Industrial Design Project II

Innovative Application of Steel in Housing
Floor Slab

By
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136130011
(2013-15)

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Approval Sheet

Industrial Design Project II
Innovative Application of Steel in Housing :
Floor Slab

by **Omkar R Jambovane**
M. Des. Industrial Design 2013-15
is approved as partial fulfilment of requirement of post-graduate degree in Industrial Design.

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Internal examiner

External Examiner

Chairperson

Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all the principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/ data/ fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Signature:

Name: Omkar R Jambovane
Roll No.: 136130011
Date: 24/05/2015

With heavy heart, dedicated to my late father,
Ranappa Jambovane *(1943-2011)*
—an amazing soul, painter and sculptor—
who instilled in me the value of honesty,
pursuing higher education, and always aspiring for excellence.

Abstract

Human population has grown leaps and bounds over the last century. Consequently, the demand for housing has also gone up. But in the name of development and land for housing, we, as a species, have violated our planet, depleted the resources and disturbed its fragile ecological balance. It is obvious from the above facts, that calcination arising due to cement manufacturing needs to be curbed and we need to look at alternative techniques that have lesser carbon footprint. The perspective shift can happen either by reducing cement concrete in housing wherever not required or by totally looking at material based innovation in construction techniques. The project was conceived and executed keeping this "rapid construction of economical, eco-friendly and structurally sound houses" in mind. Within the scope of the project, it has been tried to address all issues related to housing. While working on this project we came up with one very innovative concept called Criss-Cross Corrugation. Here, this CCC concept is used for flooring structure which is reducing almost 50% cost.

Acknowledgement

I cannot but acknowledge the unquantifiable help God gave me throughout this project work, always showing up whenever I got to the end of my line and felt like changing the project to a simpler one. Most remarkable was the breakthrough He gave me when I was stuck at point for a week!

I wish to express my deep gratitude towards Prof Vijay Bapat Without whom none of this would have ben possible. Very soft spoken and always helpful, I learnt a lot from him.

Also, I must acknowledge the co-guide P. Kumaresan. The acknowledgement, and consequently the report, would be incomplete without thanking all IDC staff.

I also express my thanks my friends and specially project met Tushar and Baisampayan for encouraging me and their constant support.

- Omkar Ranappa Jambovane
136130011 | Sr PD

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Concern About the carbon footprint of cement

"According to the World Business Council for Sustainable Development (WBCSD www.WBCSD.org),
'Concrete is the most widely used material on earth apart from water, with nearly three tons used annually for each man, woman, and child.' "

"Carbon dioxide emissions from a cement plant are divided into two source categories: combustion and calcination. Combustion accounts for approximately 40% and calcination 60% of the total CO2 emissions from a cement manufacturing facility. "

"The manufacture of cement produces about 0.9 pounds of CO2 for every pound of cement. Since cement is only a fraction of the constituents in concrete, manufacturing a cubic yard of concrete (about 3900 lbs) is responsible for emitting about 400 lbs of CO2." [7]

http://www.greenrationbook.org.uk/resources/footprints-concrete/ as seen on 13/11/2014

Ecological Concerns

Human population has grown leaps and bounds over the last century. Consequently, the demand for housing has also gone up. But in the name of development and land for housing, we, as a species, have violated our planet, depleted the resources and disturbed its fragile ecological balance. It is obvious from the above facts, that calcination arising due to cement manufacturing needs to be curbed and we need to look at alternative techniques that have lesser carbon footprint.
The perspective shift can happen either by reducing cement concrete in housing wherever not required or by totally looking at material based innovation in construction techniques.

Fig. 1: All efforts and innovations should be driven to lessen our carbon footprint and ensure that we leave behind a better, greener planet for our future generations.

Fig.2 Set guidelines and intelligent techniques can help in speeding up the process of building a house, even by an unskilled worker.

http://www.coscienzasalute.it/_upload/Image/conferenza%20usura%20bancaria%202.jpg as seen on 08/11/2014

Introduction

A home is a place used as residence for an individual, family, household or several families. It is often a house, apartment, or other building, or a mobile home, houseboat, yurt or any other portable shelter. Larger groups may live in a nursing home, children's home, convent or any similar institution. A homestead also includes agricultural land and facilities for domesticated animals. Where more secure dwellings are not available, people may live in the informal and sometimes illegal shacks found in slums and shanty towns. More generally, "home" may be considered to be a geographic area, such as a town, village, suburb, city, or country. Following are the main elements of the home

1.Windows & doors

2.Roof and floor

3.Floor Slab

4. Wall

The scenario here in this project is a house having ground plus first floor construction.

Fig. 3: A typical under-construction house
http://beodom.com/sr/news/entries/amadeo-2-1st-floor-slab-and-installation-of-avi-thermokorb as seen on 12/11/2014

Fig.4 Details of Eiffel Tower floor slab
http://www.grontmij.dk/EN/News/press-releases/PublishingImages/eiffel.jpg as seen on 12/11/2014

Floor Slab

A concrete slab is a common structural element of modern buildings. Horizontal slabs of steel reinforced concrete, typically between 4 and 20 inches (100 and 500 millimeters) thick, are most often used to construct floors and ceilings, while thinner slabs are also used for exterior paving. Sometimes these thinner slabs, ranging from 2 inches (5.1 cm) to 6 inches (15 cm) thick, are called mud slabs, particularly when used under the main floor slabs or in crawl spaces. In many domestic and industrial buildings a thick concrete slab, supported on foundations or directly on the subsoil, is used to construct the ground floor of a building. These can either be "ground-bearing" or "suspended" slabs. In high rise buildings and skyscrapers, thinner, pre-cast concrete slabs are slung between the steel frames to form the floors and ceilings on each level.[1]

Cement Concrete Floor Slab Construction

1. Set the forms for your slab by giving supports. Building lines which have been laid out on the outside building line and on grade (at the proper elevation), will allow you to form the edges of the slab straight and level.
2. Install plumbing or electrical pipes, as well as sleeves for air conditioning piping and wiring.
3. Install the reinforcing wire or rebars required by the architect/engineer .
4. Determine the method you will use to place the concrete in your forms. This should be done early in the process so that concrete trucks and other required equipment will be able to get into the area they will need access to during the concrete placement.
5. Check forms for alignment and make sure all braces are tight and well anchored so the weight of the concrete does not cause them to bow or fail during the pour.
6. Calculate the quantity of concrete you will need to complete the slab.
7. Order the concrete from a ready mix concrete supplier, and schedule the delivery to coincide with the concrete placement schedule. This means both the date and time of the pour, and the interval of delivery for multiple trucks to arrive on the job site so the concrete crew has time to discharge and tend to each truckload, while not having to wait for the next truck to arrive.
8. Coordinate concrete testing with a qualified testing laboratory if the construction contract requires it.
9. Begin the concrete placement at a corner and continuing placing the concrete along the grade or screed lines as you have established.
10. Make sure the reinforcing wire mat or rebars are not forced to the bottom of the concrete while placing.
11. Keep placing the concrete and pulling it roughly level with Come Along and screeding it off with a straightedge.
12. Continue pouring the concrete until the forms are filled to the finished grade of the slab.
13. Allow the concrete to set.
14. Remove the forms and clean them for reuse on the next project. [6]

The illustration 1 on the following page depicts all the processes listed above, with respect to the time consumed by each of them in days.

Time Study of RCC Floor Slab (10'*10')

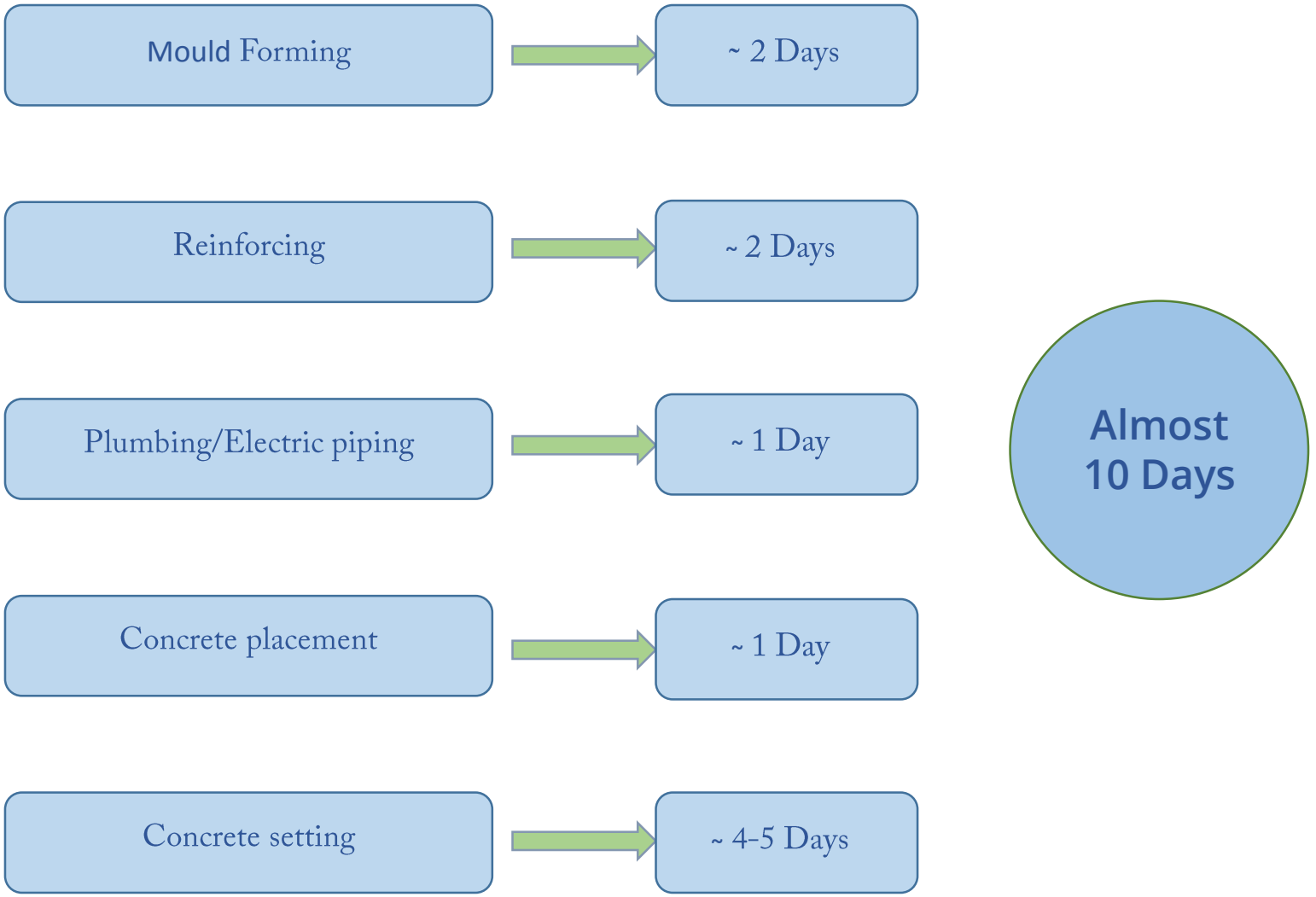


Illustration 1

Fig. 6 Typical wooden flooring
http://thehomealarms.com/interior-small-house-design-with-great-flooring-design/small-house-interior-great-flooring-ideas as seen on 09/11/2014

Floor

Flooring is the general term for a permanent covering of a floor, or for the work of installing such a floor covering. Floor covering is a term to generically describe any finish material applied over a floor structure to provide a walking surface. Both terms are used interchangeably but floor covering refers more to loose-laid materials.

Materials almost always classified as floor covering include carpet, area rugs, and resilient flooring such as linoleum or vinyl flooring. Materials commonly called flooring include wood flooring (fig 6), ceramic tile(fig8), stone, terrazzo (fig7), and various seamless chemical floor coatings.[2]

Fig. 7 Typical Floor
http://symbolsflooring.com/images/fl-1.jpg as seen on 09/11/2014

Fig. 8 Typical Ceramic tiles flooring
http://www.huckerfloorcoverings.com/images/slideshows/pic2.jpg as seen on 09/11/2014

Fig. 9 Hardwood flooring for kitchens
ttp://www.carsonshardwoodfloors.com/wp-content/uploads/2012/06/big-kitchen-hardwood-floor.jpg as seen on 10/11/2014

Fig.10 Bamboo flooring
http://www.accentcarpets.com.au/timber/images/bamboo-flooring.jpg as seen on 09/11/2014

Types of Flooring

The type of flooring could make a significant difference in the appearance and finishing of your project. Good looking flooring could enhance the value of the home and could possibly attract new customers. Let's read about the most popular flooring types from which to choose for your home.

1. Hardwood Flooring

One of the favorites types of flooring. Hardwood flooring (fig 9) presents a combination of beauty and durability that you would rarely have on a flooring type. Hardwood flooring comes in Maple, Pecan, Beech, Cherry, Oak, Pine, Birch, Walnut, Hickory and more. This type of flooring provides a long-lasting product, wear resistant surface that could be refinished if necessary. However, certain types of hardwood flooring might darken with age and some others could shrink and expand creating gaps in the floor surface.

2. Bamboo Flooring

One of the latest additions of flooring types, the bamboo flooring (fig10) could be a greener solution when compare to traditional flooring materials.

