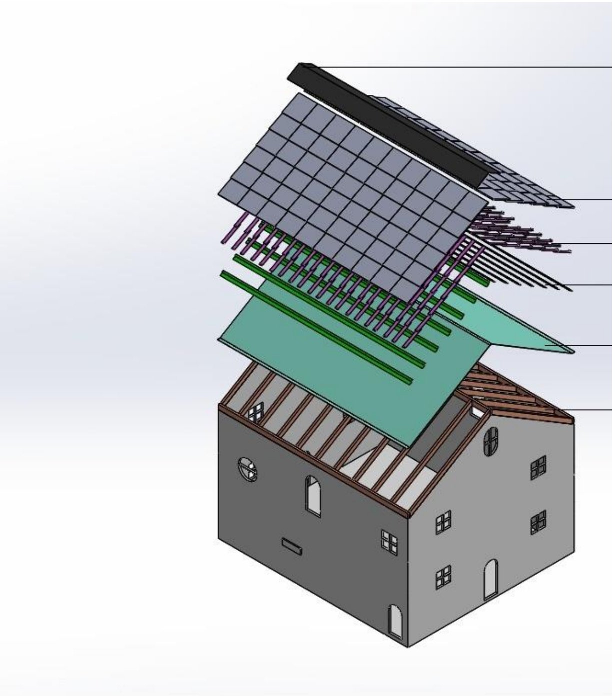

OPTIMAL STRUCTURAL DESIGN AND PROTOTYPING OF CONNECTORS TO SUPPORT ROOF MOUNTED SOLAR TILES

BY

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NIVED RAJAN
TONY PAULY
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1 INTRODUCTION

A design of well-engineered solar roof tiles mounting system is presented here by eliminating the drawbacks associated with the existing solar roof. In the comprehensive literature review, we have identified gaps in research in the area of solar roof mounting units, conflicts in previous studies, and open questions left from another investigation. The innovative design presented here is easy to install and can accommodate a range of solar tiles manufactured by leading manufacturers. The design presented here also solves the roof leaking issues, tilting of the tiles, and corrosion of mounting units by design optimization and surface protection methods. The final report for this project will hold engineering calculations, drawings, simulation results, and prototypes test results and future recommendations.

2 PROJECT BACKGROUND

Solar roof replaces the existing roof with aesthetically pleasing solar tiles that can power our homes for decades; however, solar tile technology itself is very complicated technology and often besieged with problems. Based on our findings, there are three main problems with the roof solar tile designs.

- × Damage due to uplift from the wind.
- × Corrosion of the solar roof tiles mounting units.
- × Leaking issues of the rooftop due to poor installation.

There are four leading causes of the above-addressed problems. The first and foremost issue is the structural collapse, which happens when the mounting unit fails to withstand the force of wind and gravity effectively and thus causes uplift from the wind.

On to the second issue, the corrosion occurs because, in solar panel assembly, both anode and cathode contain metals, in most of the case rainwater, acts as the electrolyte and eventually leads to corrosion, also we noticed that photovoltaic hardware currently used to construct and install solar tiles are less noble metals.

The final problem is roof leaking; this happens because the mounting clamps currently available in the market are required to bolt it down on the roof; therefore, they don’t compromise the waterproofing capability of the roof and consequently cause leakages and void the roof warranty. The gap between the adjacent tiles is another leading cause of roof leakage

3 PRELIMINARY DESIGN BACKGROUND

This section briefly explains our design objectives, specifications, assumptions, and contains in design point of view.

3.1 Design Objectives

- ✓ Designing a solution to maximize roof strength and minimize installation time
- ✓ Designing a solution for water leakage issues by introducing Primary water proofing unit
- ✓ Designing solar tiles supporting bars
- ✓ Designing locking mechanism and spacers to accommodate solar tiles

3.2 Design specifications

Table 1 shows the Design Specifications

S/N	Descriptions	Demand	Requirement	Assessment method
01	Aesthetics of the assembly	High	Visually pleasing Stainless brushed stainless-steel finish	Visual analysis
02	Cost of the clamping unit	Moderate	Cost of product should be less than $200/meter	Cost analysis
03	Functionality	High	Eliminate roof leakages, corrosion issues and able to take wind load of 80mph	Prototype testing
04	New Zealand Regulations	High	Comply with the safety standard of the district.	Approval from Building consent authority of New Zealand

3.3 Design Assumptions

- ❖ The roof-mounted solar tiles could vary considerably in terms of their overall dimension; however, the majority of the solar tiles available in the market are square-shaped (200 x 200 x 10mm), so our preliminary design is based on this assumption.

- ❖ Assumed that 30mm clearance is sufficient to accommodate all the electrical wirings
- ❖ Material properties are assumed based on the ASTM standard.

3.4 Design Constraints

- × Accurate dimensions of the existing solar tiles are hard to obtain from the manufacturers.
- × Difficult to come up with a promising low-cost solution that meets the needs.
- × The design should not compromise with the roof strength as there are safety concerns.
- × Integration is another design constraint. The clamping unit should be able to accommodate all types of solar tiles

4 PRELIMINARY DESIGN METHADOLODY

This section covers the methodological approach of the preliminary design.

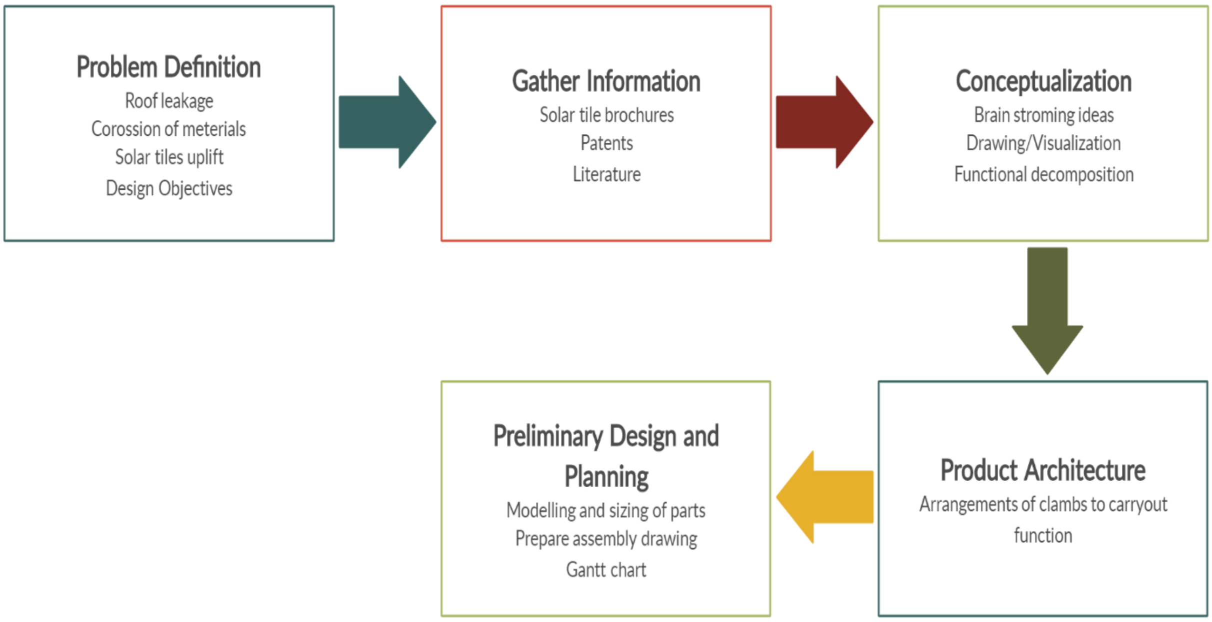


Figure 1 shows Flow chart of the methodological approach

We highlighted the current issues of the roof-mounted solar roof tiles. Our objective is to design an ideal clamping unit that eliminates the problems addressed in the problem statement. We gathered all the information about the problems. Here we reviewed journals and referred solar tile brochures to get the updated information. In the conceptualization stage step, we did brainstorm ideas and come up with a design solution and prepared the hand sketches (Attached in the appendix). In the next stage, we created a product architecture. The functional elements and physical components are defined here.

