left(A^4 - \left(A^4 + (-2t)^1 A^3 + (-2t)^2 A^2 + (-2t)^3 A^1 + (-2t)^4\right)\right)$$

$$= \frac{1}{12}\left(A^4 - \left(A^4 - 2tA^3 + 4t^2A^2 - 8t^3A + 16t^4\right)\right)$$

$$= \frac{1}{12}\left(2tA^3 - 4t^2A^2 + 8t^3A - 16t^4\right)$$

$$\boxed{= \frac{tA^3}{6} - \frac{t^2A^2}{3} + \frac{2}{3}t^3A - \frac{4}{3}t^4 \ m^4}$$

Euler's buckling formula says:

$$F_{crit} = \frac{n\pi^2 EI}{L^2},$$

Since one end is fixed & one end is free $\boxed{n = 0.25}$

$L = l_p$

$\boxed{E = 69 \times 10^9 \ N/m^2}$

$$F_{crit} = mg \times FOS, \quad m = \left(4M_{face} + M_{roof} + M_{ref} + 4M_{person}\right)$$

$$= 4 \times 1.27 + 3.8 + 4 \times 70 = 288.88 \text{ kg}$$

so $F_{crit} = 288.88 \times 10 \times 3 = 8666.4$,

So say $\boxed{9KN.}$

re arranging Euler's buckling formula gives

$$I = \frac{F_{crit} L^2}{n\pi^2 E}$$

for steel: 7.66×10^{-8}

$$= \frac{9 \times 10^3 \times (2.05^2)}{0.25 \times \pi^2 \times 69 \times 10^9}$$

for aluminium:

$$= 2.22 \times 10^{-7} \ m^4$$

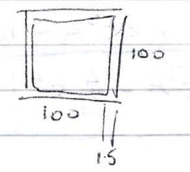
70
210

Derivation of a general formula for inertia of a square tubular section and calculation of minimum inertia required.

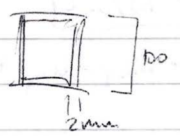
Structural Analysis
Rationalise dimensions

From the MATLAB script you would require A = 0.078 m & t = 3.05 mm so the sections available from Capa lex would not be any good.

For a thickness of 1.5 mm the length of square has to be 0.0971 m (97 mm). Alco supplies square box sections which are 100x100x1.5 so these would do the job well.

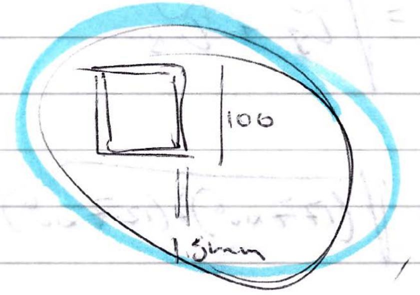


For a thickness of 2mm, the length would have to be at least 0.0896mm, the closest Alco supplies so this is



For a thickness of 3mm, A ≥ 0.0782m, also Alco supplies 150x150x3.

The cheapest option would be the

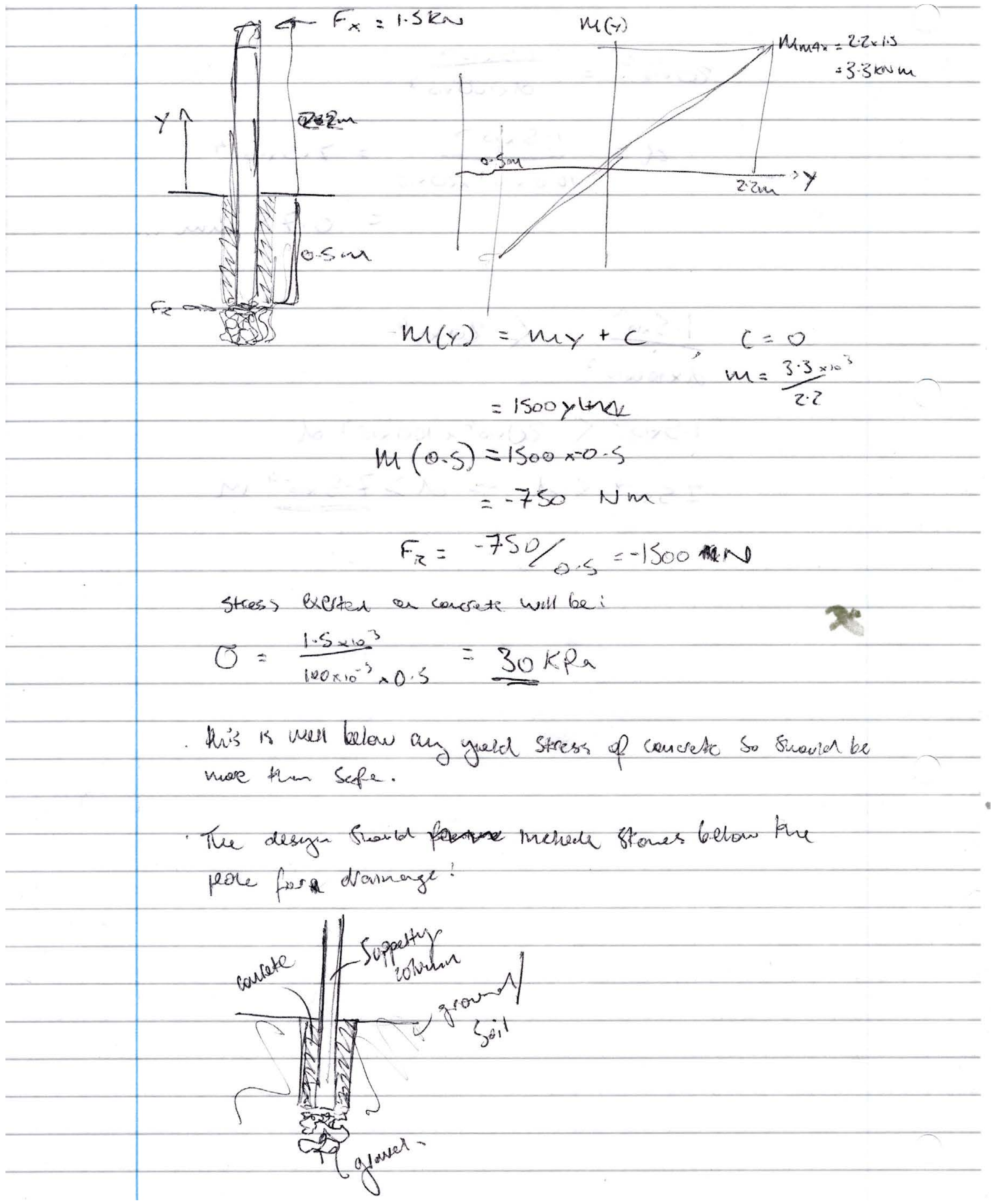



```
%script for calculating dimensions of (a square tubular section) supporting
%column, given inertia (calc from Euler's buckling equation) and thickness.

%init
clc, clear

%thickness (outer square - inner square)
t = 3E-3;

for A = 8.4E-3:0.001E-3:0.5 %set limits of squares length

    I = ((t*(A^3))/6) - ((t^2)*(A^2)/3) + (2/3)*(t^3)*(A) - (4/3)*(t^4);

    %check to see if I is large enough to support load
    if I >= 2.22E-7 %then the load will be supported

        fprintf('the load will be supported if')
        t
        A
        break
    end

end
```