Fig.11 Ceramic tiles with wooden patterns
http://home-partners.com/wp-content/uploads/2014/09/21928Amora-Ceramic-Floor-Tile_large.jpg as seen on 10/11/2014

Bamboo flooring is durable, elegant and comes in a variety of colors usually ranging from honey brown to light tan. It provides a strong, clean surface, but could darken over time or when exposed to sunlight. Bamboo flooring should not be left wet. Manufactured bamboo floors are typically made available in planks with either vertical or horizontal-grain orientation. In vertical bamboo floors, the component pieces are stood vertically on their narrowest edge and then press laminated side to side. The effect is a lined, almost uniform look to the surface of the finished floor plank. In horizontal bamboo floors, the slats are arranged in a horizontal direction, on their widest edge, and then joined side by side with adjacent pieces using a high-pressure laminate system.

3. Ceramic Tile

When selecting flooring type that requires waterproofing, ceramic tile (fig 11) is the best alternative. Ceramic tile could be used as floor tiles, indoors, or as counter tops. Some types of ceramic tiles with high gloss finish tend to scratch over the time.

Fig.12 Elegant Marble flooring
http://www.nalboor.com/wp-content/uploads/2013/09/Marble-luxury5-1024x678-marble-tiles-spelling-luxury-and-strength-in.jpg as seen on 10/11/2014

Fig 13 Marble slabs for flooring
https://images.justlanded.com/classifieds/Singapore/Services_Cleaning/Need-Marble-Parquet-Flooring-Polishing-CALL-65696024-267504-1so.jpg as seen on 10/11/2014

Ceramic tiles with unglazed finish are the best alternative for outdoor flooring because of the possibility of standing water. Finishes available are: matte, embossed, glazed and textured ones for anti-slip. Ceramic tiles made of porcelain color through tile body, are the best to hide scratches or damages due to their composition. One of its biggest drawbacks is that grout lines could be very hard and difficult to clean and low quality tiles may chip.

4. Marble Flooring :

Marble tiles (fig 12 and 13) are one of the most durable and versatile tiles to use. They can be used for your floors, walls and hallway columns. These tiles are easily cleaned and maintained. They are also very easy to engrave with stylish textures and designs that suit your artistic tastes. Marble tiles make an elegant foyer and come in many colors. It comes in a wide range of colors and variations and is used in such things as sculpture as well as architecture and a building material for thousands of years, but its main use is in flooring. The tiles come in different sizes, usually around 12×12″ and are easy to install yourself.

Fig.14 Special flooring to reduces chances of slipping
http://www.belson.com/Images/SafetyGrid-001-M.jpg
as seen on 12/11/2014

Fig.15 Floor level designer mouldings
http://www.designpartners.com/archive/dremelweekends_Mar/images/moulding_step3_image.png as seen on 12/11/2014

Special Features of Flooring

There are a number of special features that may be used to ornament a floor or perform a useful service:

- ✓ Floor medallions decorative centerpieces of a floor design
- ✓ Doormats to help keep a floor clean
- ✓ Gratings used to drain water or to rub dirt off shoes
- ✓ Tactile or rumble strips to warn of for instance a wheelchair ramp, these would normally also be distinctively colored or patterned.
- ✓ Light strips to show an escape route out, especially on airplanes.
- ✓ Moldings (fig 15) or baseboards to decorate the sides of a floor or to cover the edge of a floating floor.
- ✓ Anti-slip mats (fig 14) : The addition of either granular or rubberized particles that will allow wheels, shoes, or feet better traction.

Problems with Ordinary Floors

Fig.16 Damage to traditional cement flooring
http://www.madstonefloors.com/wp-content/uploads/2011/02/IMG_4454.jpg
seen as in 12/11/2014

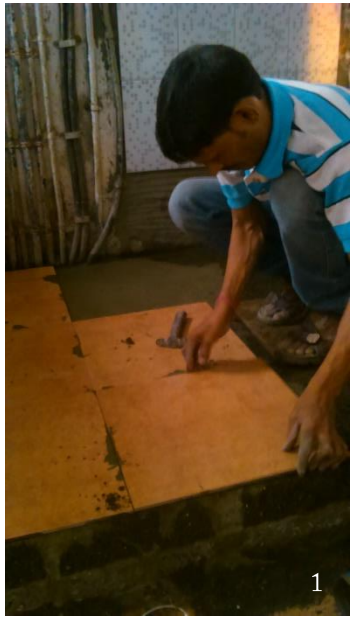
Wood floors, particularly older ones, will tend to 'squeak' in certain places. This is caused by the wood rubbing against other wood, usually at a joint of the subfloor. Firmly securing the pieces to each other with screws or nails may reduce this problem.

Floor vibration is a problem with floors. Wood floors tend to pass sound, particularly heavy footsteps and low bass frequencies. Floating floors can reduce this problem. Concrete floors (fig 16) are usually so massive they do not have this problem, but they are also much more expensive to construct and must meet more stringent building requirements due to their weight.

The flooring may need protection sometimes. A gym floor cover can be used to reduce the need to satisfy incompatible requirements.[8]

In addition of this problem list, While tile assembling worker bangs the tile placing this tile on uneven surface and because of this every 6-7tile breaks.

Tile Assembly on Concrete Floor



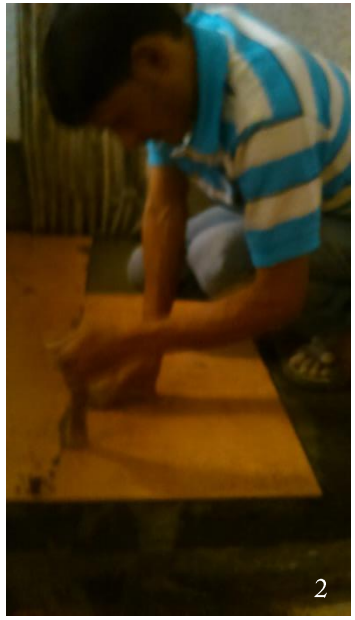


Fig 17. Tile assembly process

Placing tile on a grid and cement slab

After manual leveling , leveling by hammer.

Again manual leveling but by hammer. Tile gets breaks if leveling is not done properly due to cavity below or unbalanced tile.

Useless tile after breakage

Parallel Products

Fig 18 : Typical image of air plane interior where floor is under constant loading.
http://i2.mirror.co.uk/incoming/article1795824.ece/alternates/s615/Virgin-launch-new-jet-with-see-through-floor.jpg as seen on 10/11/2014

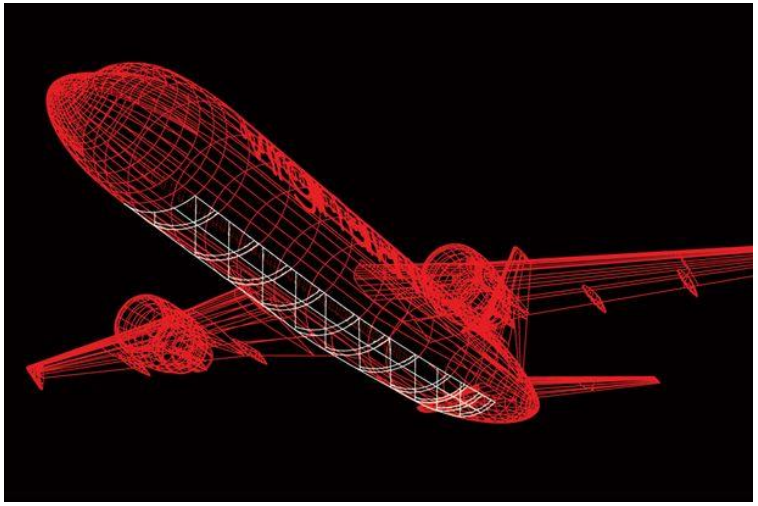


Fig 19 : Airplane floor structure
http://www.boeing.com/commercial/aeromagazine/articles/2011_q4/2/ as seen on 10/11/2014

Fig 20 : Typical photo of bus flooring
http://i00.i.aliimg.com/img/pb/419/504/256/1278492081971_hz-myalibaba-web5_4753.JPG as seen on 10/11/2014

Floor assembly for transport vehicles (fig 18,19,20) :
Transport vehicles are subject to constant loads. To optimize movement, fuel efficiency and effective load bearing, a lot of innovation is done is terms of form, materials and optimization of space.
A typical example is the under belly of a typical airplane fuselage, where panels are riveted, linked together. Here, weight is a crucial factor and that has been successfully tackled by use of aluminium and other alloys. Of late, the bottom part is proposed to be of plexiglass, to enhance the passenger experience.
In case of transport buses, much retrofitting is done by local vendors on a standard chassis. The customization allows optimum usage of space as the urban scenario demands.

Steel Housing : A new Era in Rapid Construction

A steel building is a metal structure (fig 21) fabricated with steel for the internal support and for exterior cladding, as opposed to steel framed buildings which generally use other materials for floors, walls, and external envelope. Steel buildings are used for a variety of purposes including storage, work spaces and living accommodation. They are classified into specific types depending on how they are used.

Advantages :

Steel provides several advantages over other building materials, such as wood. Steel is a "green" product; it is structurally sound and manufactured to strict specifications and tolerances. It is also energy efficient. Any excess material is 100% recyclable.

- Steel does not warp, buckle, twist or bend, and is therefore easy to modify and offers design flexibility. Steel is also easy to install.
- Steel is cost effective and rarely fluctuates in price.
- Steel allows for improved quality of construction and less maintenance, while offering improved safety and resistance.
- With the propagation of mold and mildew in residential buildings, using steel minimizes these infestations. Mold needs moist, porous material to grow. Steel studs do not have those problems.

Disadvantages

- Heat conductivity: Calculations show that the web of an 18-gauge steel stud is about 31 times thinner than a "two-by" wood stud; however, steel conducts heat 310 times more efficiently than wood. As a net result, a "two-by" steel stud will conduct 10 times more heat than a "two-by" wood stud.
- Corrosion: Faulty design leads to the corrosion of iron and steel in buildings [5]

Fig 21 : Steel construction
http://www.steelhomes.org/images/welcome.jpg as seen on 14/11/2014

Given today's scenario, where every resource has to be used sparsely and wisely, it is necessary to re-look at traditional construction techniques. Steel, with its recyclability ensures maximum use and re-use over long durations. Add to its properties as a durable and rigid material, steel can be highly recommended for construction activities.

Design Approach

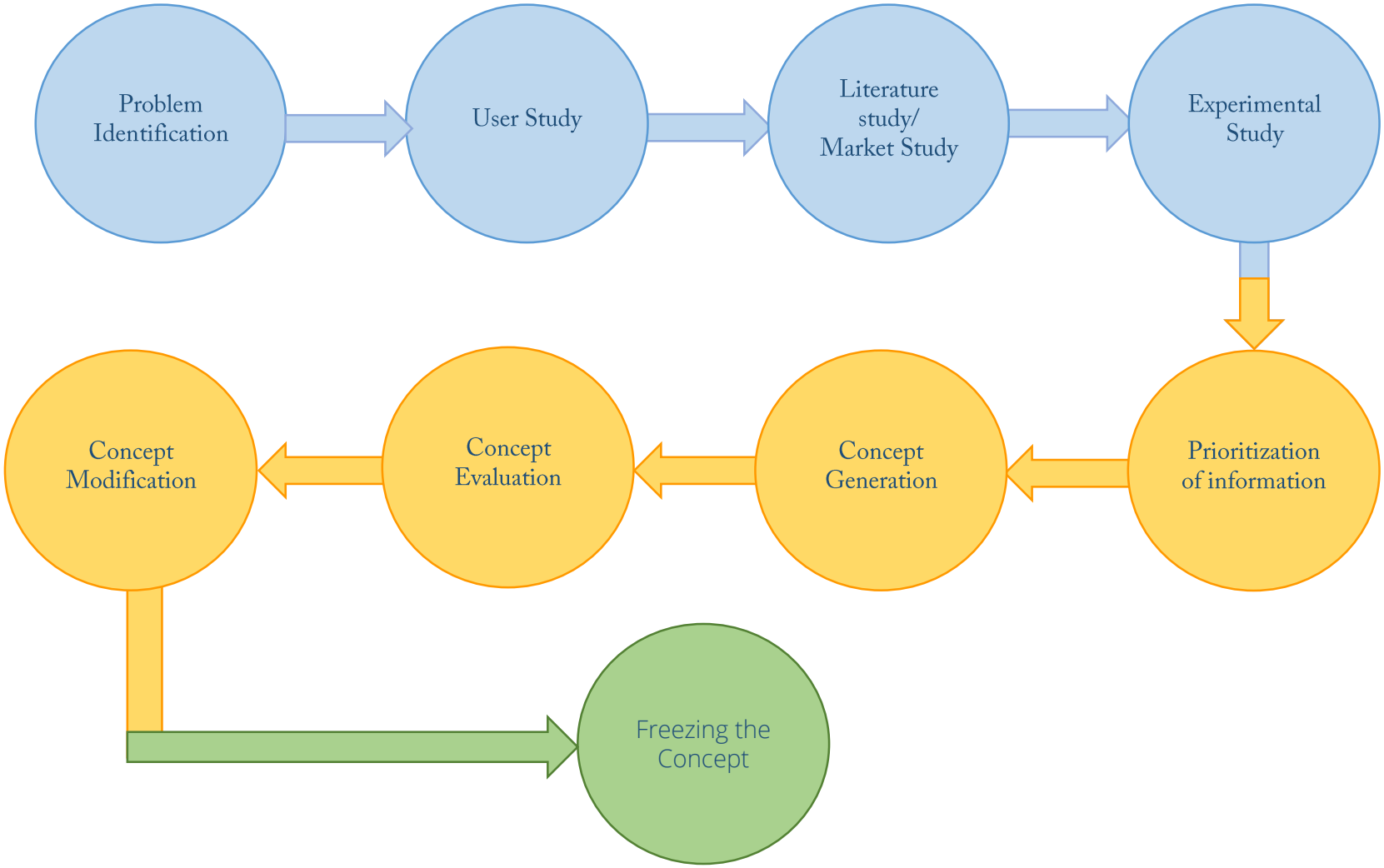


Illustration 2 The Design Approach

Design Brief

"To explore innovative application of steel in flooring and ceiling ,which may result in solving User centered issues like reduction in construction time, better design of joints, less involvement of skilled labor force and finally come up with a working prototype or scaled model of product."