The final step in the design process is Preliminary design and Planning; We used Solidworks 3D modelling software. We also updated the Gantt chart to track the project progress and made a fabrication plan.

4.1 Design of the roof mounted solar tiles clamping unit

The preliminary design is made by using SOLIDWORKS 3D CAD solutions. An easy-to-learn, yet remarkably powerful functionality that cuts product development time reduces costs and improves the product quality. Integrated CFD AND FEA analysis in Solidworks help us to perform analysis on the same platform.

We designed an ideal solution for the roof leakage issues, corrosion of mounting units and solar tile uplift due to heavy wind. The clamping units consist of the following.

1. Roof cover
2. Solar tiles
3. Battens
4. Link Channels
5. Water proofing Tile support panel

The exploded view of the assembly drawing with the bill of materials is given below.

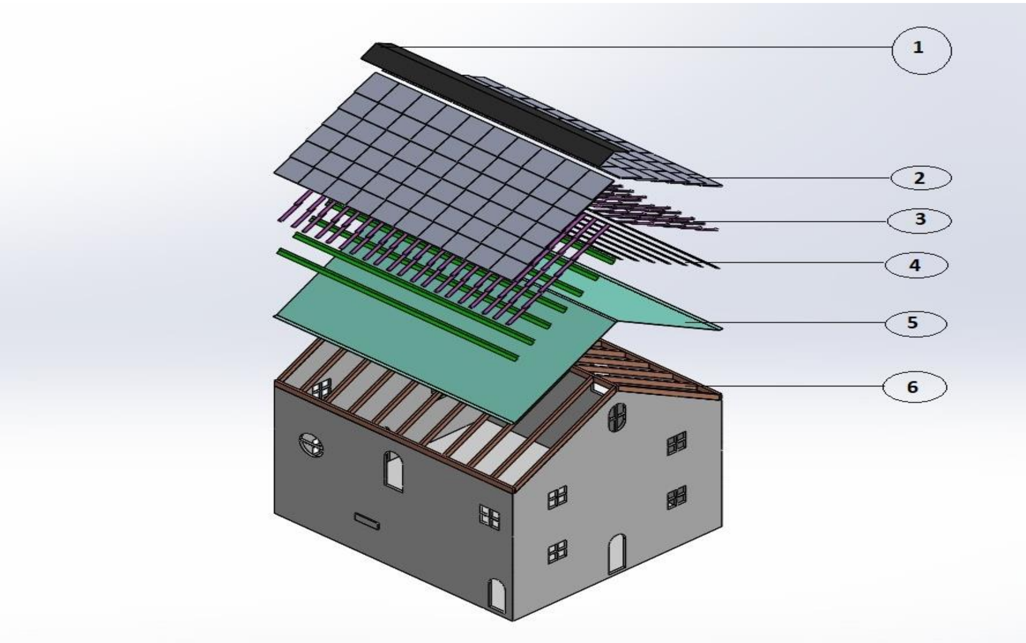


Figure 2 shows the exploded view

Table 2 shows the Bill of Materials

BILL OF MATERIALS (BOM)			
Item #	**Description**	**Material**	**Overall dimensions in mm**
1	Roof cover	Stainless steel grade 316L	
2	Solar tiles	N/A	200 X 200 X 12
3	Link channels	Stainless steel grade 316L	200 x 30 x 4
4	Battens	Stainless steel grade 316L	2000 x
5	Water proofing sheet	High Density Polyethylene (HDPE)	As per the roof size
6	3D model of the House	N/A	

4.1.1 Roof Cover

Function of the roof cover:

The function of the roof cover is to prevent water from entering or flowing into houses due to any mismatch between the solar tile joints adjacent to each other. It also regulates moisture flow in the walls.

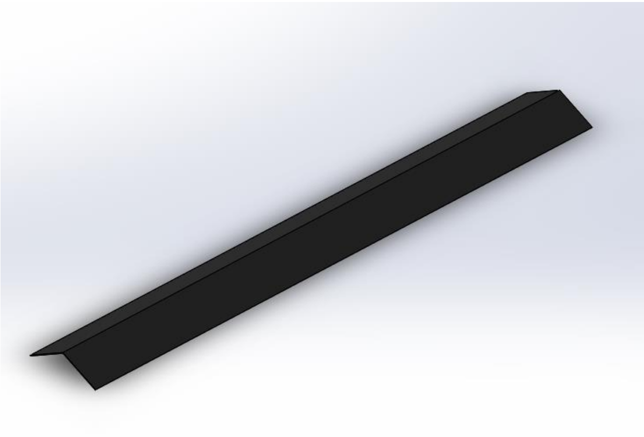


Figure 3 shows the roof cover

Installation Procedure.

The roof cover is securely screwed down with battens and adjacent link channels. The design avoids uplift from the wind and roof. Leakages.

4.1.2 Solar tiles

We selected a 200 x 200 x 10mm rooftop solar tile as it is prevalent among the manufacturers.

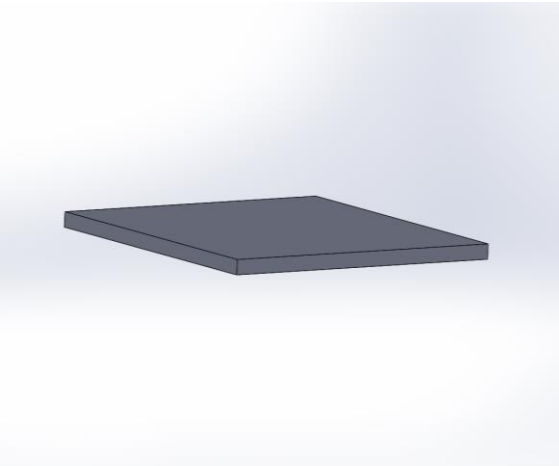


Figure 4 shows the 3D model of the selected solar tiles

4.1.3 Link channel

Function of the Link Channels:

Link channels with a secured locking mechanism is used to space the batten to accommodate solar tiles. As shown in the below 3D model. Link channels can be locked into the lower batten.

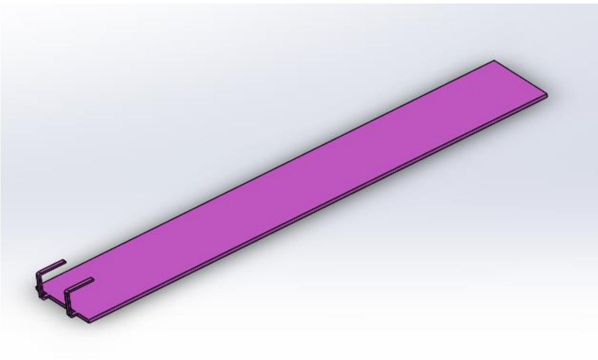


Figure 5 shows the Link channel

Each link channel is also essential in waterproofing the roof. Should a storm hit, the excess rainwater flows into the link channel then out on to the tile below, keeping the roof waterproof and free from debris. The gap between solar inserts and tile support panels underneath ensures valuable airflow inside the roof cavity, which in turn maximizes solar energy output.

Installation procedure:

The link channel is securely bolted down with the battens to accommodate solar tiles. The advantage of this design is that link channels can accommodate solar tiles of different sizes. Maintain the spacing as per the width of the solar tiles.