Matlab script for identifying mininimum width given thickness and required inertia.

Identifying optimum solution for supporting column shape.

- The script shown on the bottom left of this page cycles through widths and calculates the inertia.
- When the inertia becomes larger than the required inertia (as calculated using Euler's buckling theorem on the previous page) the script "breaks" the loop and returns the minimum required width required to support the load.
- The optimum solution (closest to what Matlab returned) was a 100x100x1.5mm square tubular section, this can be supplied by Aalco in the appropriate alloy 6082.



$F_x = 1.5kN$

$M(y)$

$M_{max} = 2.2 \times 1.5 = 3.3kNm$

y 2.2m   0.5m F_z

$M(y) = my + c$ $c = 0$ $m = \frac{3.3 \times 10^3}{2.2}$

$= 1500y$ ~~Nm~~

$M(-0.5) = 1500 \times -0.5$

$= -750$ Nm

$F_z = \frac{-750}{0.5} = -1500$ N

Stress exerted on concrete will be:

$\sigma = \frac{1.5 \times 10^3}{100 \times 10^{-3} \times 0.5} = \underline{30 KPa}$

. this is well below any yield stress of concrete so should be more than safe.

. The design should ~~include~~ include stones below the pole for drainage!

concrete, Supporting column, ground, Soil, gravel

Static analysis to calculate depth of foundation.

Required depth of foundation.

- Under the ground the lamp will be fixed in place with concrete.
- If fixed with 0.5m under the ground then the maximum stress exerted on the cement can be calculated as the horizontal loading spread over the area of one side of the pole under the ground. Doing this showed that a stress of 30 KPa would be exerted on the cement which is well below it’s compressive strength meaning that the design should be stable.
- In order to confirm the stability of the design a static and dynamic finite element analysis should be completed. This would confirm the internal stresses of the components and how likely they are to buckle. A dynamic FEA would reveal the structure’s Eigenfrequencies and reveal the likely-hood of self excited oscillations which could result in undesired effects.
- In order to allow for proper drainage gravel should be placed below the supporting column.

Development:
Access via the door

Render showing how access is gained.

Access for maintenance gained via door.

- Access can be gained for maintenance purposes by using the door.
- A lock could be fitted as shown on the assembly drawings.
- Access should only need to be gained every ten years for replacing the LED and possibly the polycarbonate.
- The light should require very little maintenance and when it does this door should make the job easy.

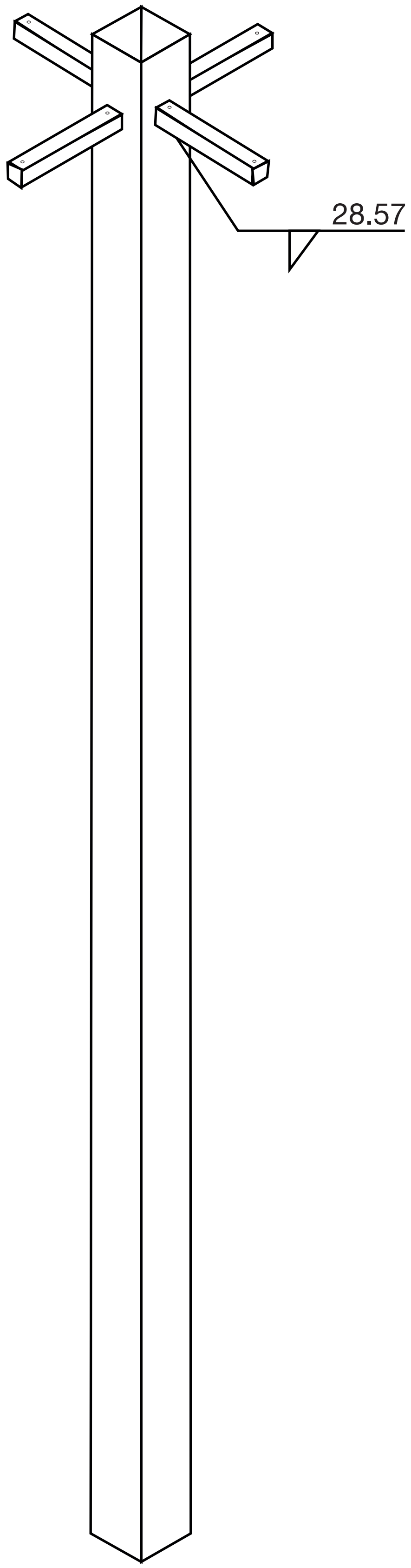
Development:
1:1 Scale Model, material test

Photographs of 1:1 scale prototype for testing material and roof size.

Choosing what kind of PC and what method for diffusing the light as well as establishing minimum roof size.