Fig 22 : Old wood flooring
http://woodflooringtrends.files.wordpress.com/2012/03/fontenay-hb-1.jpg
as seen on 12/11/2014

Problem Identification

From the design approach map following problems are identified which are measure. Some problems are found after brain storming among group mates and people around

Problems with floors

Wood floors (fig 22) , particularly older ones, will tend to 'squeak' in certain places. This is caused by the wood rubbing against other wood, usually at a joint of the subfloor. Firmly securing the pieces to each other with screws or nails may reduce this problem.

Floor vibration is a problem with floors. Wood floors tend to pass sound, particularly heavy footsteps and low bass frequencies. Floating floors can reduce this problem. Concrete floors are usually so massive they do not have this problem, but they are also much more expensive to construct and must meet more stringent building requirements due to their weight.

The flooring may need protection sometimes. A gym floor cover can be used to reduce the need to satisfy incompatible requirements.[8]
In addition of this problem list, While tile assembling worker bangs the tile placing this tile on uneven surface and because of this every 6-7tile breaks.

Mind Map For Floor

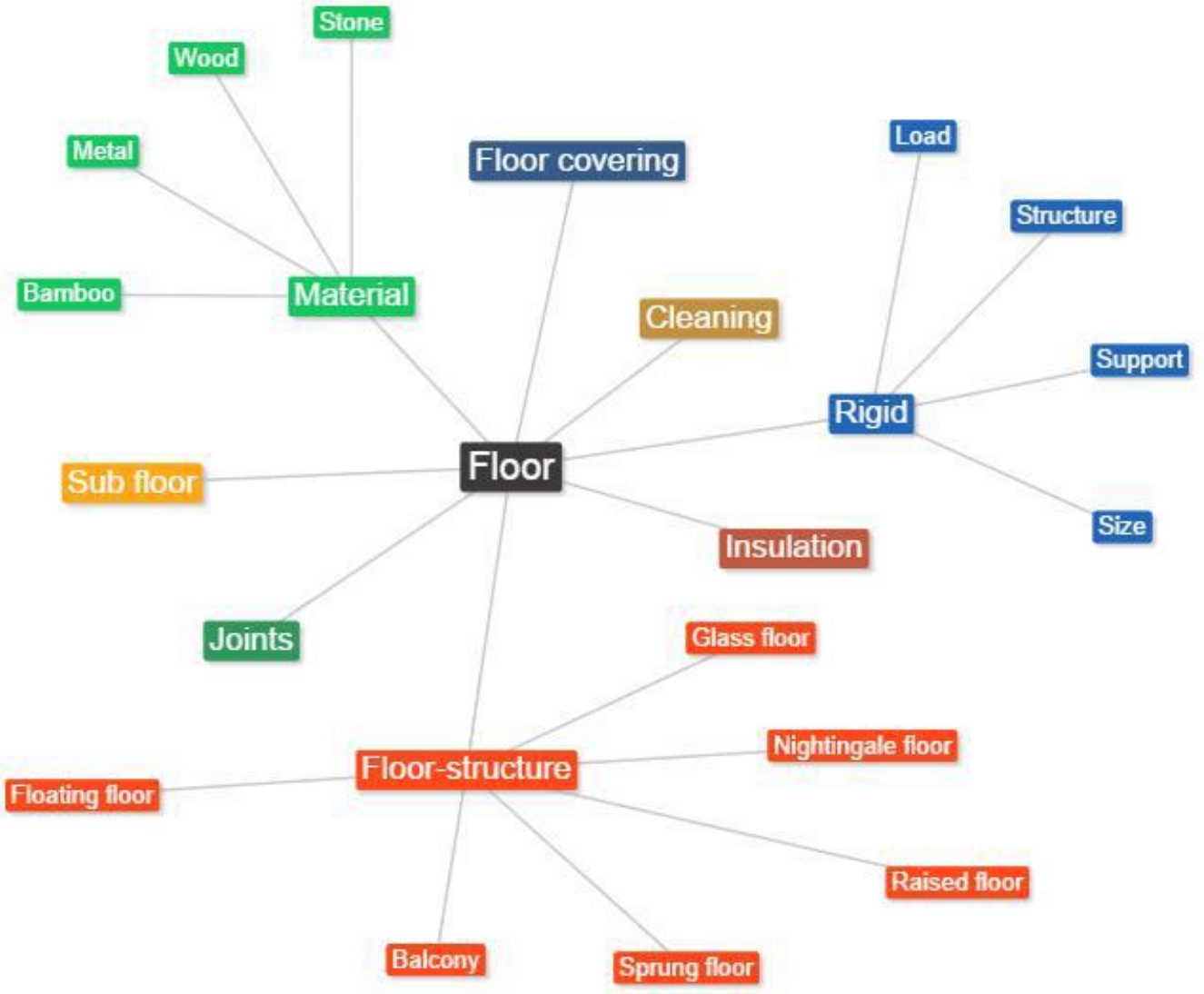
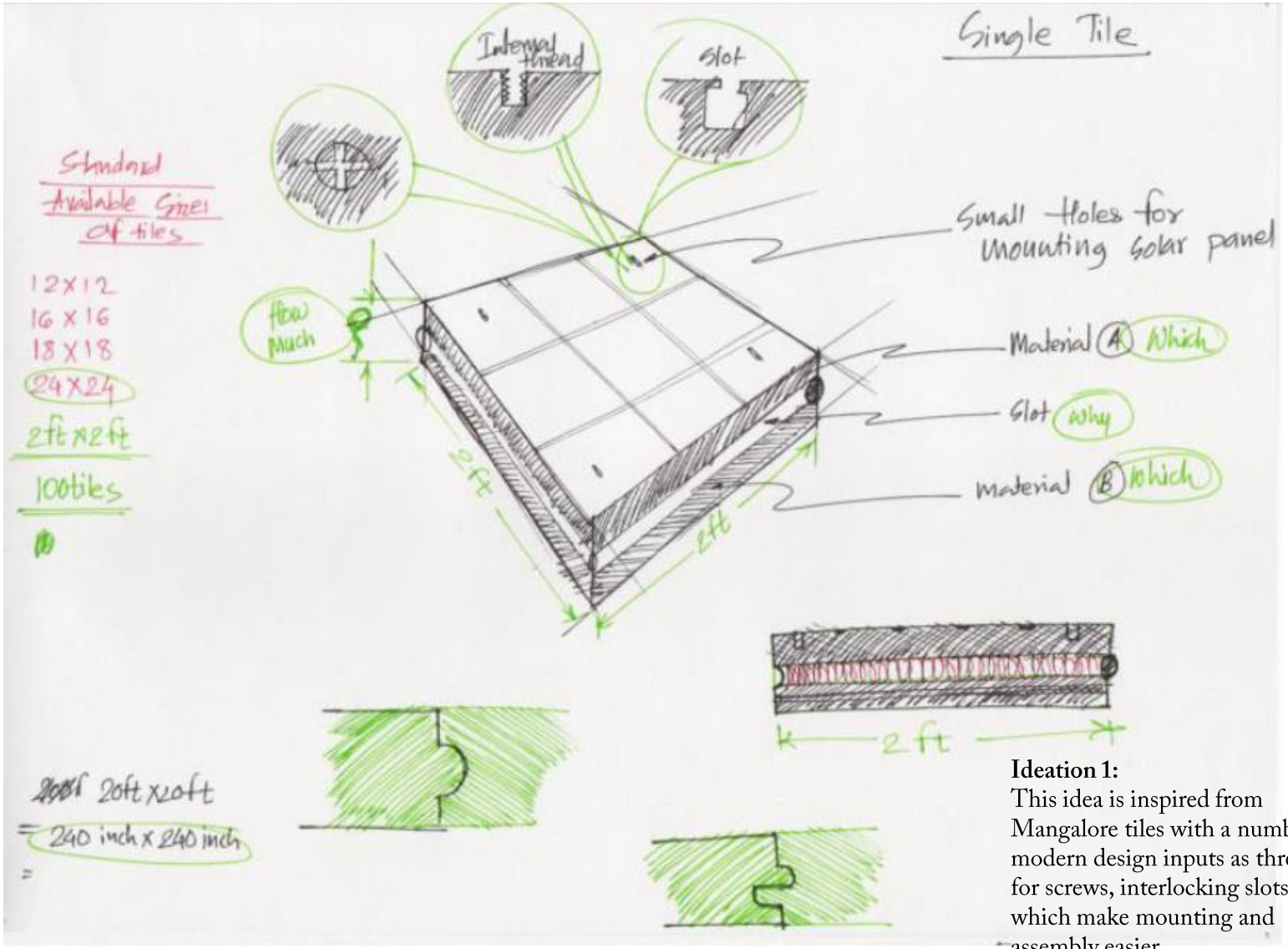


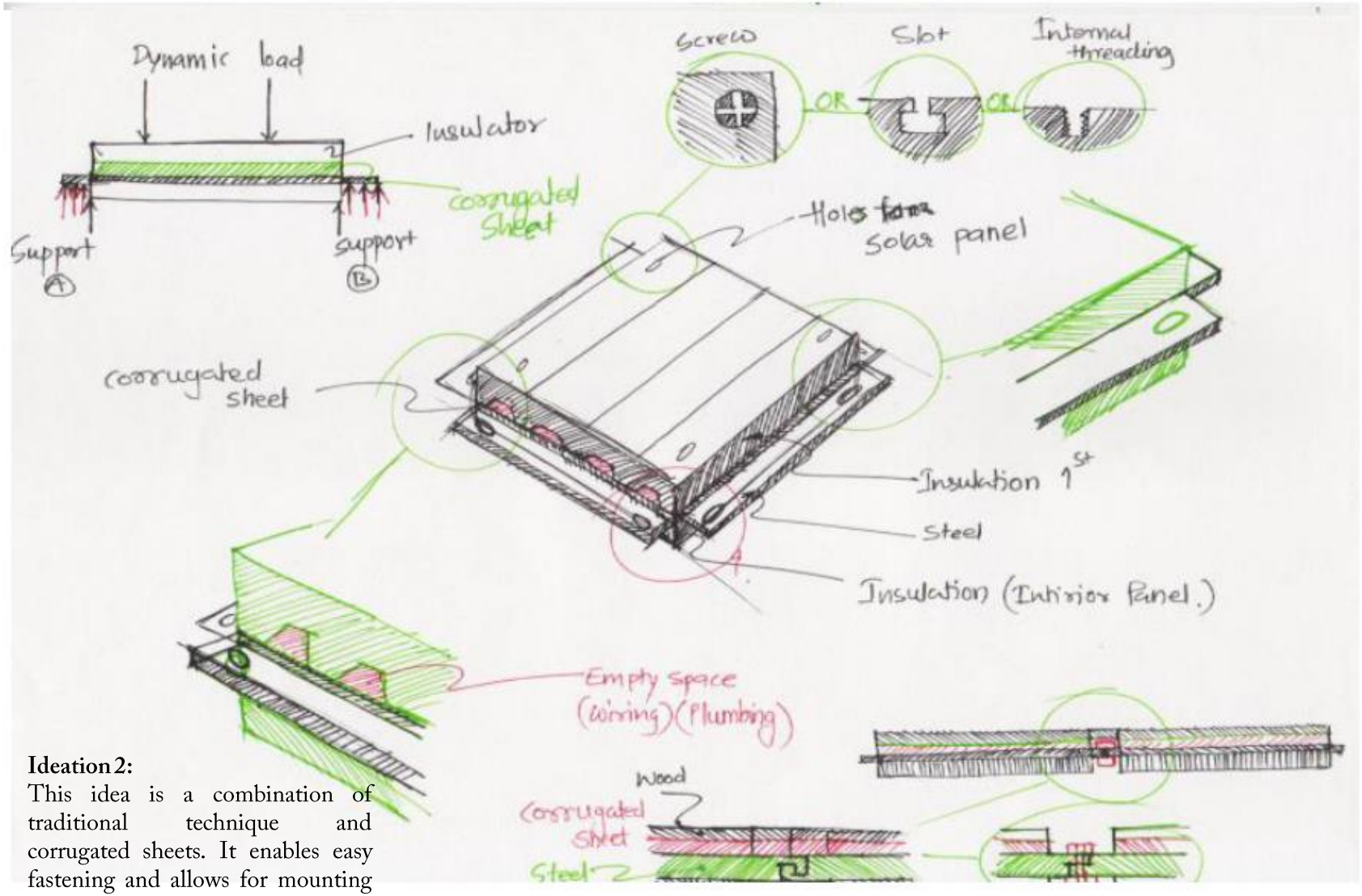
Illustration 3rd

Some Initial Ideations (After Stage 1)