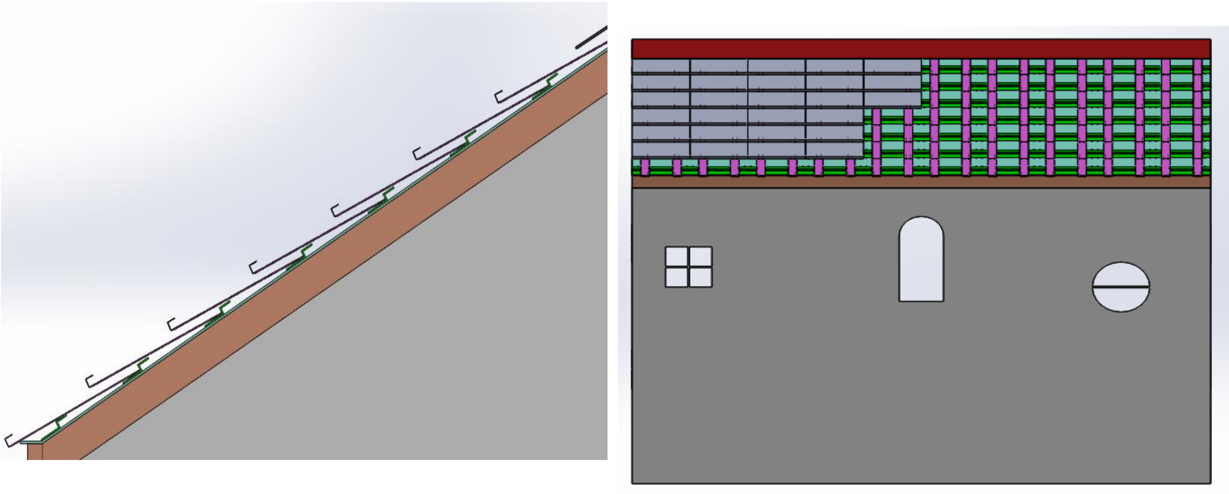
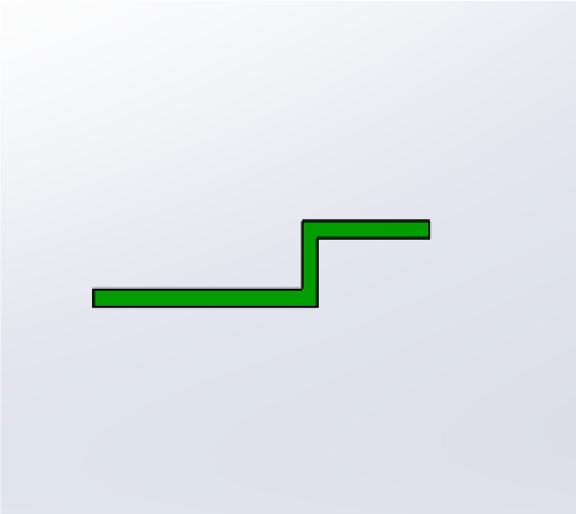


Figure 6 shows the installation procedure

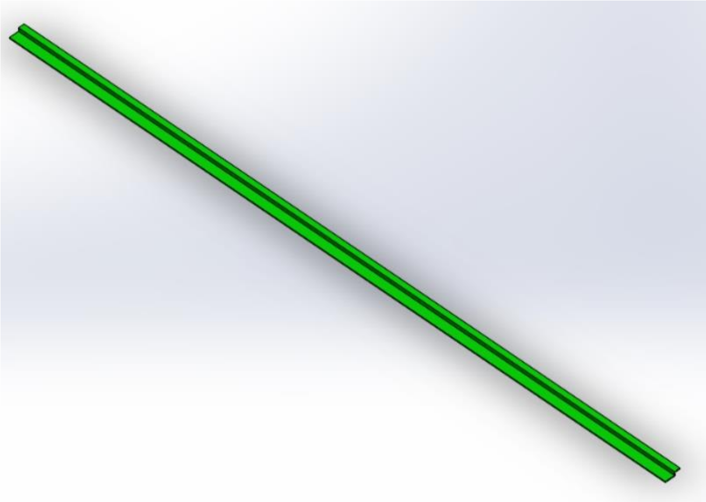
4.1.4 Battens

Function of the Battens

The function of battens is to secure the link channels and tiles onto the roof. The innovative design of the batten allows the roof pitch to go as low as 5 degrees, Keeping the roof waterproof and clear from debris.



Right side view of the Batten



Isometric view of the Batten

Figure 7 shows the Battens

Installation procedure

The process begins by installing the first batten into its correct position using specially designed fixing screws, followed by more rows of battens from side to side up to the ridge at the top of the roofline. The installation process is depicted in the below 3D model.

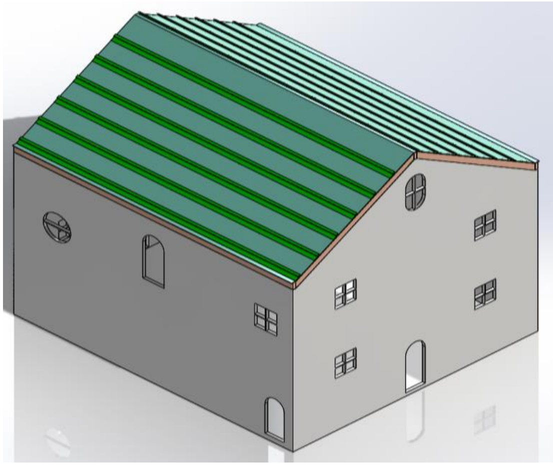


Figure 8 shows the Installation procedure of Battens

The length of the solar tiles determines the space between the battens. In this design, the length of the solar tiles is 200mm, so maintained 200mm spacing between the battens.

4.1.5 Water proofing sheets

Function of the Water proofing sheet:

A waterproofing sheet laid above the rooftop, as depicted in the image, does not allow water to seep through and eliminates the roof leakage issues due to the installation of the solar tiles.

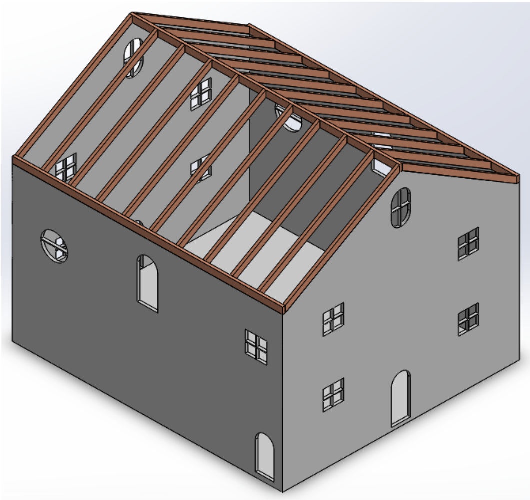
Figure 9 shows the 3D model of the waterproofing sheet

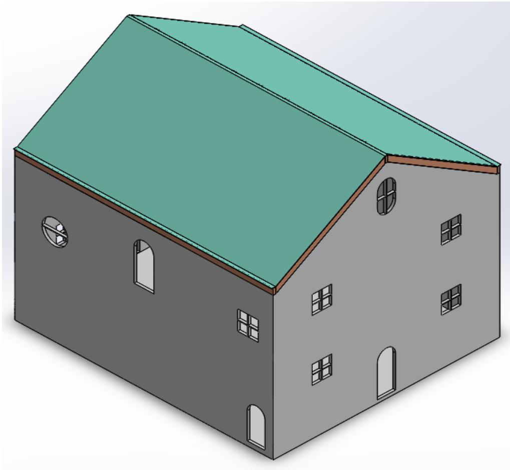
Installation procedure:

The waterproofing membrane design allows safe and quick installation and also grant maximum architectural freedom. The simple two step installation process is outlined below.

1. Prepare the roof for waterproofing membrane. Timber surface should be free from grease, oil, dust, and other contaminants
2. Roll out the waterproof membrane with an overlap of 100mm and cut to length and fix the membrane onto the timber using fasteners.

The above steps are depicted in below 3D model.





Step 1: Prepare the roof for waterproofing sheet

Step 2: Install the waterproofing sheet

Figure 10 shows the installation steps with the help of 3D models

4.2 Assigned materials for parts

Link channels, battens, and roof cover:

The material assigned for link channels, battens, is Stainless steel 316 or 304 (SS316/SS304). The SS316 has better properties and corrosion resistance than SS304; however, SS316 is much expensive than SS304. So, according to the budget of the customer, they can either go for SS304 or SS316.