This prototype allowed me to establish a number of things. By using a torch with an equivalent quantity of Lumen to the chosen light fixture and having the five sides made out of various options I found:

- In order to spread enough light only a 200mm over hang is required.
- Of the five plastics, all 3mm thick [Opal PC (with a sheet of light diffusing film), Opal Light Diffusing PC, Clear PC (with a light diffusing film), Prismatic Light Diffusing PC, LED Light Diffusing Opal Acrylic Sheet] the Opal Light Diffusing Polycarbonate sheet diffused the light most evenly and had the nicest quality (although in the photos they all look the same). The torch used would not be the same colour as the real light fixture, the real light fixture would be 3000K so would be a warmer, more yellow tone. The torch also had a lens which concentrates the light more so the actual light would have a more even spread of light as it is coming from a point source.

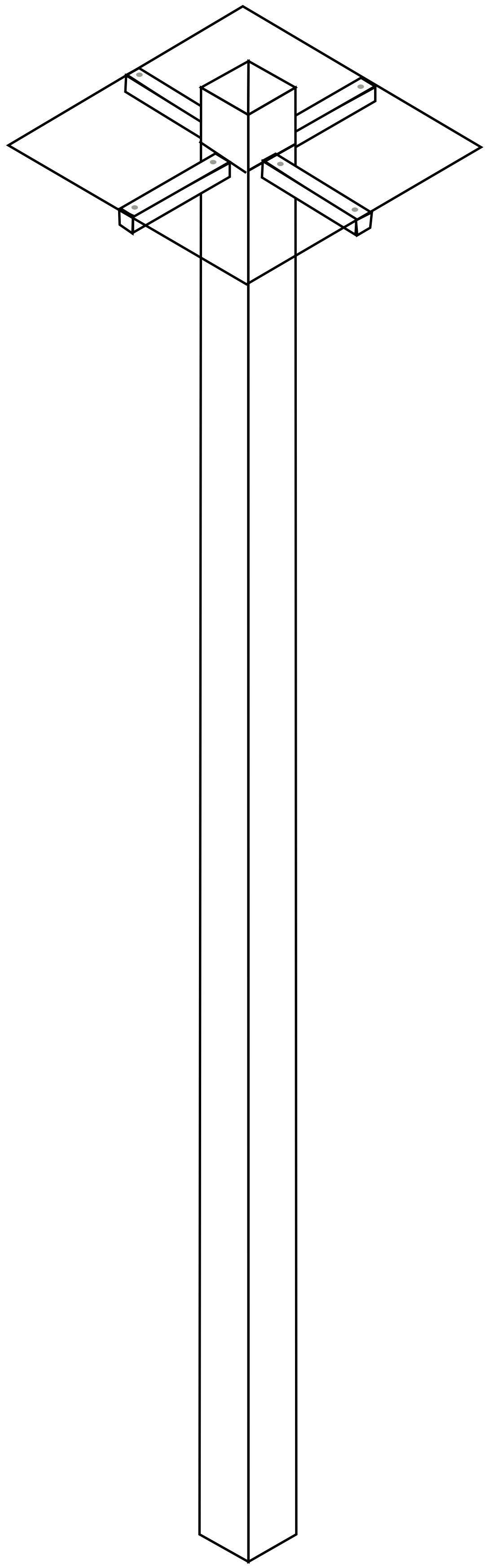


First the 28.57mm² square aluminium section is fillet welded along it's base to the supporting column at a distance of 53mm from the top. The reason it is only welded on the underside is that the top area must be flat for the polycarbonate to sit on flush so that there is not a gap that would reduce the IP rating. The fillet weld should have a height of 1.7mm and a throat of 1.2mm, this will ensure appropriate strength to with stand 3 x (self weight + 4 people + extreme wind load), see calculations for reasoning.

The alloy used is 6082 aluminium, see material selection for reasoning. An appropriate and recommended filler for welding is 4043. The aluminium can be welded with TIG (Tungsten Inert Gas) or MIG (Metal Inert Gas). Before welding the components should be pre-heated.

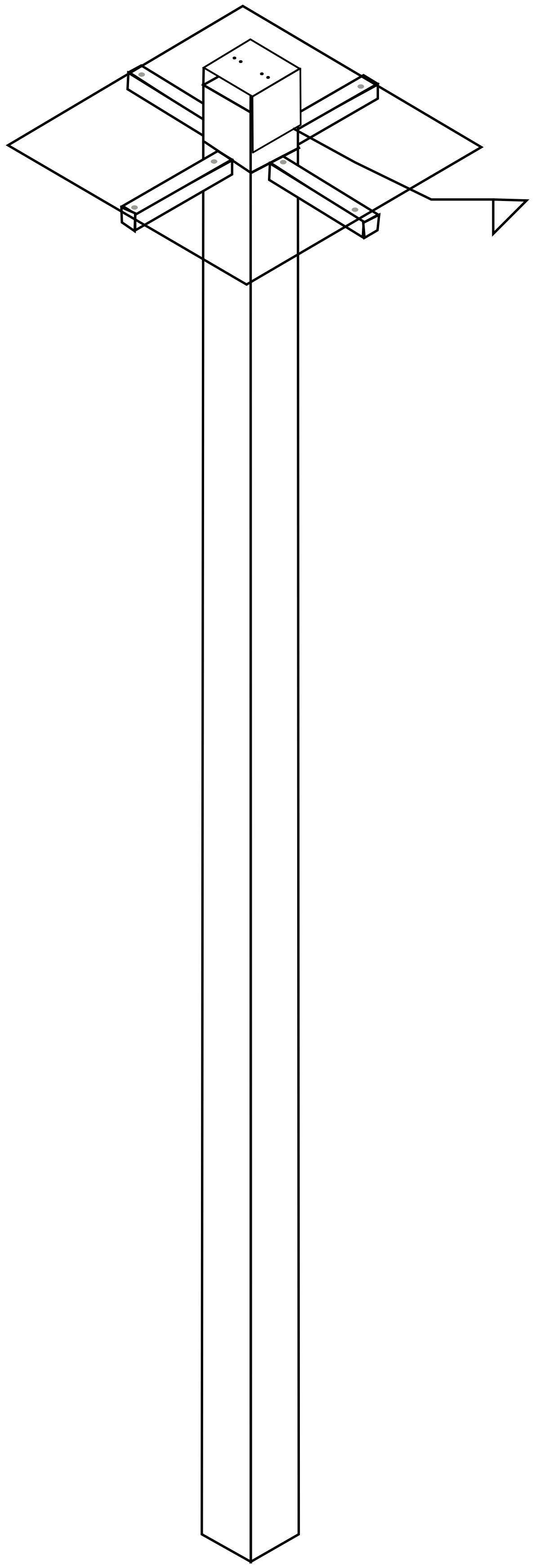
The tolerance for square bars, according to Aalco's product literature, is in keeping with EN755, so a square bar (EN755-4) of group I (includes 6082) between 26mm and 40mm will have a tollerance of ±0.3mm. A square box section with a width of 100mm will have a tolerance of ±0.7mm, a thickness of 1.5mm a tolerance of ±0.25mm.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: brushed alumium TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION	
	NAME	SIGNATURE	DATE	TITLE: Assembly - step 1	
DRAWN					
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: 6082 Aluminium for main components with 4043 as the filler between welds.	DWG NO.	A3
			WEIGHT:	SCALE:**1:10**	SHEET 1 OF 1