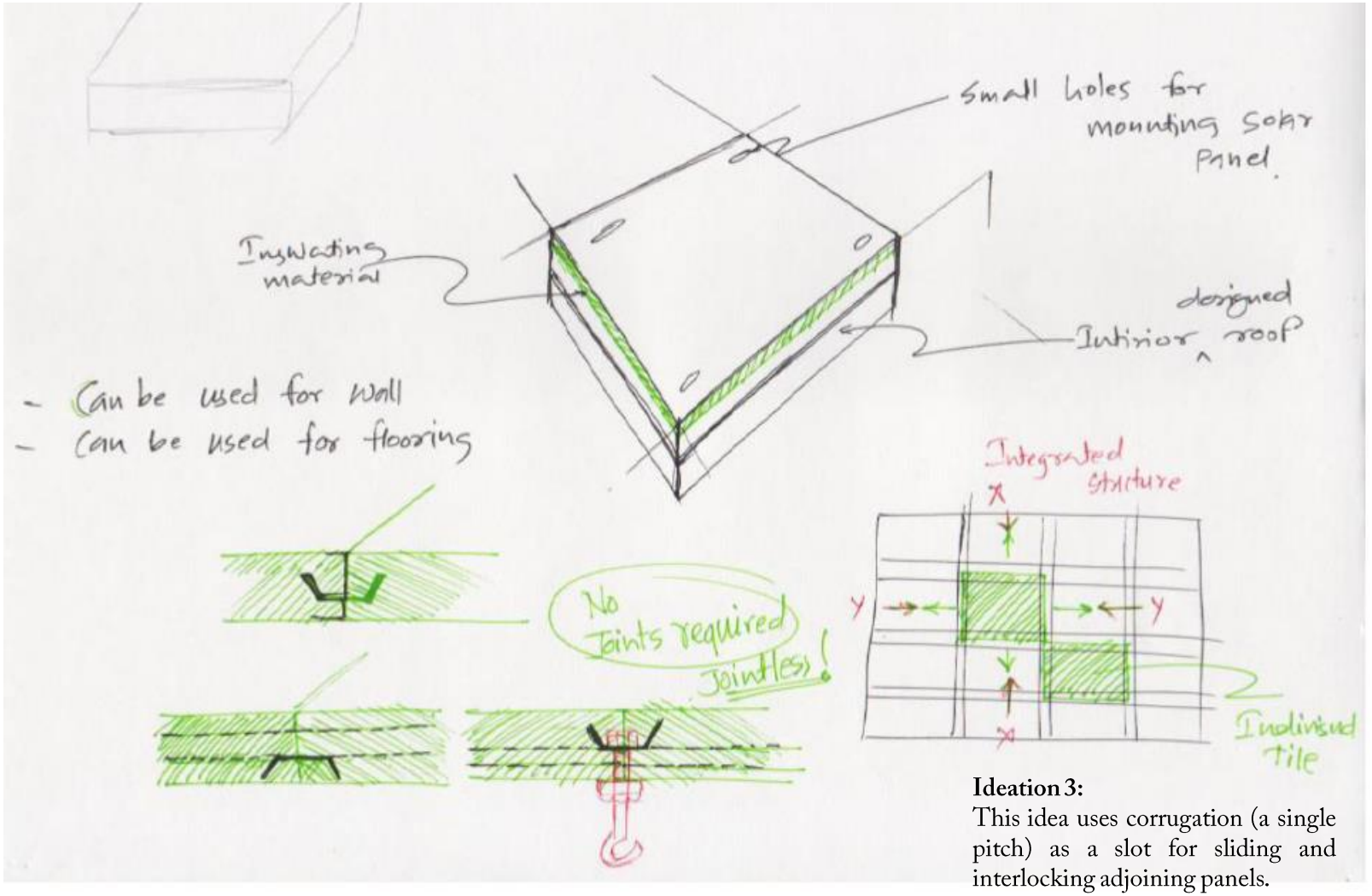
Ideation 1:
This idea is inspired from Mangalore tiles with a number of modern design inputs as threading for screws, interlocking slots, etc which make mounting and assembly easier.

Some Initial Ideations (After Stage 1)



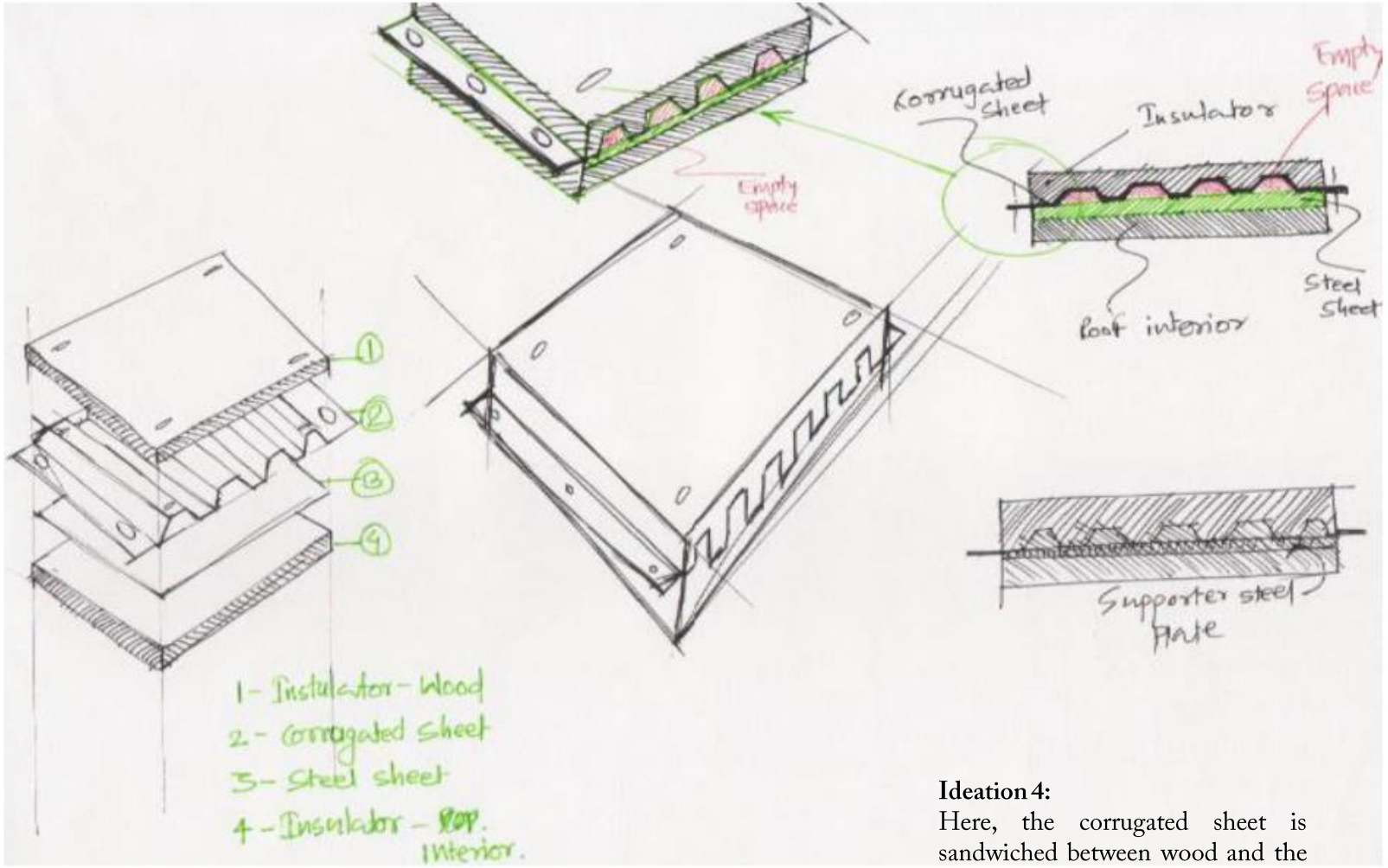
Ideation 2:
This idea is a combination of traditional technique and corrugated sheets. It enables easy fastening and allows for mounting of fixtures, etc.

Some Initial Ideations (After Stage 1)



Ideation 3:
This idea uses corrugation (a single pitch) as a slot for sliding and interlocking adjoining panels.

Some Initial Ideations (After Stage 1)

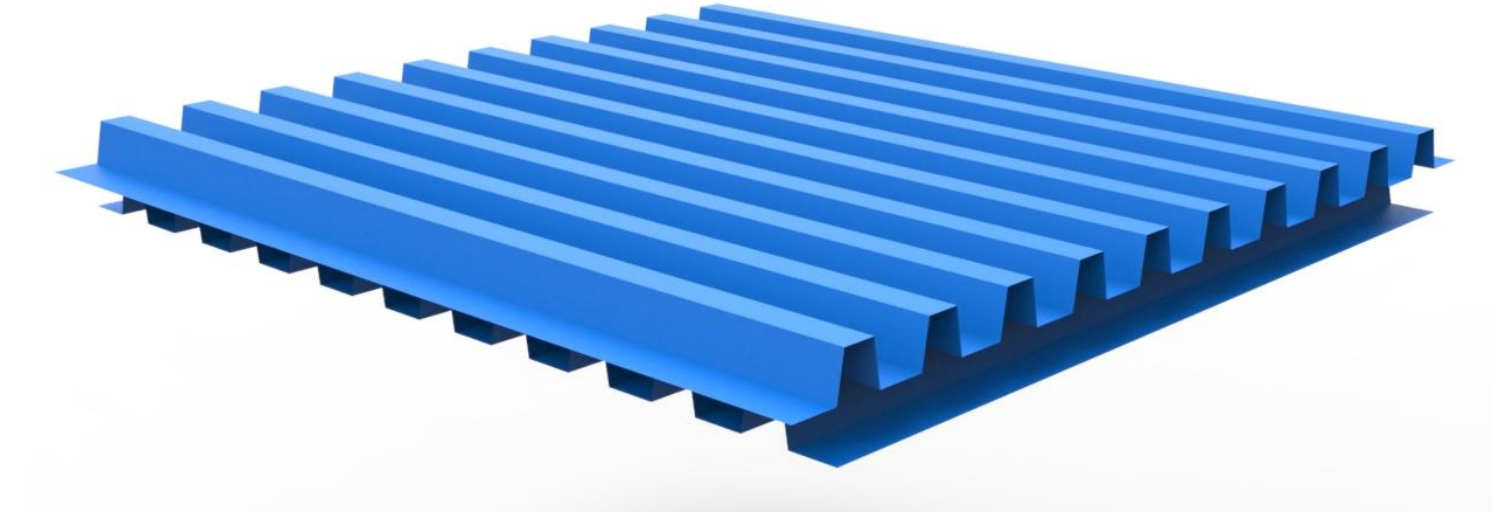


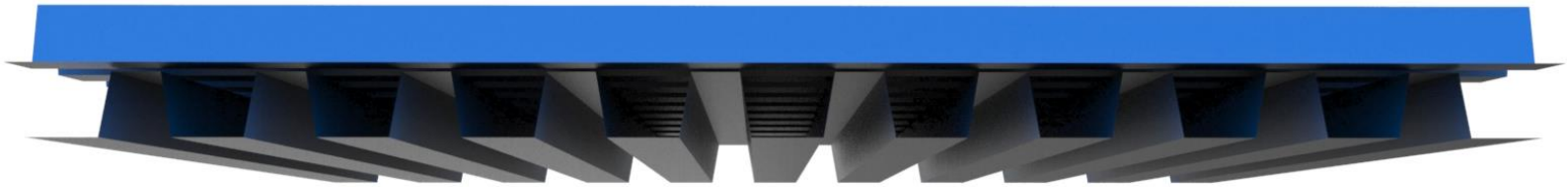
Ideation 4:
Here, the corrugated sheet is sandwiched between wood and the gaps between corrugation could be used for wirings

Criss-Cross Corrugation (CCC Structure)

What is it?

It is a innovative concept where two corrugated sheets are joined together in criss cross manner.





Research on Galvanized Corrugated Sheets

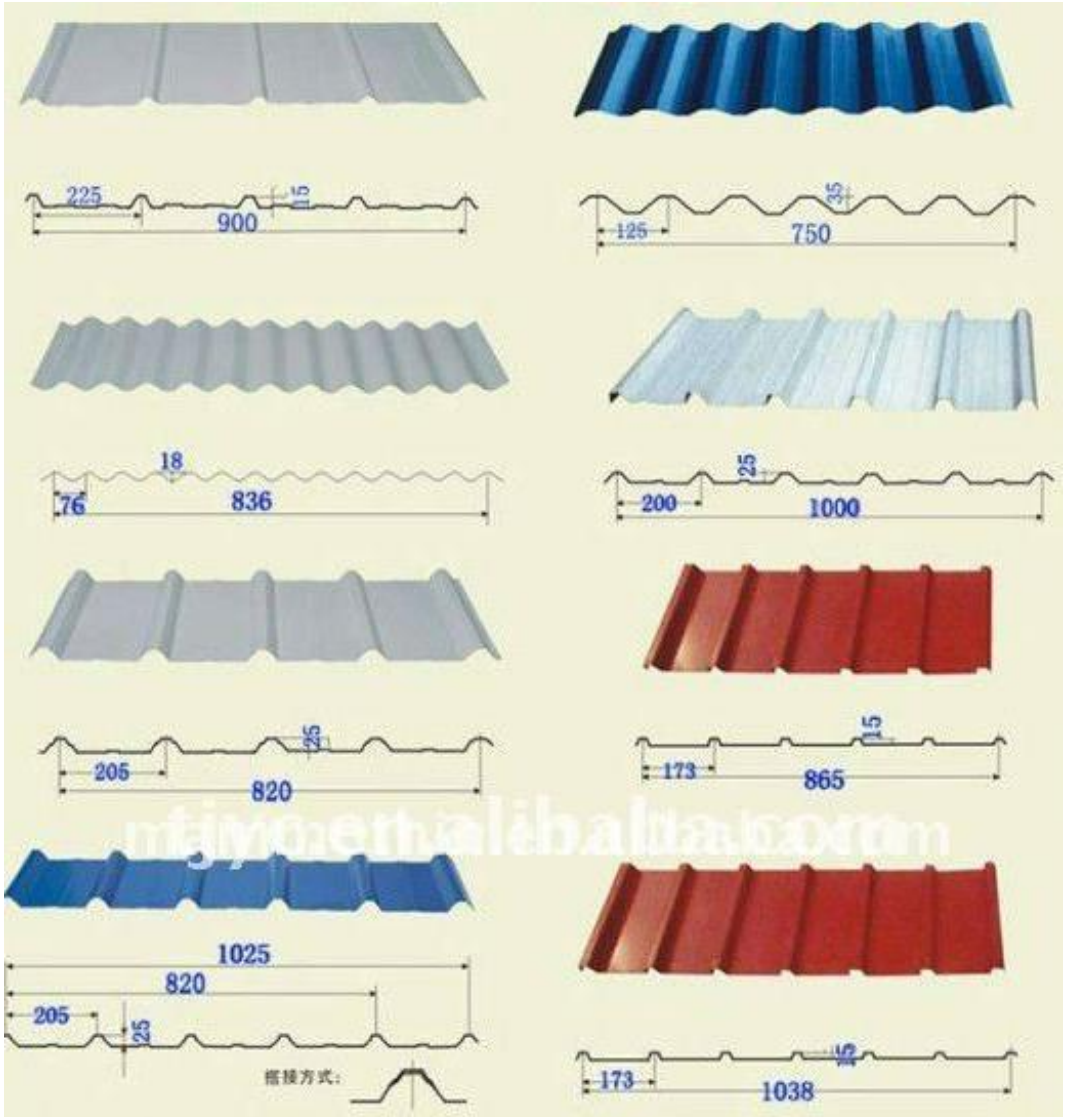


Fig 23 (a)Typical types of corrugated sheets available in Indian market
http://i01.i.aliimg.com/img/pb/785/865/384/384865785_447.jpg as seen on 10/11/2014