Waterproof Tile support panel:

Material assigned for waterproof tile support panel is High-Density Polyethylene (HDPE). HDPE is very environmentally friendly, non-toxic, low cost, excellent anti-aging performance, and high chemical stability, HDPE is a blend of about 97.5% polyethylene, 2.5% carbon black, a trace amount of antioxidant and heat stabilizer.

4.3 Fabrication process

To construct a functional prototype of the design, we must fabricate the battens, link channels, and roof cover. Solar tiles, mounting screws, and waterproofing sheets can be purchased locally.

Materials and Equipment required:

- SS316L/SS304 stainless steel sheets (Thickness 3mm).
- Laser cutting machine.
- Tig welding Machine.
- SS316/SS304 welding rods
- Bending Machine

To calculate the bending Allowance, we have the below equation.

$$BA=(A*(\pi/180))*(R+(K*T))$$

BA = Bending Allowance for sheet metal

A = Bending angle in degrees

K= Constant

T= Material thickness in meters

4.4 Fabrication of link channels, Battens and Roof cover

Based on the 2D shopfloor drawing stainless steel sheets can be cut to the dimensions using a laser cutting machine. Deburr all the sharp corners and bend using a bending machine. Clamping hooks is then welded to link channels (stainless steel TIG welding using SS316 welding rod)

6 PRELIMINARY DESIGN DRAWINGS

Detailed 2D shop drawings are made with specifications

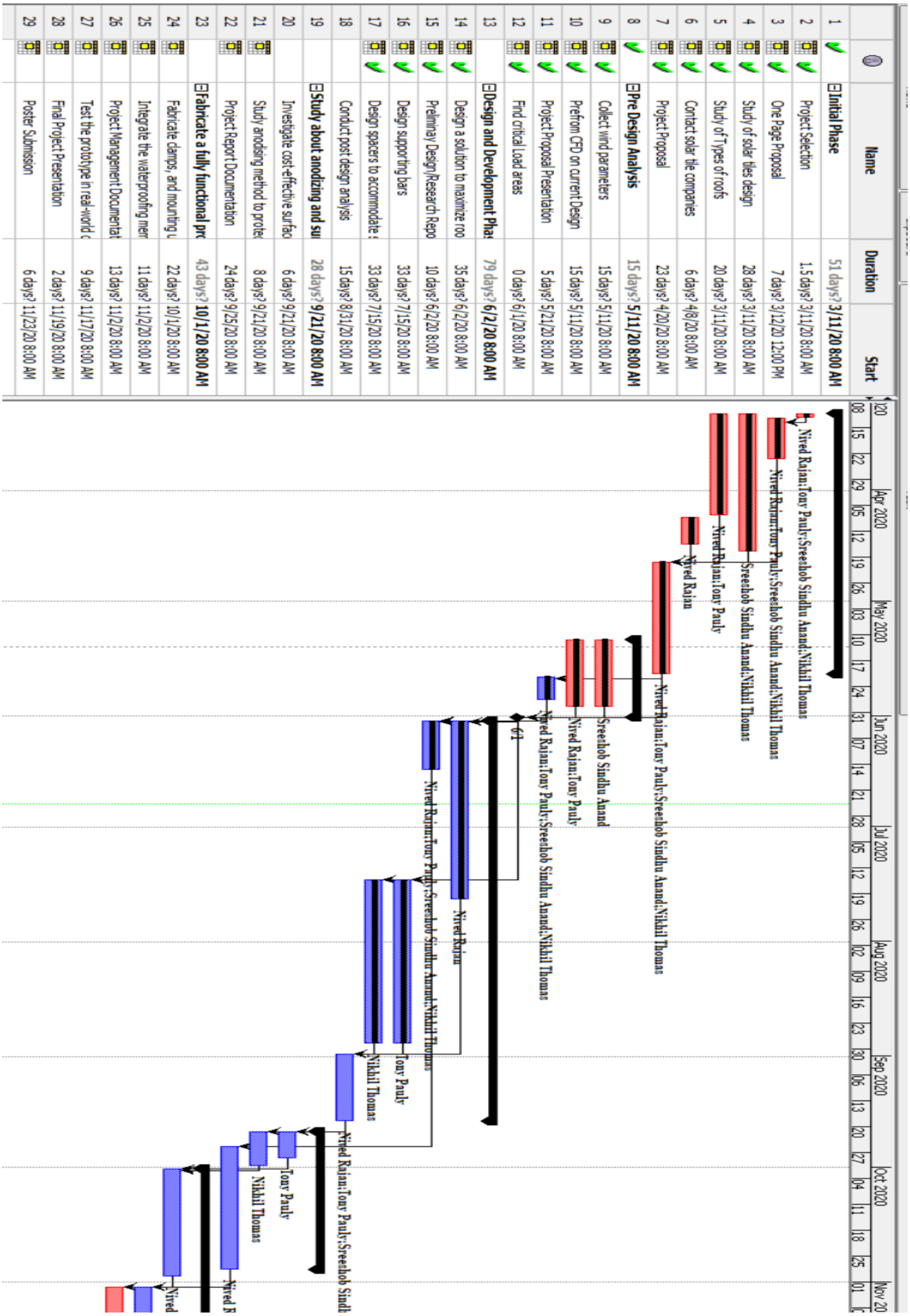
Please refer to last pages of the report

7 GLOSSARY AND LIST OF ABREVIATIONS

Table 3 shows the list of Abbreviations

S/N	**Abbreviations**	**Explanation**
01	HDPE	High-Density Polyethylene
02	CAD	Computer Aided Designing
03	3D model	Mathematical representation of a model in 3 dimensions
04	mph	Meter per hour
05	CFD	Computational fluid dynamics
06	FEA	Finite Element Analysis
07	BOM	Bill of Materials

8 GANTT CHART



9 REFERENCES

1. *Black Hdpe Polyethylene Material Roof Garden Geomembrane Liner Sheet for Waterproofing*. www.alibaba.com. (2020). Retrieved 20 June 2020, from https://www.alibaba.com/product-detail/Black-hdpe-polyethylene-material rogarden_60792808482.html?spm=a2700.galleryofferlist.0.0.5b2356f2LWmgrO&s=p.

2. Dheev, N. *Concept Generation*. Engr.uvic.ca. Retrieved 24 June 2020, from https://www.engr.uvic.ca/~mech350/Lectures/MECH350-Lecture-4.pdf.

3. *Properties of Type 316 and 316L Stainless Steels*. ThoughtCo. Retrieved 15 June 2020, from https://www.thoughtco.com/type-316-and-316l-stainless-steel-2340262#:~:text=Type%20316%20steel%20is%20an,increases%20strength%20at%20high%20temperatures.

10 APPENDIX

Hand sketches made during concept generation.