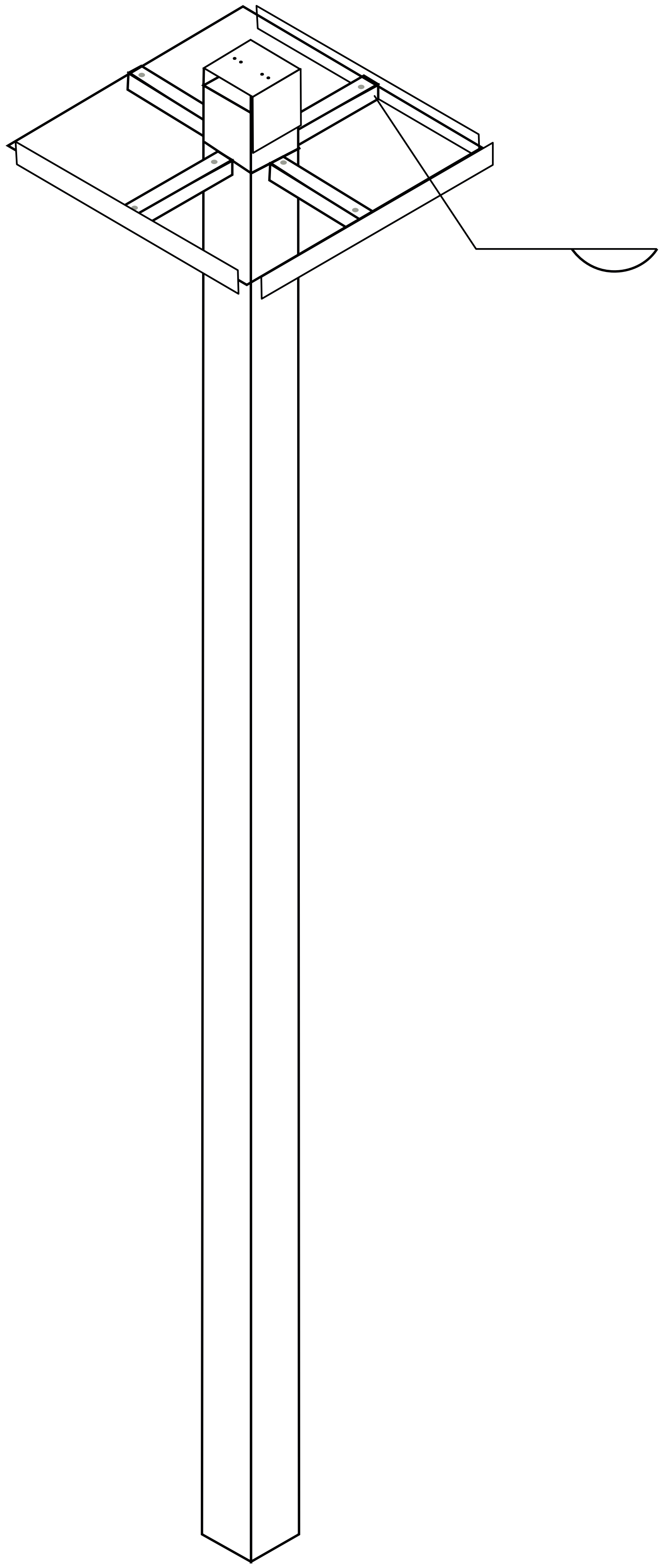
The polycarbonate base is placed on top of the bars and fixed in place with self tapping aluminium scews. Using aluminium screws eliminats the possibility of glasvanic corrosion, the electrochemical phenomenon that occours when two different metals come in contact.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: brushed alumium TOLERANCES: LINEAR: ANGULAR:	FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN						Assembly - step 2	
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL: 6082 Aluminium for main components with 4043 as the filler between welds. Opal light diffusing PC.		DWG NO.	A3
				WEIGHT:		SCALE:**1:10**	SHEET 1 OF 1



A fillet weld is used to fix the bracket which the lighting fixture sits on. Calculations to see what volume of weld is required to hold the weight of the light fixture and bracket aught to be completed. It is likely that cost could be reduced by using a pattern of welding as opposed to a constant striaght line as the weight of the fixture will not cause very high stresses.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: brushed alumium TOLERANCES: LINEAR: ANGULAR:		FINISH:				DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE				TITLE:	
DRAWN							Assembly - step 2	
CHK'D								
APPV'D								
MFG								
Q.A				MATERIAL: 6082 Aluminium for main components with 4043 as the filler between welds.			DWG NO.	A3
				WEIGHT:			SCALE:**1:10**	SHEET 1 OF 1



A butt weld is used to fix a 2x40x482 mm flat bar to the square bar. The weld must be on the underside to allow the polycarbonate panels to sit flush on the frame without impacting on the IP rating. This is only done on three sides, one side is left free for a door.