During project worked we visited almost 14 people for validation of this concept and 90% of them give very positive feedback. But moving a head we decided to make 1:1 scale model of this concept just to get a actual feel and some validations. We visited lot of GI corrugated sheet suppliers for various sizes and profile selection. Following are the profiles available in the market.

Among these all profiles we selected following profile having thickness 0.5 mm.

Selected Profile

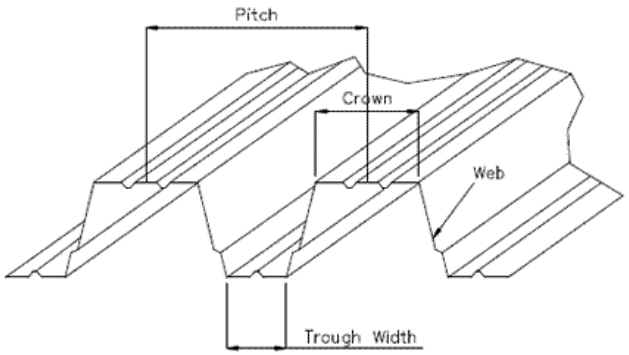


Figure 23 (b) Corrugation terminology
http://www.slecladding.co.uk/comtrisomet2.jpg as seen on 10/11/2014

HIGH TEMPTURE / CHEMICAL RESISTANCE

lOCTITE® H8600 HYSOL® STRUCTURAL ADHESIVE

Galvanized Bonder

Excellent impact and shear strength on steel and aluminium. Especially designed for severe environments.

Joining of Corrugated Sheets

We found lot of joining methods for joining corrugated sheets.

Following are they,

- ✓ **Adhesive bonding**
- ✓ Welding
- ✓ **Riveting**
- ✓ Clinching
- ✓ **Fastening (Nut-bolt)**
- ✓ Crimpling
- ✓ Stamping
- ✓ Magnet fixing
- ✓ Stitching
- ✓ Snap on
- ✓ DST
- ✓ Brazing
- ✓ Eyelet

These three are selected for joining CCC

Out of these **fastening method** is good because of easiness in assembling and disassembling corrugated sheets.

Joining of Corrugated Sheets :

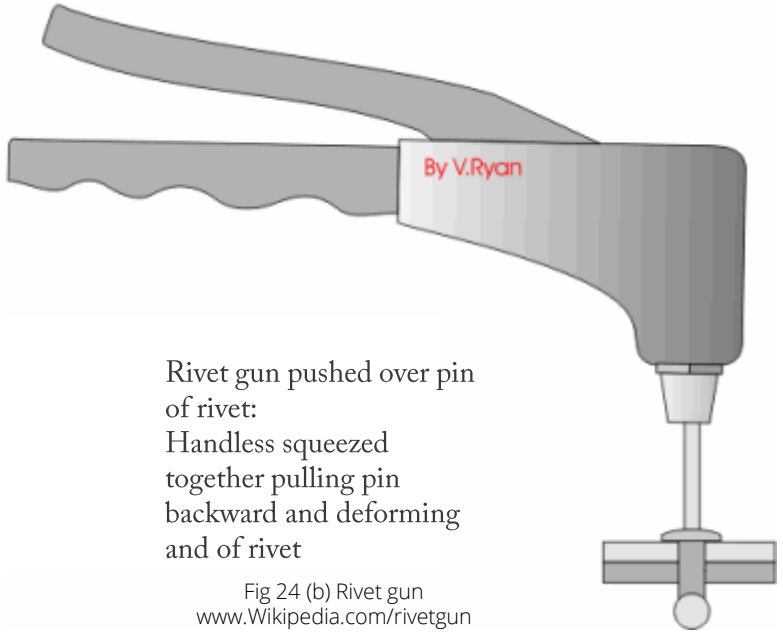
1. Adhesive Bounding

Fig 24 (a) : Locktite adhesive bottles available in market
http://www.loctite.com.au/loctite-tereson-products.htm as seen on 10/11/2014

Key characteristics of thread lockers

- Single-component
- Clean and easy to apply
- Resists vibration
- Locks and seals all threads
- Reduces inventory costs

2. POP Riveting



Rivet gun pushed over pin of rivet:
Handless squeezed together pulling pin backward and deforming and of rivet

Fig 24 (b) Rivet gun
www.Wikipedia.com/rivetgun

Blind Rivets are multi-piece rivet assemblies, capable of being installed from one side of the work piece. Mainly blind rivets were used on aircraft leading edges, trailing edges, and close out areas which are limited to access to one side of the structure.

3. Joining of Corrugated Sheets Fastening (Nut-bolt)

Fig. 24 (c) Fastener bolt
)https://d2t1xqejof9utc.cloudfront.net/screenshots/pics/4bf7782e2959a8065bc393d0cf649d9a/medium.png as seen on 12/11/2014

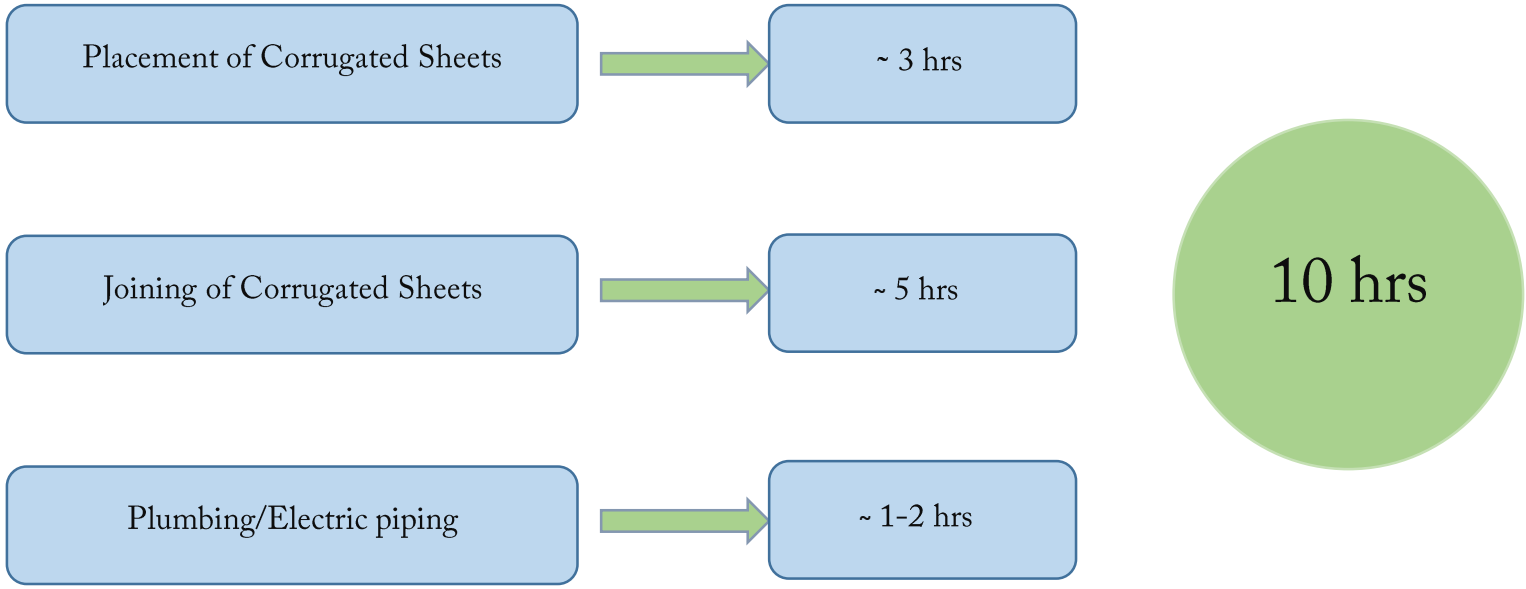
A fastener is a hardware device that mechanically joins or affixes two or more objects together.
They may involve keeping together the sides of an opening of flexible material, attaching a lid to a container, etc. Fasteners used in these manners are often temporary, in that they may be fastened and unfastened repeatedly.[4]

From the three mentioned techniques, fastening with nut bolts (Fig 24 (c)) allows ease of assembly and disassembly.
Considering our application, which has to enable easy, quick and reversible procedures, fastening is preferred over the other two techniques.

10Feet * 10Feet Actual Model : Load Validation

Successfully produced Criss-Cross corrugation. Bent test done and got only 5mm deflection, ponding effect, by approx. 250kg weight.

Time Study of Joining CCC Structure (10'*10')



Cost Estimation : RCC Vs CCC

(10'*10' Area)

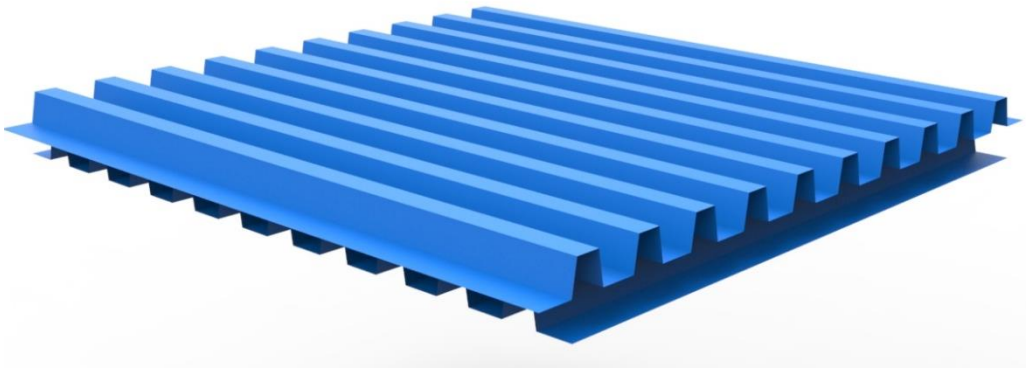
Concrete (M20)	₹ 8000 approx.
Rebar (0.4 cm)(48 meter)	₹ 2500 approx.
Rebar (0.8 cm)(48 meter)	₹ 2000 approx.
Labour, Equipment and Transportation	₹ 5000 approx.
15% Extra	₹ 2625 Approx.

₹ 20,125/- approx.

Corrugated Sheets (6 sheets)	₹ 8000
Nut-Bolts	₹ 500 approx.
Equipment and Transportation	₹ 2000 approx.