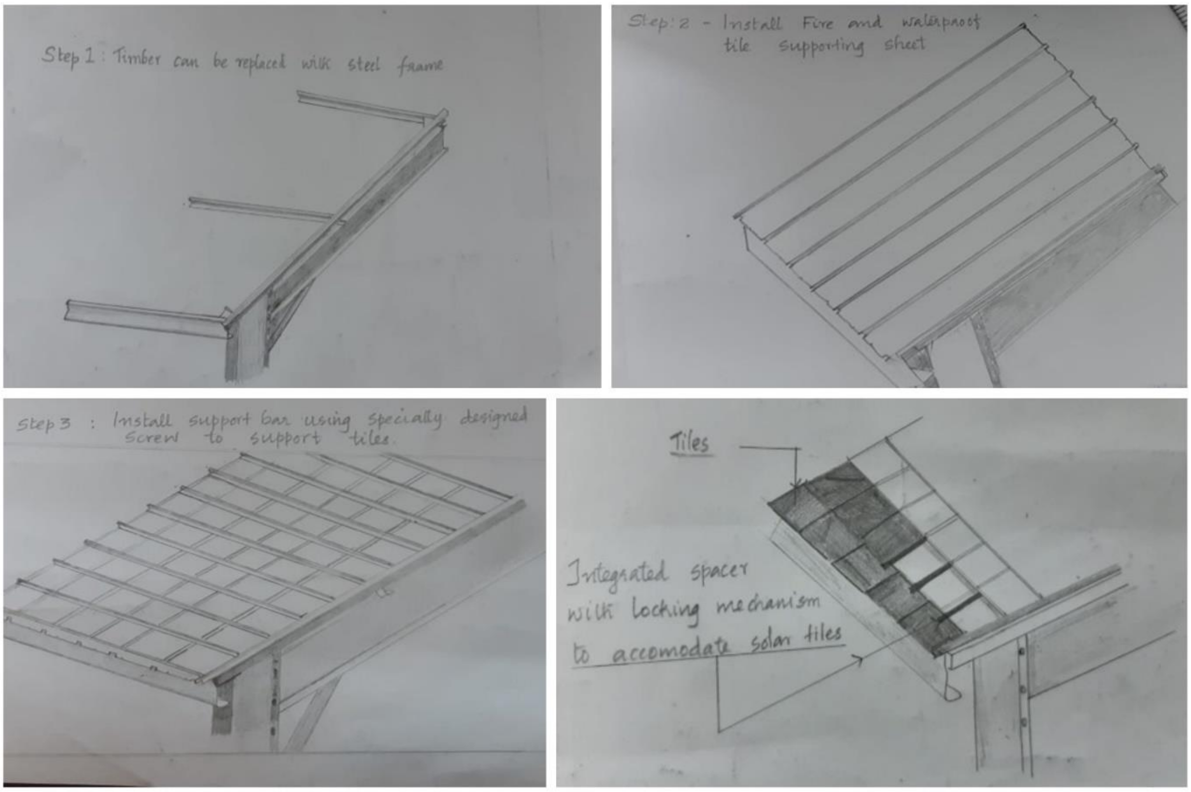
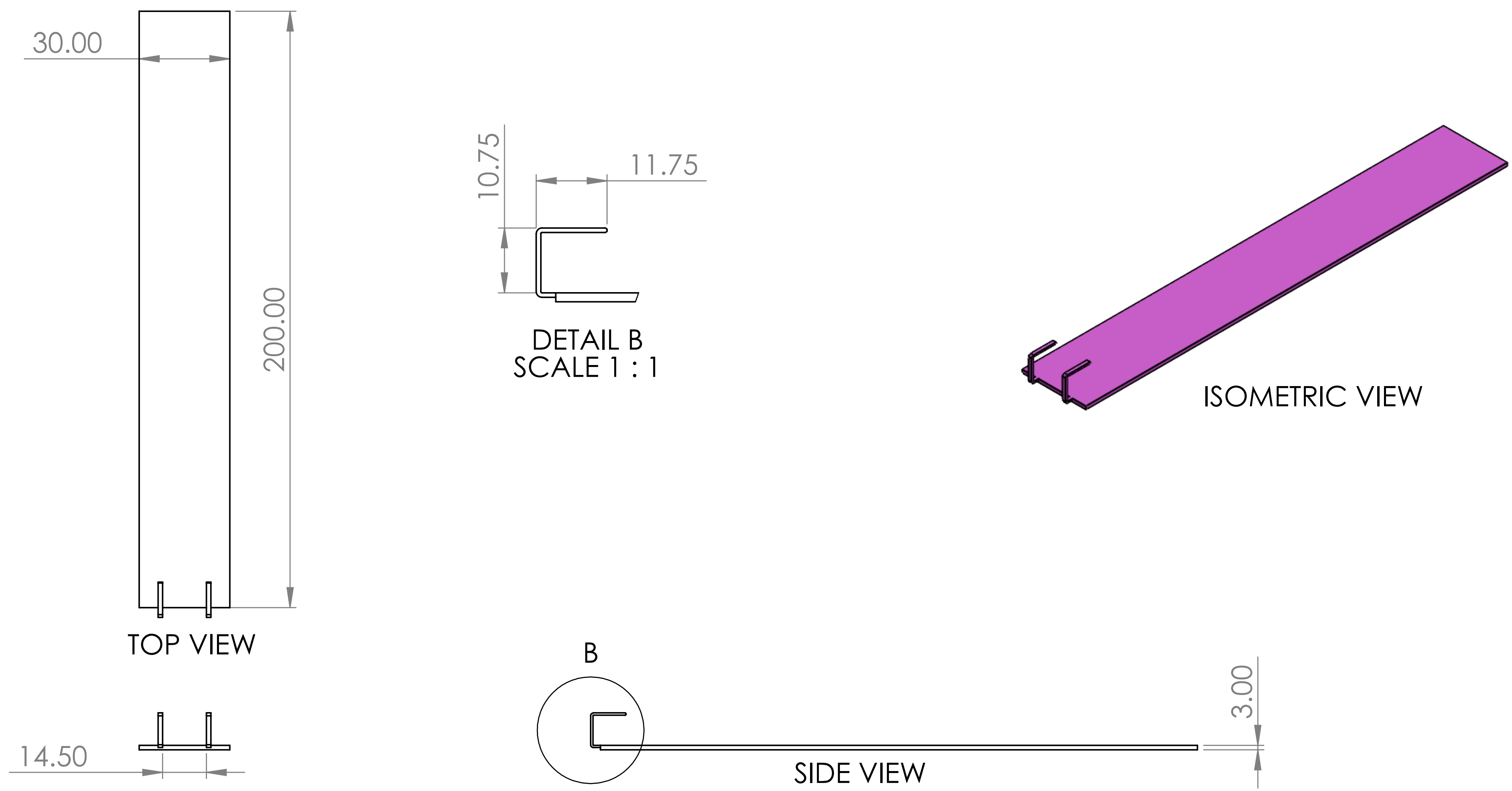


Figure 11 Shows the hand sketches of the concept design



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH: Stainless steel brushed Finish

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

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

PRELIMINARY DESIGN DRAWING

ROOF MOUNTED SOLAR CLAMPING UNIT

MATERIAL: SS316

DWG NO.