The tolerance for the width of a 40mm wide bar is ±0.4mm. The tolerance for the thickness of a 2mm thick bar is ±0.2mm.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: brushed alumium TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

Assembly - step 3

MATERIAL:
6082 Aluminium for main components with 4043 as the filler between welds.

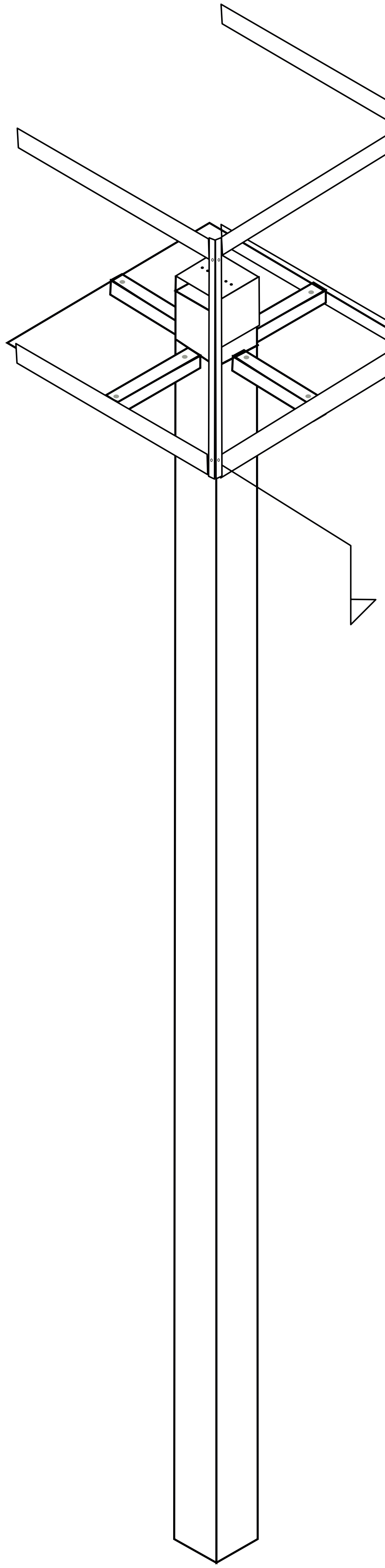
DWG NO.

A3

WEIGHT:

SCALE:**1:10**

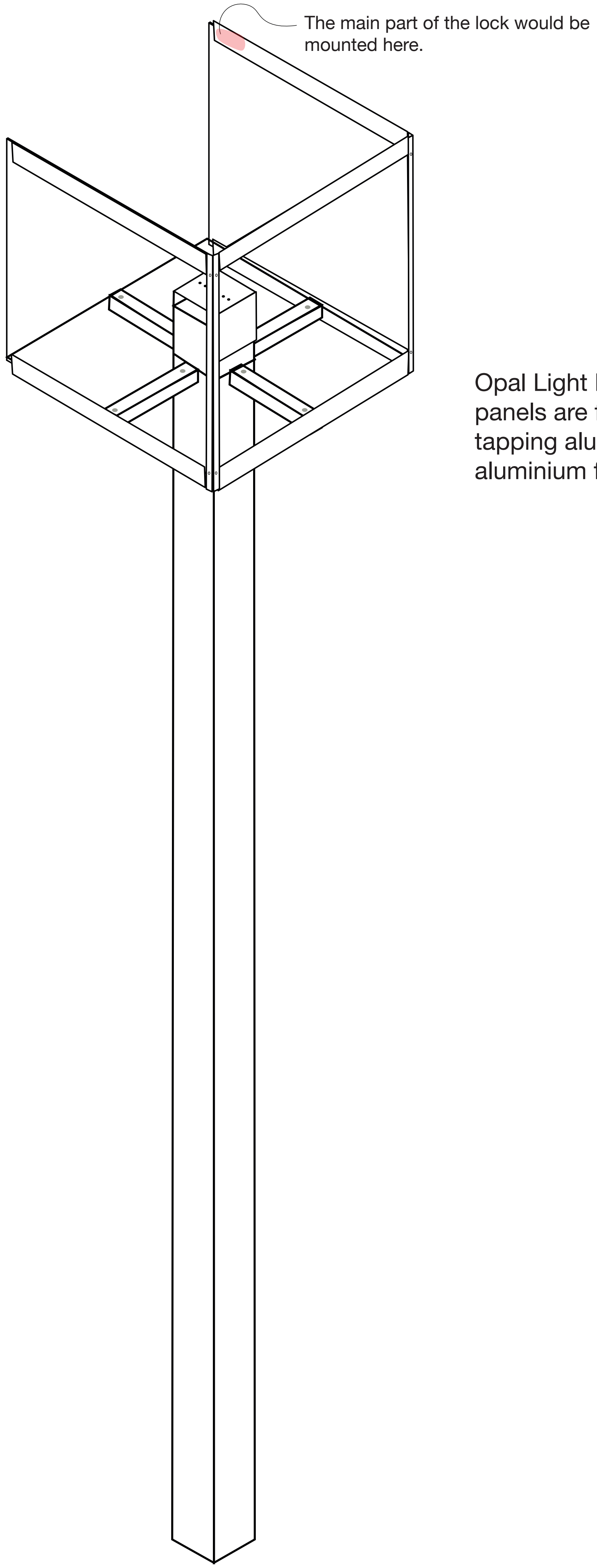
SHEET 1 OF 1



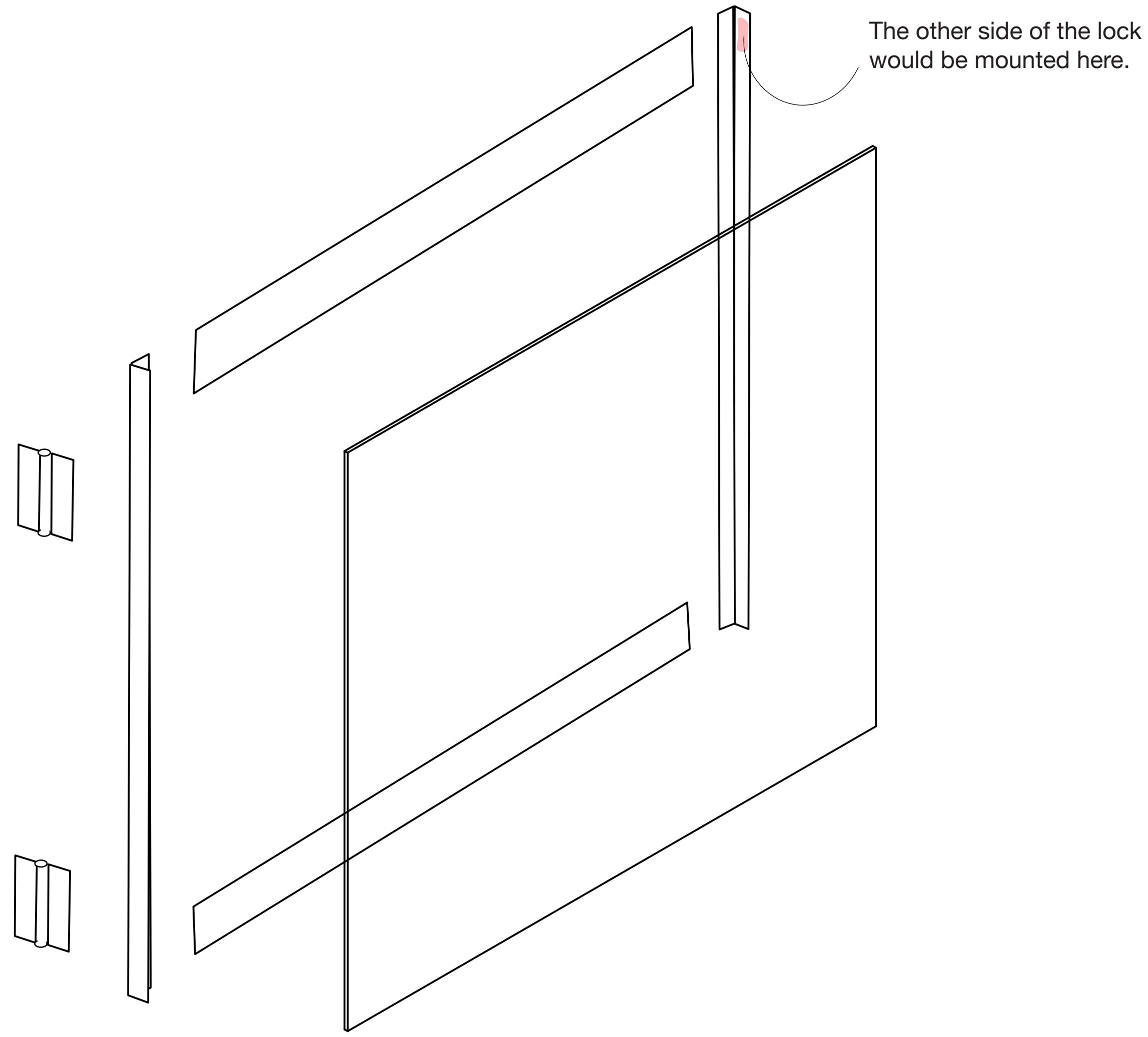
A verticle fillet weld holds the column with the equel angle section. The horizontal bar and the verticle column are 1mm different in thickness, for this reason I specified a fillet weld, other wise it would have been a butt weld. The angle and the bar line up to be flat on the inside to provide an even surfave for the polycarbonate.

Another set of 2x40x482mm bars are welded the same wat but at the top.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: brushed alumium TOLERANCES: LINEAR: ANGULAR:	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE		TITLE: Assembly - step 5	
DRAWN						
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL: 6082 Aluminium for main components with 4043 as the filler between welds.	DWG NO.	A3
				WEIGHT:	SCALE:**1:10**	SHEET 1 OF 1