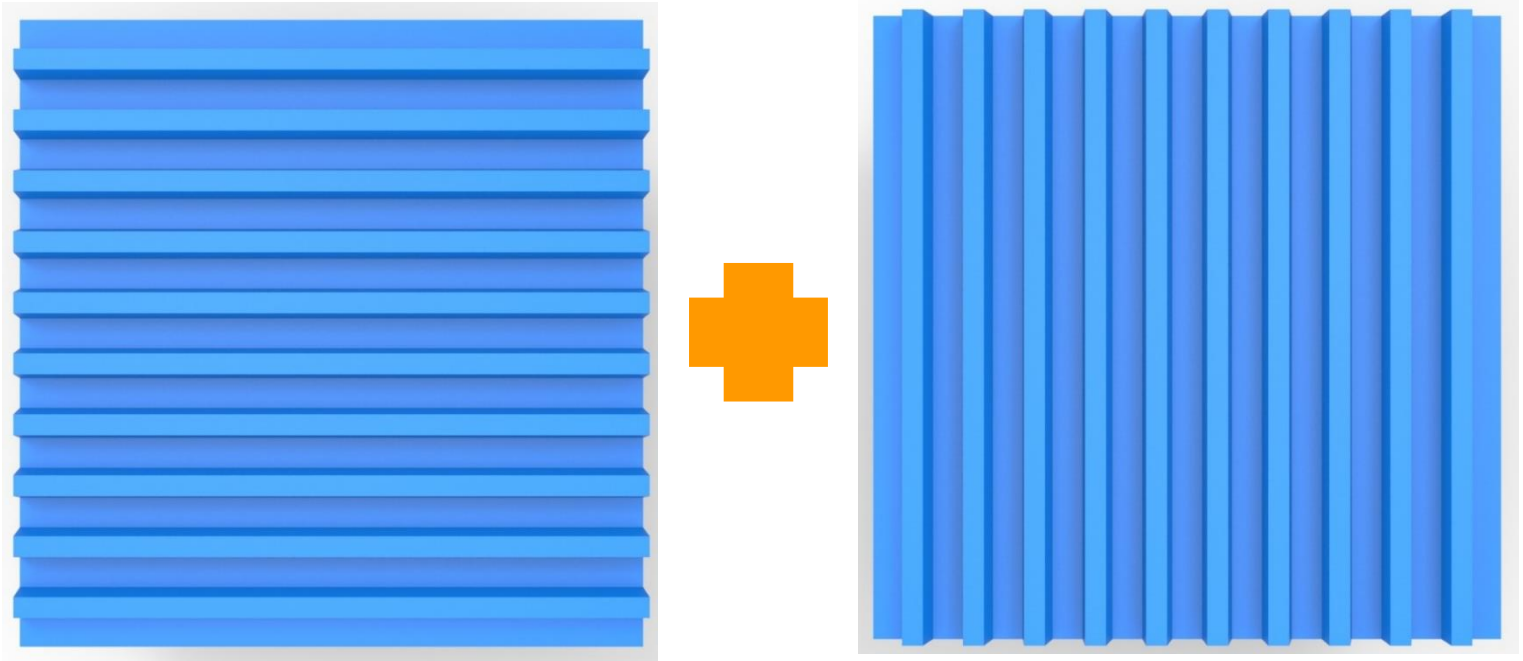
₹10500 /- approx.

Thus, from the cost analysis, it is clear that the proposed cross corrugation technique reduces the costs by almost 50%.



Why Criss-Cross?

In ordinary corrugated sheet , we are getting stiffness along with direction of corrugation only not from other side, that means the sheet can be bent or rolled from one end parallel to corrugation. That means we are getting stiffness only along corrugation. In order to achieve stiffness from both side we just joined another corrugated sheet in criss cross manner. Because of this now , nice stiffness along with x direction and y direction we are getting.



Where we can use this Structure?

By criss cross corrugation , we are getting air packets in between them. These air pockets can be used for electricity wiring but with special insulating coating. (Just like wiring done in airplane). Also these air pockets will work as a air insulator while this structure used as a wall system. We can use this structure in computer laboratory(fig 25 a.b.c) where no of wire connections are has to be fixed. We can use these air pockets for that wirings and all. Also we can use this structure in chemical laboratories where piping required ad we can hide this piping under these air pockets.

Fig 25 (a)Communication cables
https://c1.staticflickr.com/1/42/102017268_756ae32e41.jpg as seen on 10/11/2014

Fig 25 (b) laboratory wiring
http://anchorite.org/blog/wp-content/uploads/2008/03/wiringmess.jpg as seen on 10/11/2014

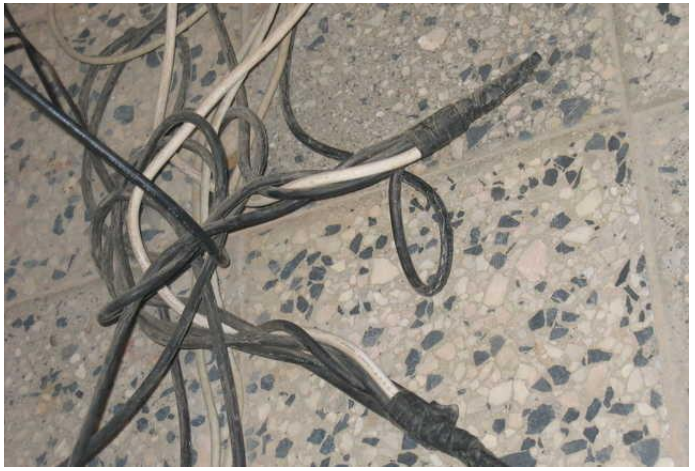
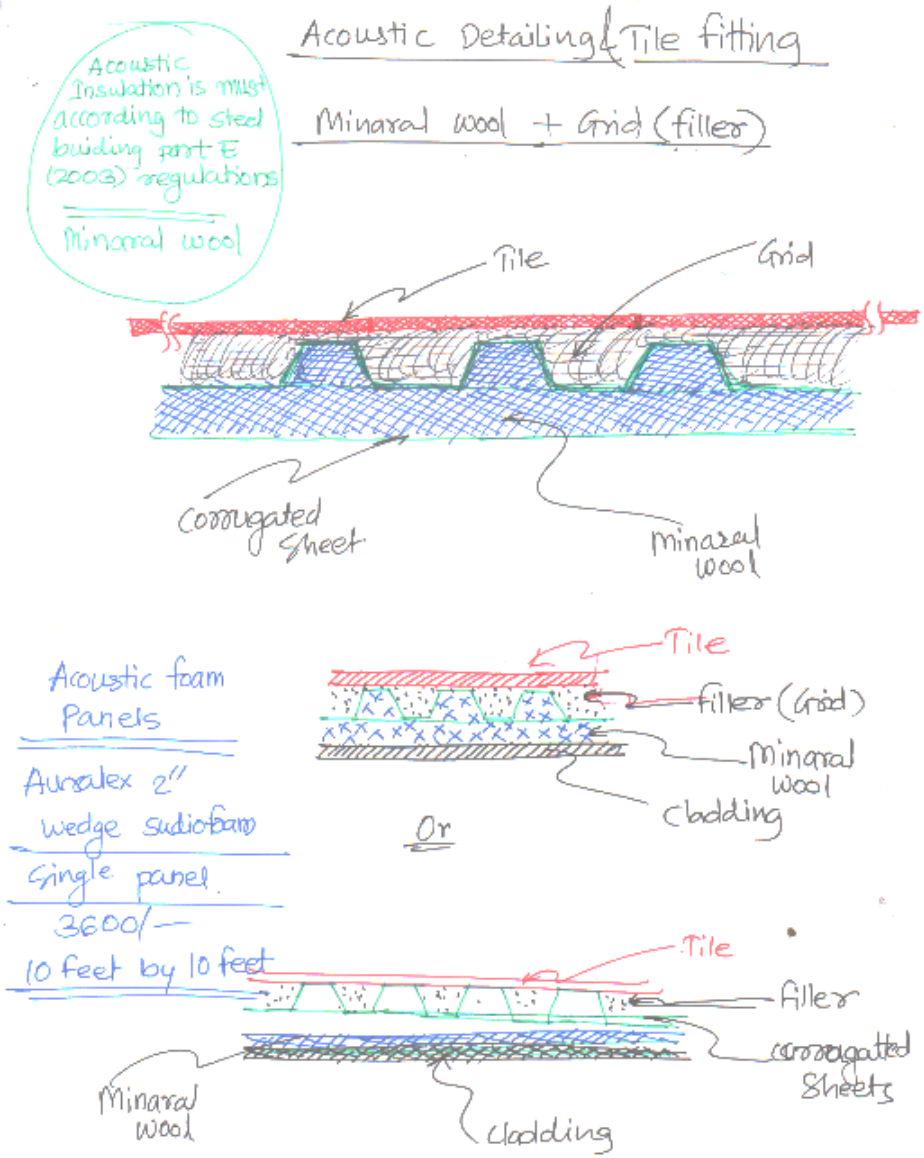


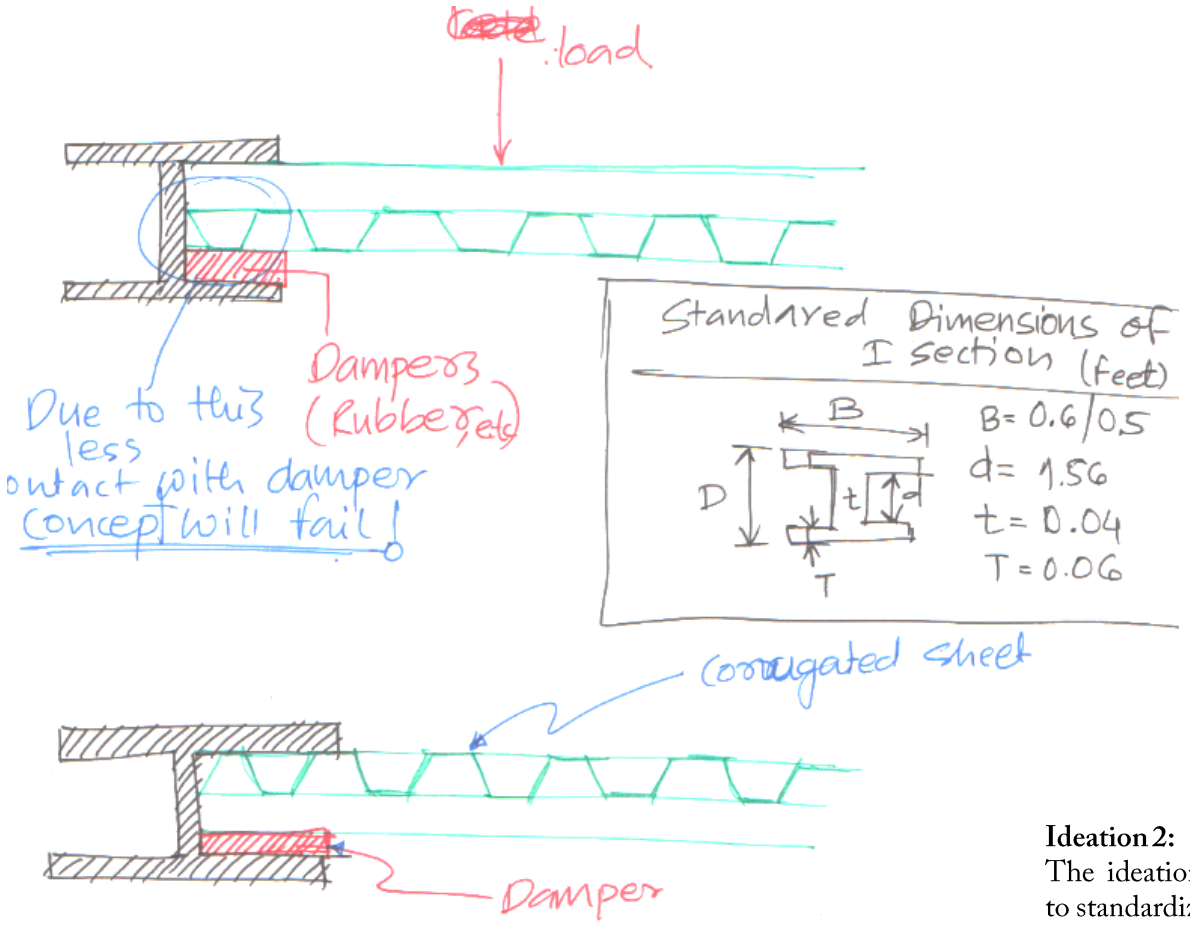
Fig.25 (c) computer wiring
http://alexlittle.net/blog/images/2008/12/img_3119.jpg as seen on 11/10/2014

Some Initial Ideations (After Stage 2)



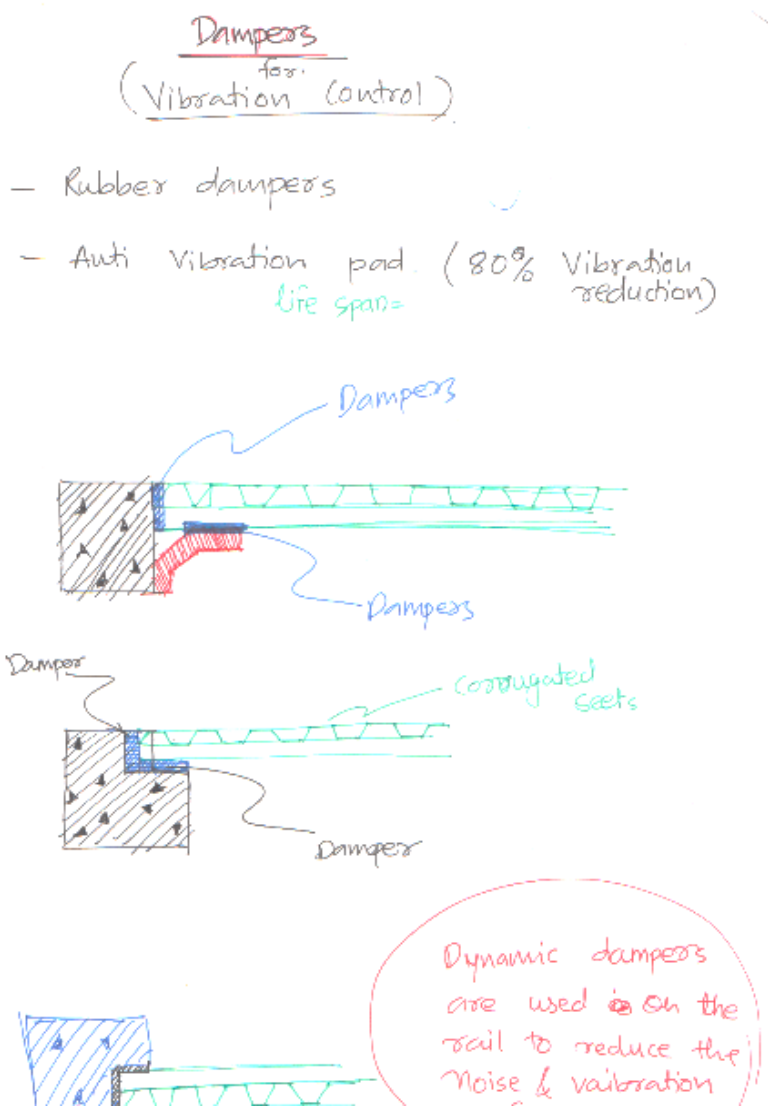
Ideation 1:
Insulation is a must as per laws laid down by construction authorities (Steel Building part-E, 2003). The ideation aims to include the same as a filler between the corrugation.