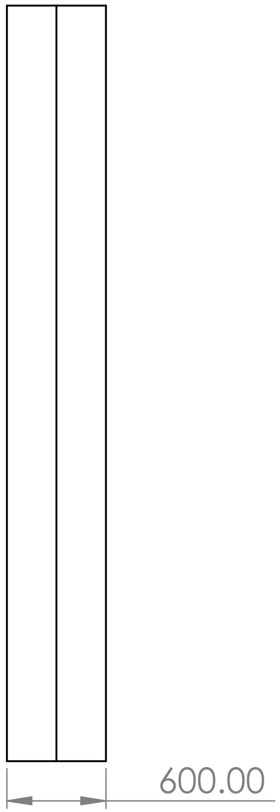
Link Channel

A4

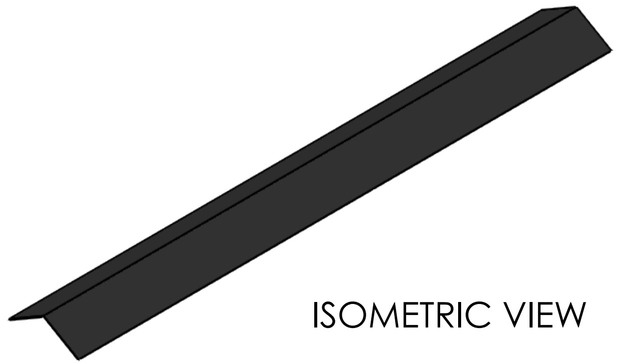
WEIGHT: 0.07kg

SCALE:1:2

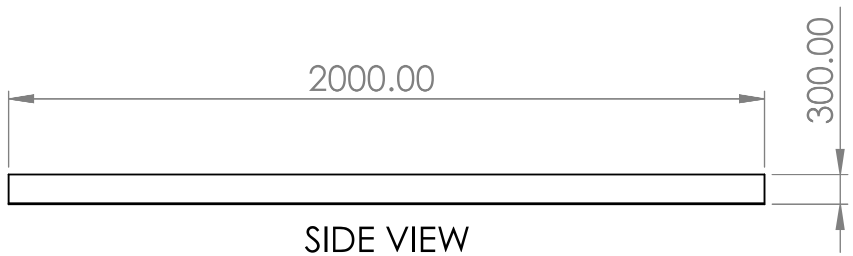
SHEET 1 OF 1



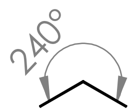
TOP VIEW



ISOMETRIC VIEW



SIDE VIEW



FONT VIEW

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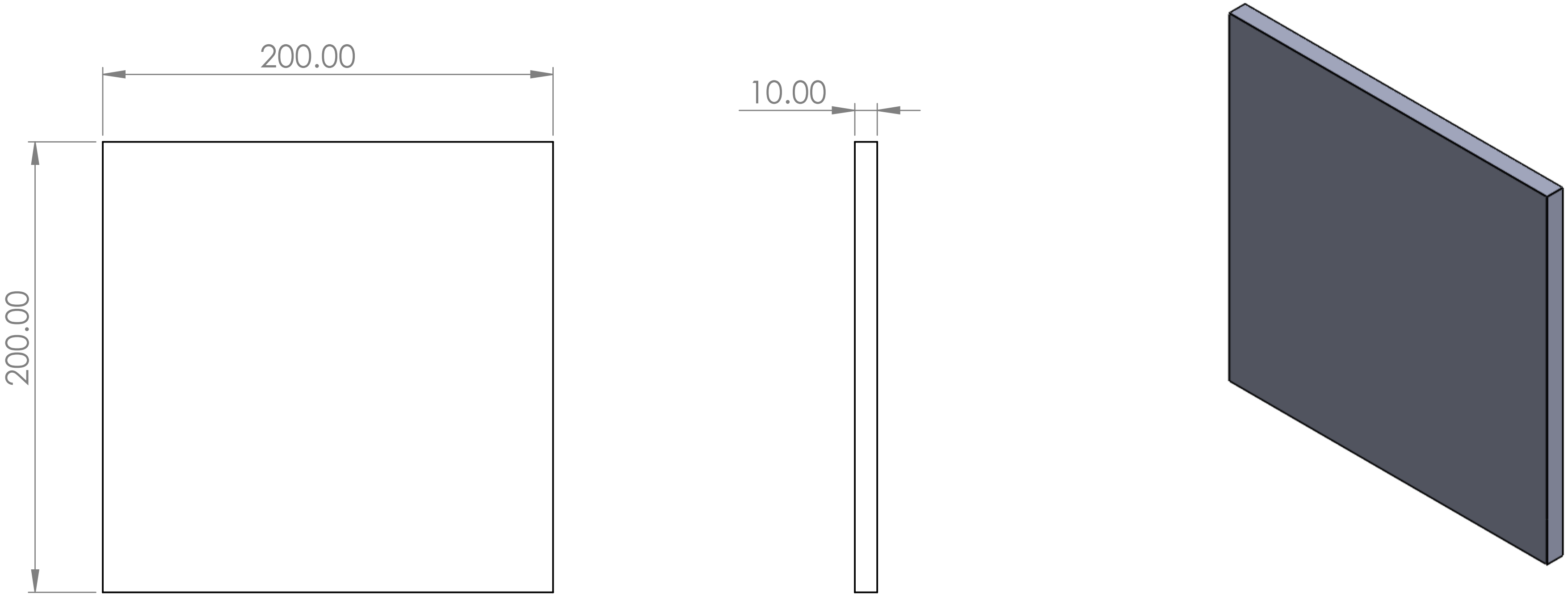
	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D	DR AL RAWI		
MFG			
Q.A			

TITLE: PRELIMINARY DESIGN
SOLAR ROOF MOUNTING UNIT

MATERIAL: SS316	DWG NO. Tile Cover	A4
WEIGHT: 4.8 kg	SCALE:1:20	SHEET 1 OF 1



FRONT VIEW

SIDE VIEW

ISOMETRIC VIEW

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

TITLE: PRELIMINARY REPORT

MATERIAL:

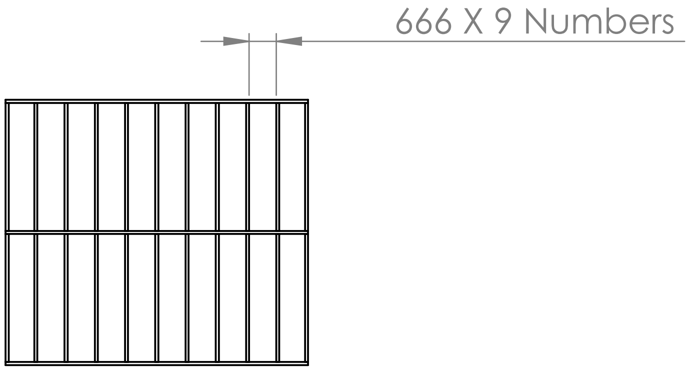
WEIGHT: 1.8 KG

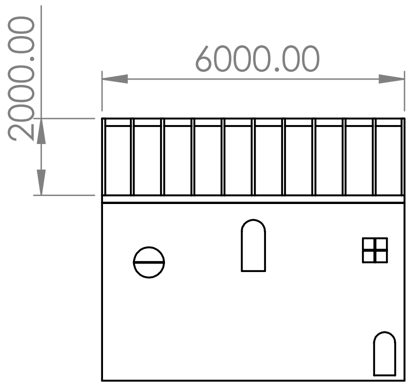
DWG NO. Tile

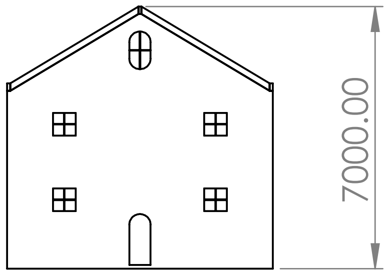
A4

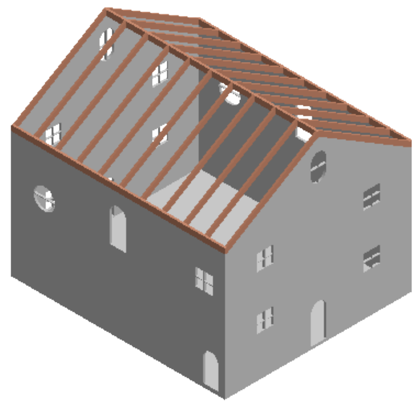
SCALE:1:2

SHEET 1 OF 1









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CHK'D						
APPV'D	DR AL RAWI					
MFG						
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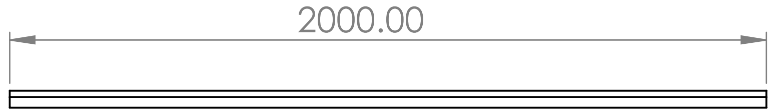
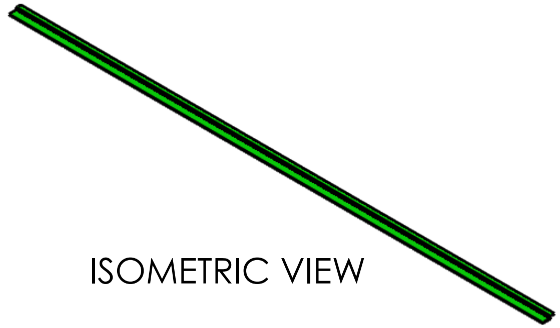
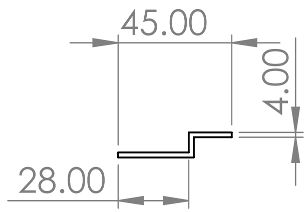