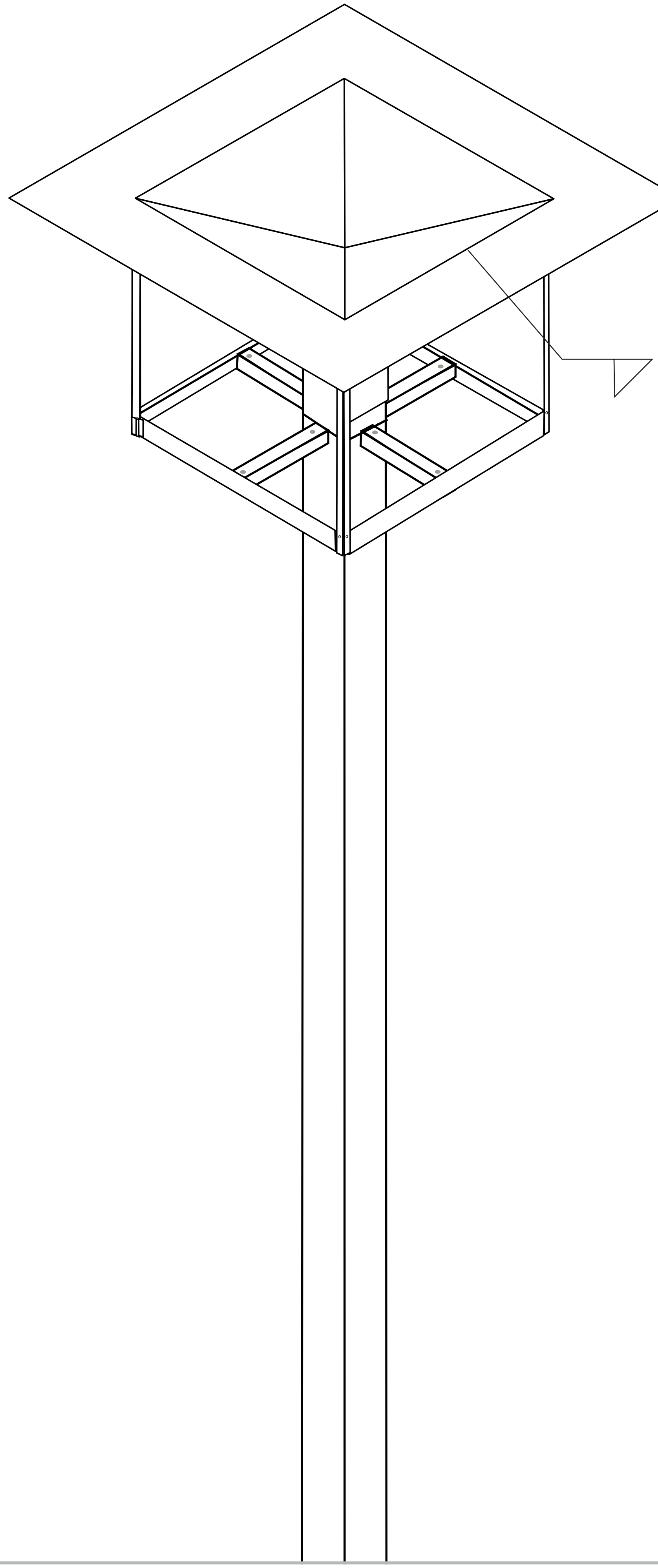


Opal Light Diffusing Polycarobonate panels are fixed into place using self tapping aluminium screws on the aluminium frame.



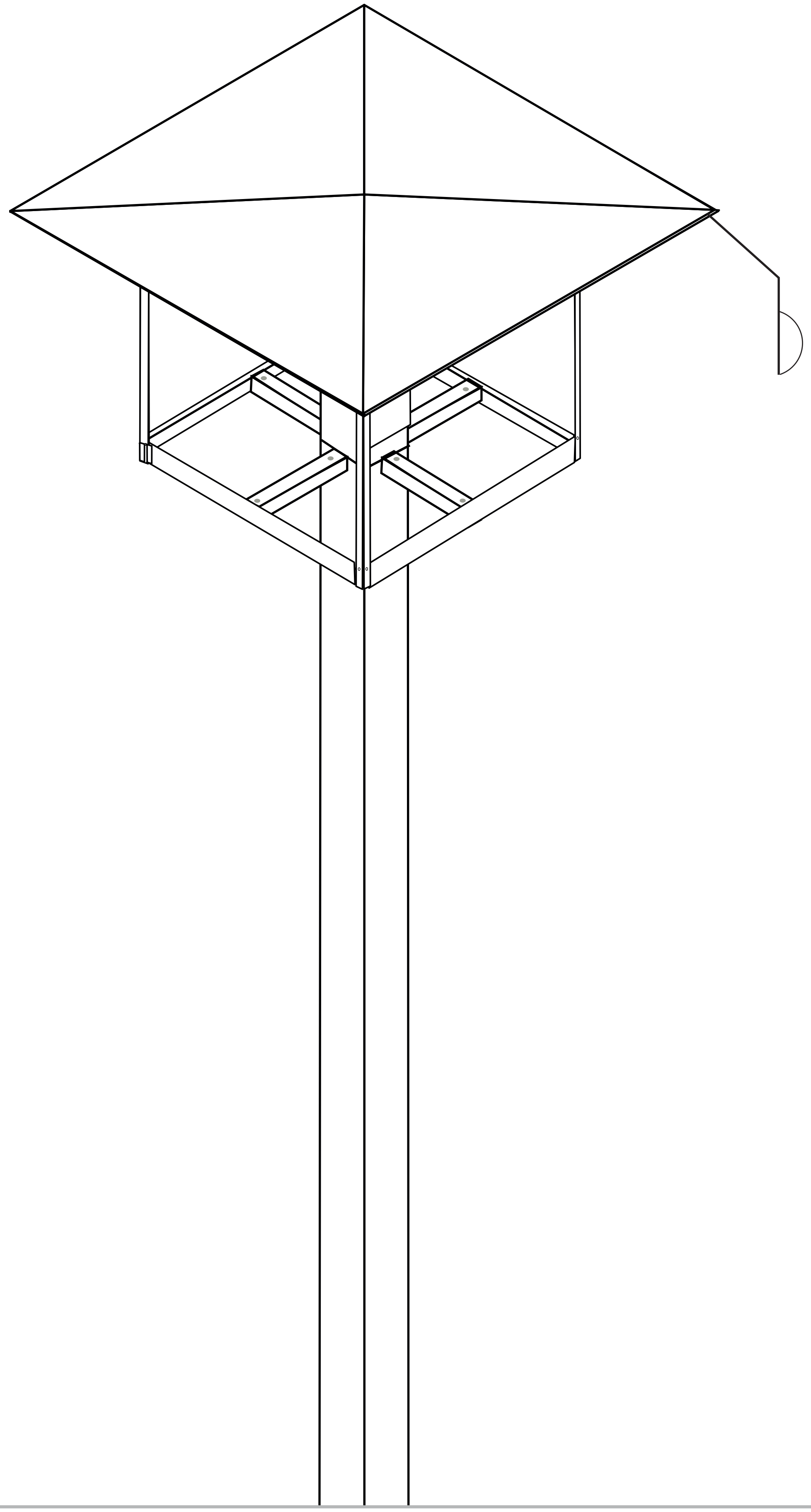
The door would be welded together the same way that the rest of the frame was. It is important that the hinge and lock are also made from aluminium to avoid galvanic corrosion, if this is not possible stainless steel has limited compatibility with aluminium so could be used. If the lock was made from an unsuitable material galvanic corrosion could be prevented through the use of a layer of electrical insulation where ever the two materials met.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: brushed alumium TOLERANCES: LINEAR: ANGULAR:	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION	
	NAME	SIGNATURE	DATE		TITLE:	
DRAWN					Assembly - step 6	
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL: 6082 Aluminium for main components with 4043 as the filler between welds.	DWG NO.	A3
				WEIGHT:	SCALE:**1:10**	SHEET 1 OF 1



The door would be fixed onto the rest of the frame via the hinges. A fillet weld would hold the reflector onto the frame although it could not be welded on the side of the door.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: brushed alumium TOLERANCES: LINEAR: ANGULAR:			FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE				TITLE:	
DRAWN							Assembly - step 7	
CHK'D								
APPV'D								
MFG								
Q.A				MATERIAL: 6082 Aluminium for main components with 4043 as the filler between welds.			DWG NO.	A3
				WEIGHT:			SCALE:**1:10**	SHEET 1 OF 1