Some Initial Ideations (After Stage 2)



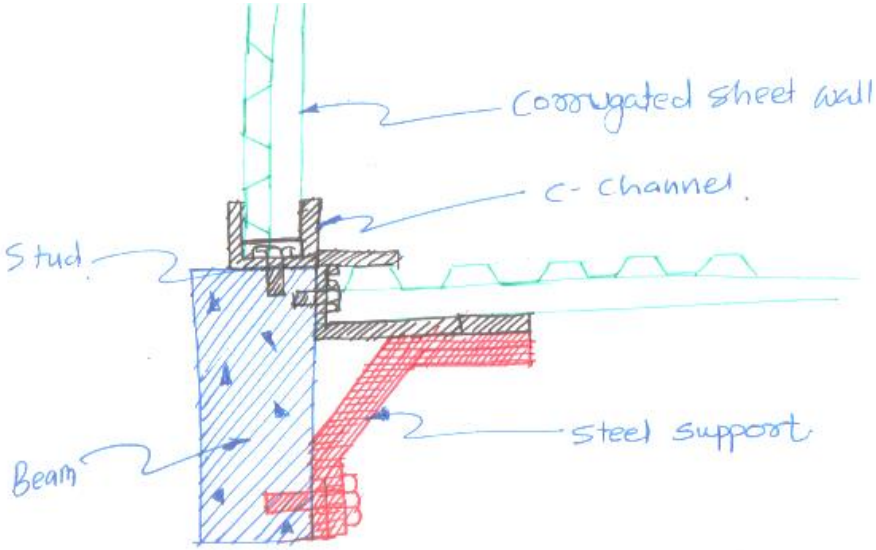
Ideation 2:
The ideation includes rubber dampers to standardize as per regulatory laws

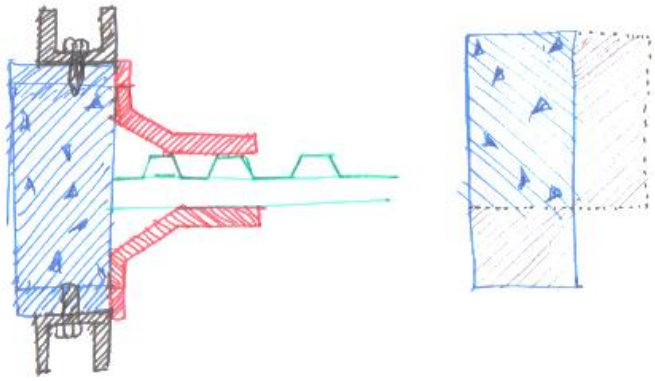
Some Initial Ideations (After Stage 2)



Ideation 3:
Considering analogies from vehicles and earlier ideations, here rubber dampers and anti-vibration pads have been used. This might lead to almost 80% reduction in vibrations.
Dynamic dampers can also be used for further stability.

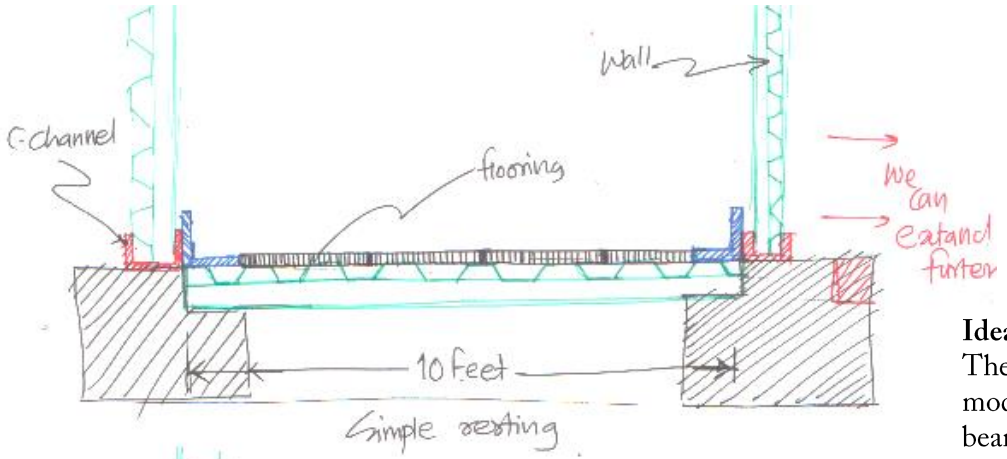
Some Initial Ideations (After Stage 2)



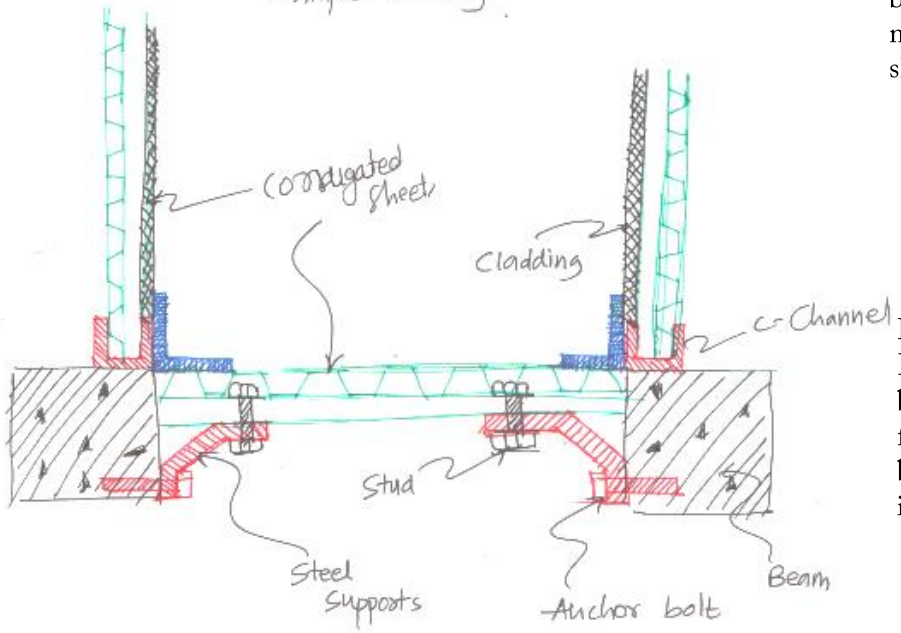


Ideation 4:
Here dedicated steel supports are bolted to concrete beams and the corrugated sheets are then held by these clamp-like supports. This allows for thermal expansion and a certain degree of freedom for movement.
(Bridges use such techniques)

Some Initial Ideations (After Stage 2)



Ideation 5:
The earlier ideations have been modified, where it is proposed that the beams are themselves precast in such a manner to allow for easy resting of sheets without any external component.



Ideation 6:
Here, the clamps are anchored to the beams as in earlier ideations, but the freedom of movement is restricted by bolting the corrugated sheets, thus improving upon the earlier design.

Construction details : How to use Criss-cross Corrugation Structure as a Floor Structure?

Cement concrete beam and column structure is casted as shown below.
These precasted concrete grids can be brought on site and la number of these precast can be laid out adjoining each other. The criss cross corrugation will be housed on the top face posing no hindrance to assembly of the precast grids in a vertical manner. The casts are such that the inner edges have slots for the corrugated sheets to rest without any fastening or other technique. They simply rest. To reduce noise and vibrations, by dynamic loading, the slots have rubber dampers.

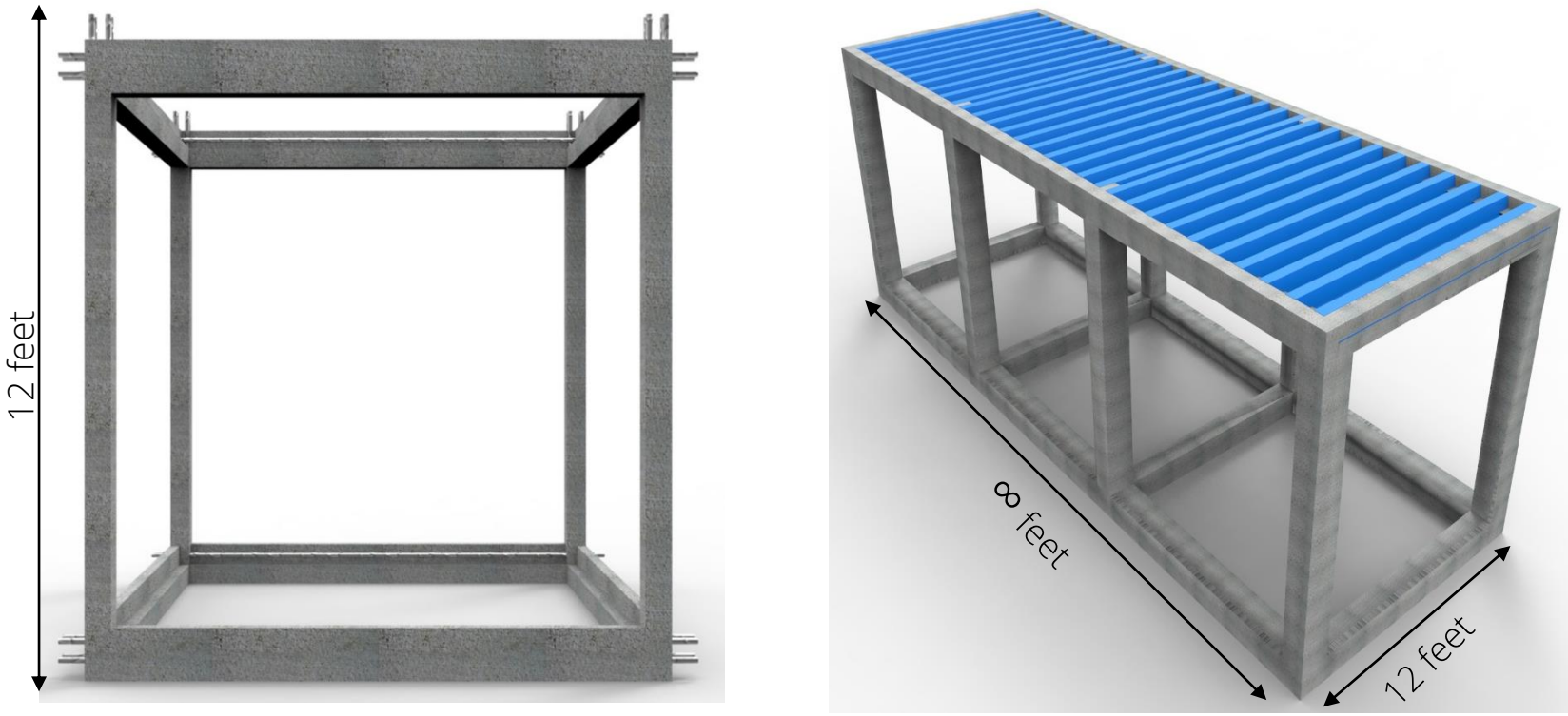
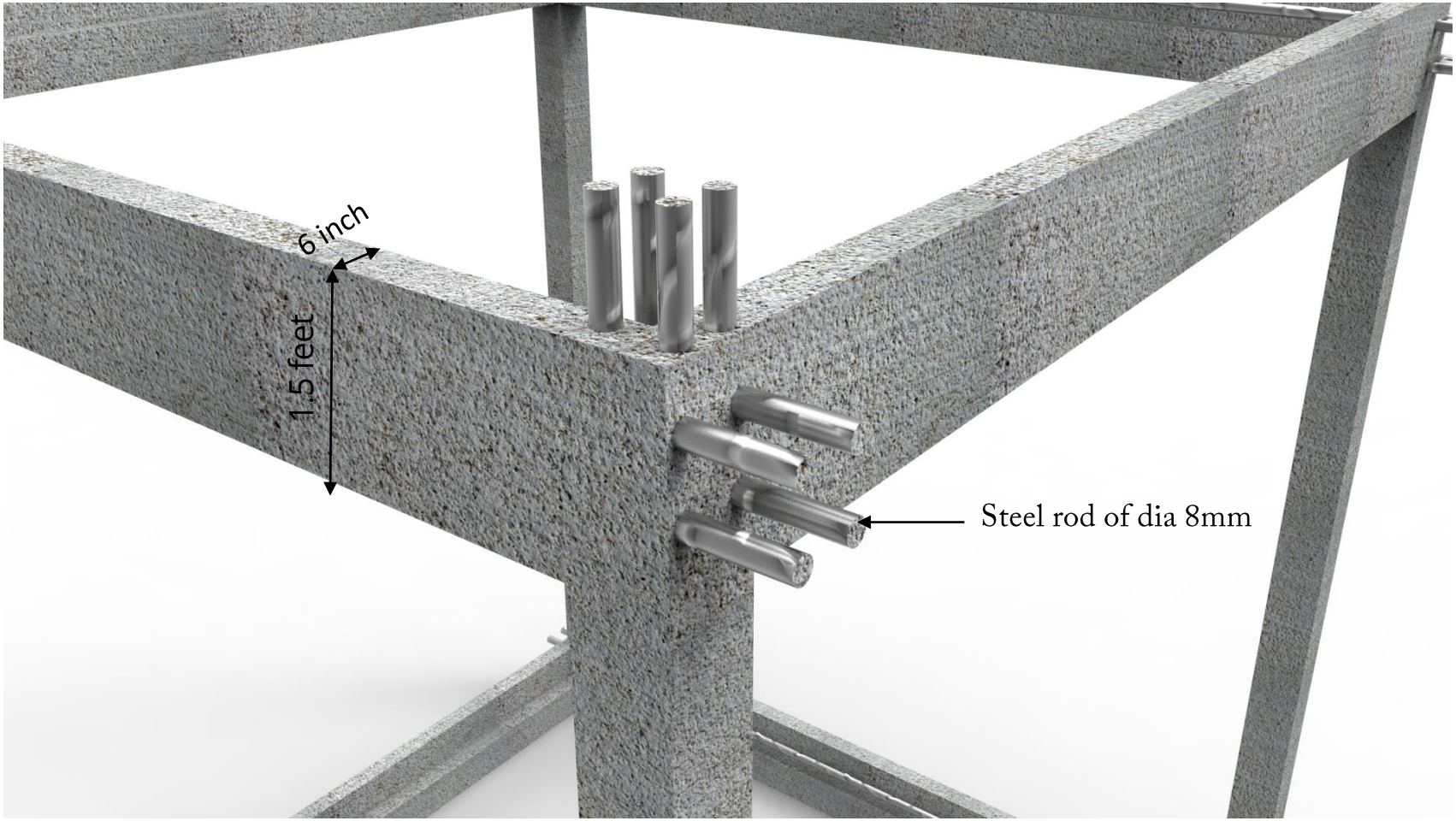