TOP VIEW



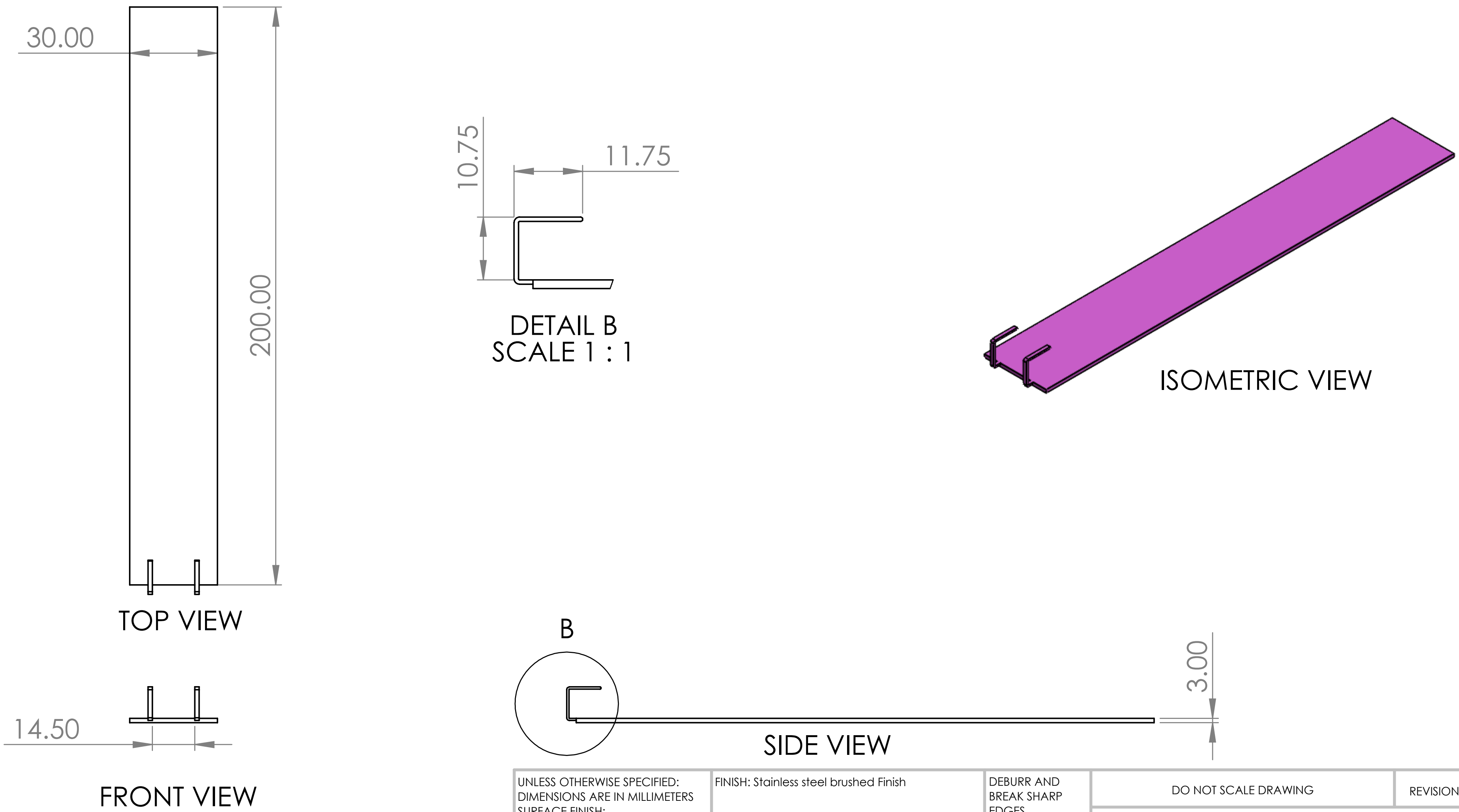
ISOMETRIC VIEW

FRONT VIEW



SIDE VIEW

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:			FINISH:	DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE		TITLE:	
DRAWN						
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL:	DWG NO. Link channel	A4
				WEIGHT:	SCALE:1:20	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH: Stainless steel brushed Finish

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

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

PRELIMINARY DESIGN DRAWING

ROOF MOUNTED SOLAR CLAMPING UNIT

MATERIAL: SS316

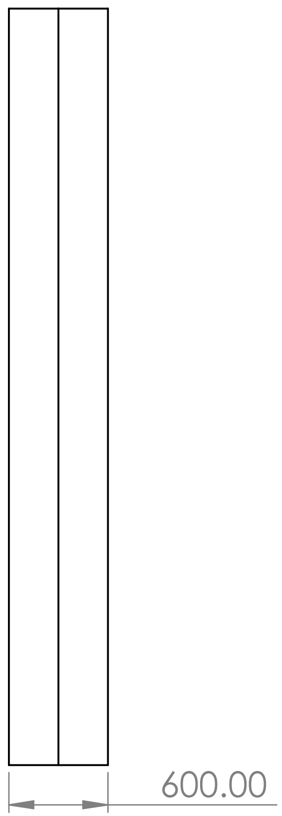
DWG NO. Link Channel

A4

WEIGHT: 0.07kg

SCALE:1:2

SHEET 1 OF 1



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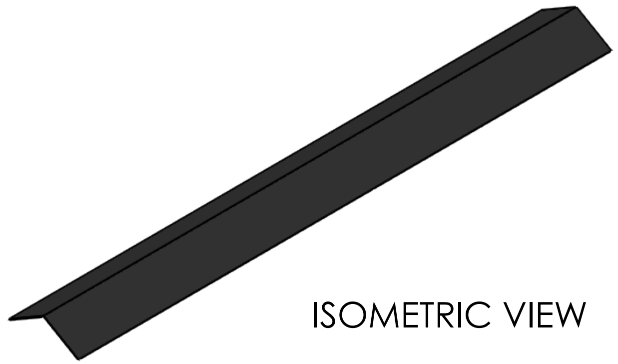

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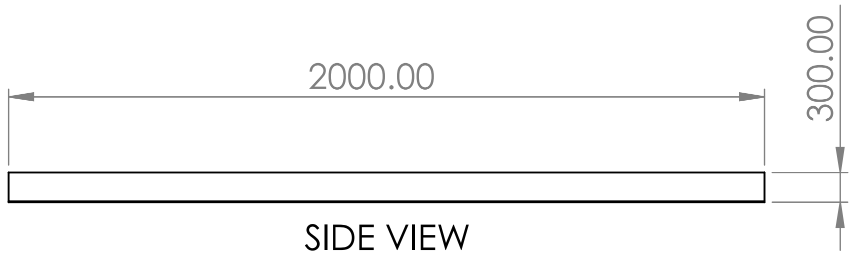
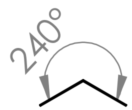