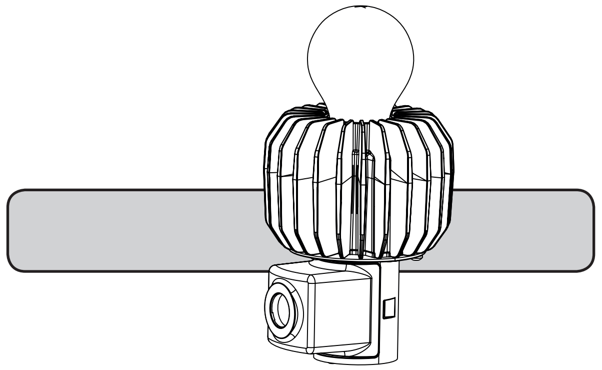


A butt weld secures the roof to the reflector.

Once this is done a 0.75m hole can be dug, 0.25m should be filled up with gravel which ensures proper drainage. Half a meter of the pole is placed under the ground in the hole and then set in concrete, see the mechanical analysis for reasoning.

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: brushed alumium TOLERANCES: LINEAR: ANGULAR:	FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE	TITLE:	
DRAWN				Assembly - step 8	
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: 6082 Aluminium for main components with 4043 as the filler between welds.	DWG NO.	A3
			WEIGHT:	SCALE:**1:10**	SHEET 1 OF 1

INSTALLATION INSTRUCTIONS
INSTRUCTIONS D'INSTALLATION



IMPORTANT SAFEGUARDS

When using electrical equipment, basic safety precautions should always be followed including the following:

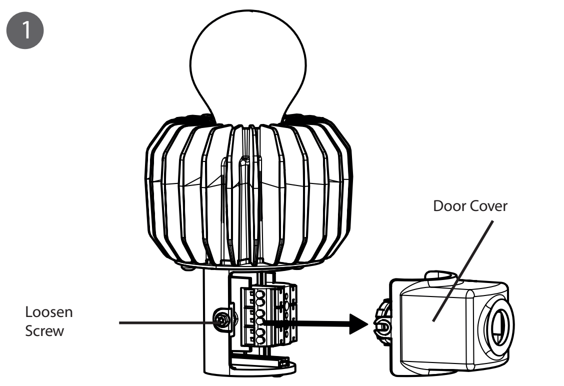
READ AND FOLLOW ALL SAFETY INSTRUCTIONS

1. **DANGER**- Risk of shock- Disconnect power before installation.
   DANGER *– Risque de choc – Couper l'alimentation avant l'installation.*
2. This luminaire must be installed in accordance with the NEC or your local electrical code. If you are not familiar with these codes and requirements, consult a qualified electrician.
   Ce produit doit être installé conformément à NEC ou votre code électrique local. Si vous n'êtes pas familier avec ces codes et ces exigences, veuillez contacter un électricien qualifié.

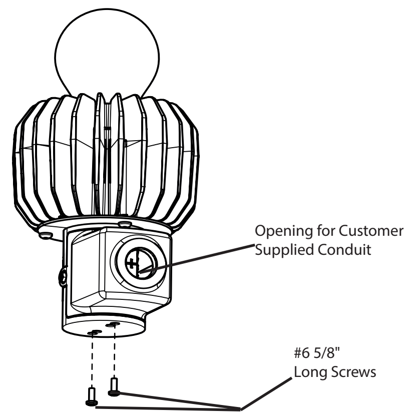
SAVE THESE INSTRUCTIONS FOR FUTURE REFERENCE

TO INSTALL:

1



2



STEP 1:
Remove door cover shown in Figure 1 by loosening screw located on the side, and gently pulling cover off. See Figure 1.

STEP 2:
Attach DPT luminaire to mounting base by inserting (2) supplied #6 5/8" long screws into customer supplied bracket and screwing into the base of DPT luminaire. See Figure 2.

STEP 3:
Feed power supply wires using customer supplied flexible conduit through opening in door cover. See Figure 2.

STEP 4:
Make wiring connections per Electrical Connection section on the back page.

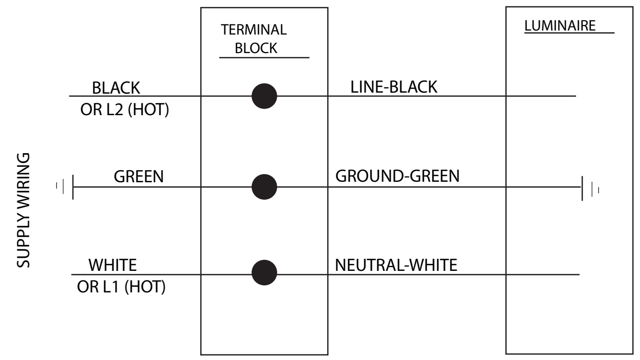
STEP 5:
Reattach door cover that was removed in Step 1 by tightening screw.

ELECTRICAL CONNECTIONS

STEP 1:
Make the following electrical connections to the terminal block:

For 120/277V applications make the following Electrical Connections to the terminal block:
 a. Connect the black lead to the voltage supply lead
 b. Connect the white lead to the neutral supply lead
 c. Connect the green or green/yellow ground lead to the supply ground lead

For 208/240 applications, make the following Electrical Connections to the terminal block:
 a. Connect L2 (Hot) supply lead to the black lead.
 b. Connect L1 (Hot) supply lead to the white lead
 c. Connect the green or green/yellow ground lead to the supply ground lead



CREE
www.cree.com/lighting

What the new lights will do for the park:

- This new luminary system improves accessibility, reduces maintenance work (and makes the maintenance work easier), improves the overall functionality of the park while keeping the much loved original identity envisioned by Dieter Magnus.

- Elevating the light from the ground reduces the likely-hood of them being the subject of vandalism. The materials are also far more robust than the previous design.

- It is designed to hold three times: it’s own weight with four people hanging off it and loading from wind.

- The plastic diffuses the light providing a soft glow while the reflector ensures the lamp illuminates the area required avoiding unnecessary light pollution.