SIDE VIEW



FONT VIEW

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH: STAINLESS STEEL BRUSHED SHEET		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE		TITLE: PRELIMINARY DESIGN SOLAR ROOF MOUNTING UNIT	
DRAWN						
CHK'D						
APPV'D	DR AL RAWI					
MFG						
Q.A				MATERIAL: SS316	DWG NO. Tile Cover	A4
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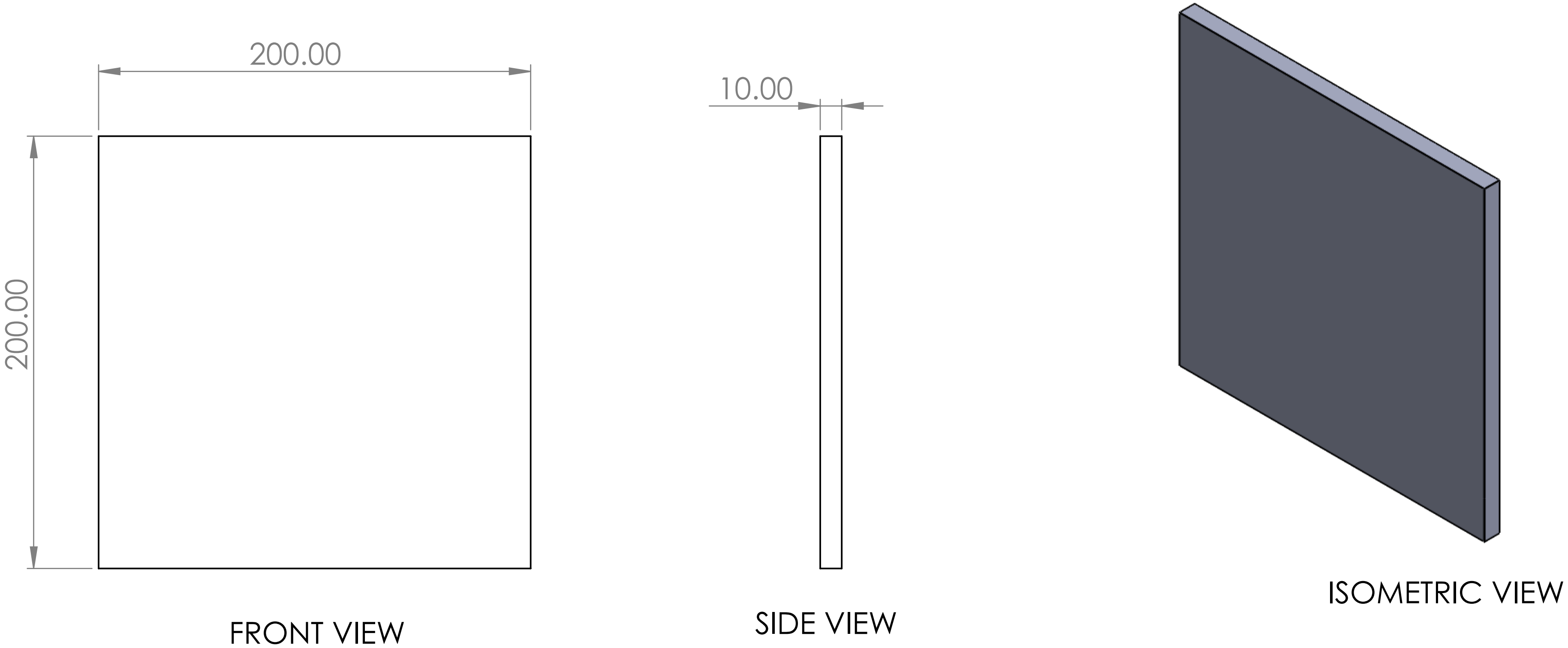

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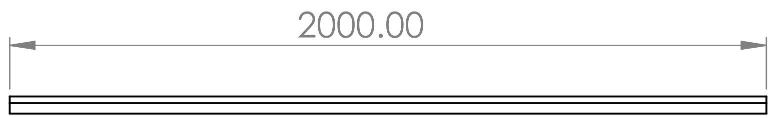
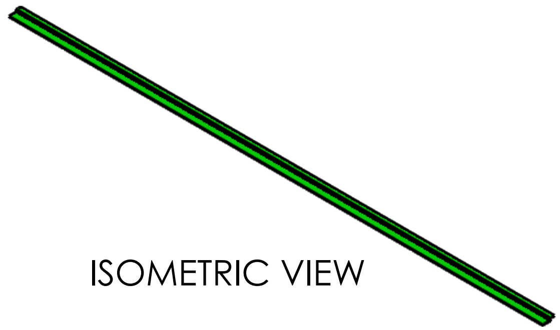
DRAWN					
CHK'D					
APPV'D	DR AL RAWI				
MFG					
Q.A			MATERIAL:	DWG NO. Tile	A4
			WEIGHT: 1.8 KG	SCALE:1:2	SHEET 1 OF 1

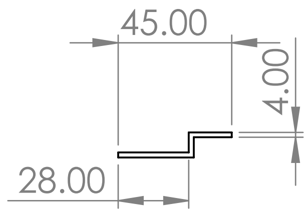


TOP VIEW



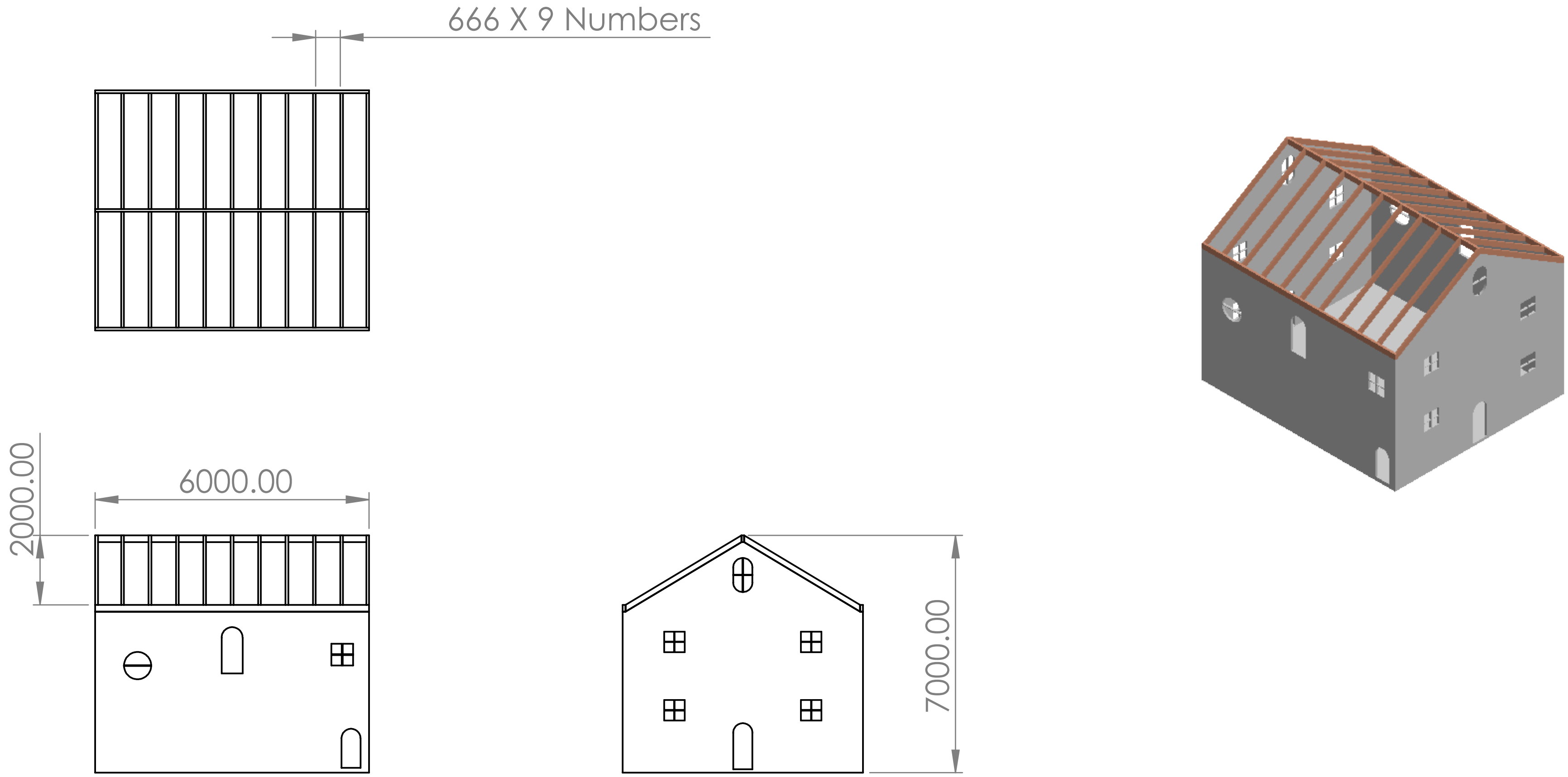
ISOMETRIC VIEW

FRONT VIEW



SIDE VIEW

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:			FINISH:		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO. Link channel	A4
				WEIGHT:		SCALE:1:20	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH: N/A		DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE		TITLE: PRELIMINARY DESIGN	
DRAWN						
CHK'D						
APPV'D	DR AL RAWI					
MFG						
Q.A				MATERIAL: N/A	DWG NO. House	A4
				WEIGHT:	SCALE:1:50	SHEET 1 OF 1