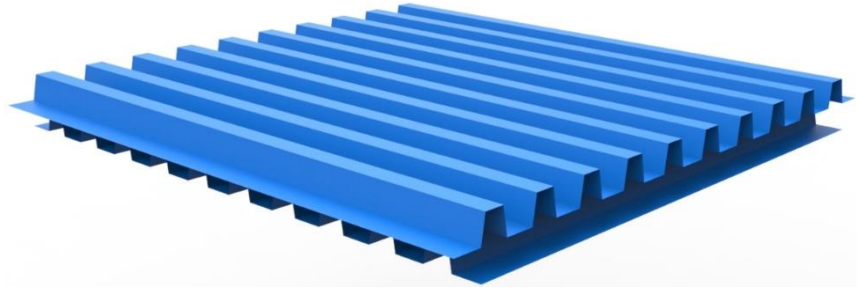
Fig. 26 3D models of ideation 5

Reinforcing Inside the Beam and Column

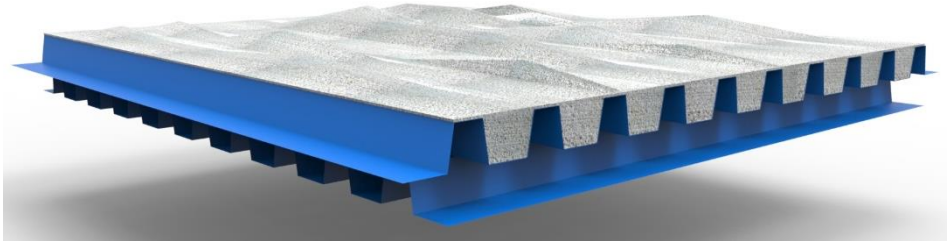


This is a minimalistic structure we can built out of rebar having minimum dia 8mm.

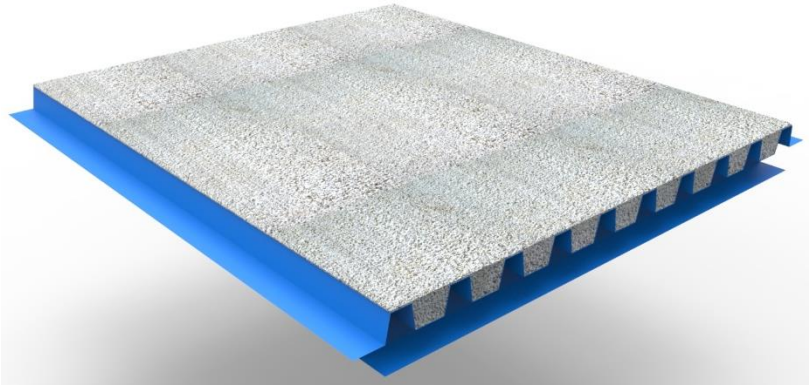
Step wise Procedure of using Criss Cross Corrugated Structure as a Floor Slab.



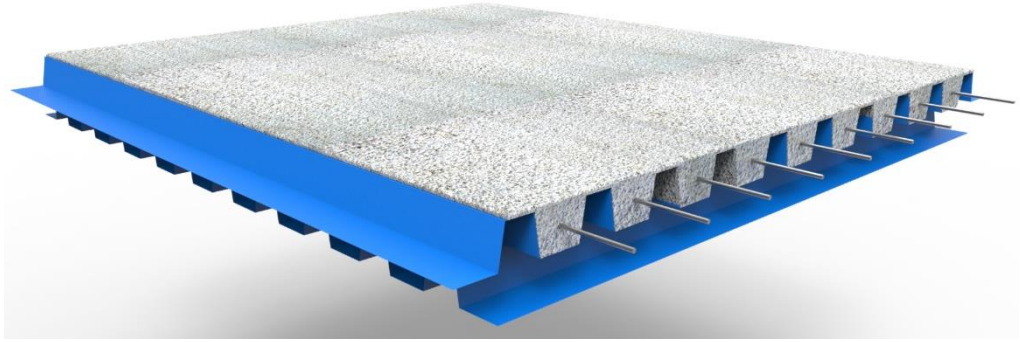
Step 1:
Two corrugated sheets are joined together by pop riveting in criss cross manner



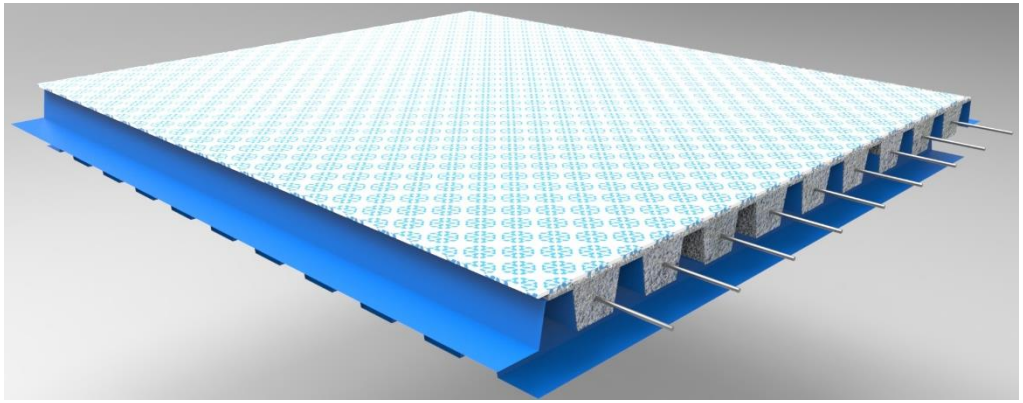
Step 2 :
Grid along with cement is placed above the structure as shown



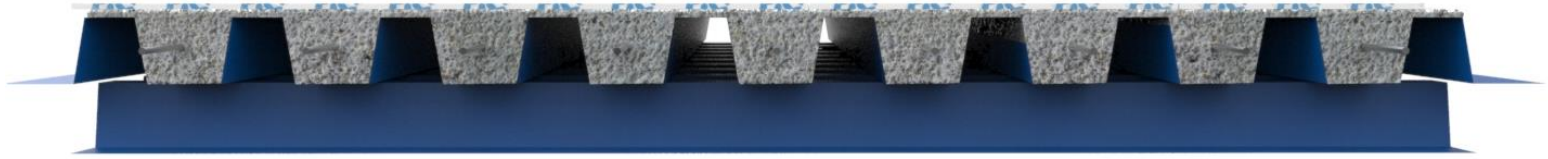
Step 3 :
By using any plane batten or a plane rod ,leaving of the grid + cement is done.



Step 4 :
Depending upon the area insert steel rod of having die 8mm inside the grid + cement.



Step 5:
As we are getting nice level of grid + cement just place the tiles above that. If needed use cement pest to settle the tile perfectly.



Floor is ready !!

Floor Support Detailing

After lot of ideations and discussions with guide and some validations, following two floor support concepts finalized.

This a simple concept where floor is placed on a beam having dimensions as discussed before. In this type of supporting the measure care is taken that is the floor should be rigid enough. For that 2 major considerations were took.

Fig.27 Woolen insulation
http://www.firestopcaulking.com/store/images/mineral%20wool.JPG as seen on 10/11/2014

1. Acoustics :

According to steel building part E (2003) regulation use of mineral wool is must in order to decrease the acoustic effect arising from steel material. So in this criss cross corrugation also take care of acoustic detailing. In the air pockets which we are getting because of criss cross ,we are using them as a pockets for filling mineral wool. (fig 27) As only 50 % area is exposed to the other sheet we are saving almost 20% of mineral wool.

Fig.28 Rubber damper
http://img.directindustry.com/images_di/photo-g/rubber-dampers-28243-2793755.jpg
as seen on 10/11/2014

Fig.29 Anti-vibration pads
http://image.made-in-china.com/2f0j00YCLafeltvBzK/ as seen on 10/11/2014

2. Vibration Control :

As we know dynamic dampers are used on the rail to reduce the noise and vibrations of steel railway bridge. Same kind of dampers are used here to control the vibrations. Following are two types of dampers selected

a. Rubber damper (fig 28)

b. Anti vibration pad (fig 29)

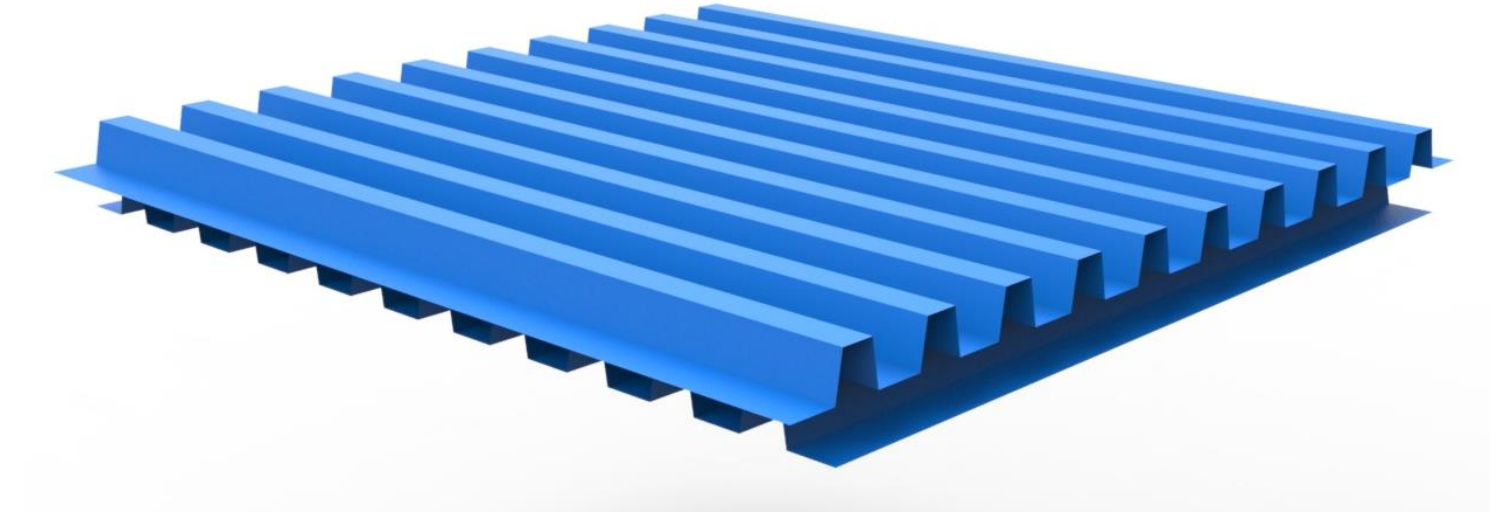
Anti vibration pad is cheap and durable as compared to the rubber dampers.

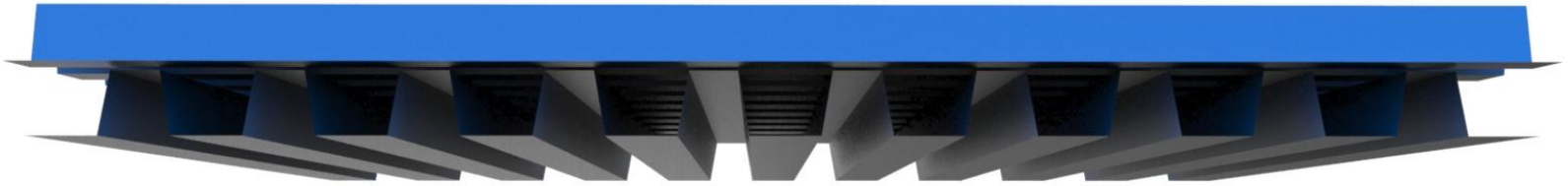
Scenarios

By considering following scenarios, CCC structure for floor slab is designed

1. CCC Structure
2. CCC to CCC joinery
3. CCC to building joinery
4. Size, Volume and Weight
5. Transportation

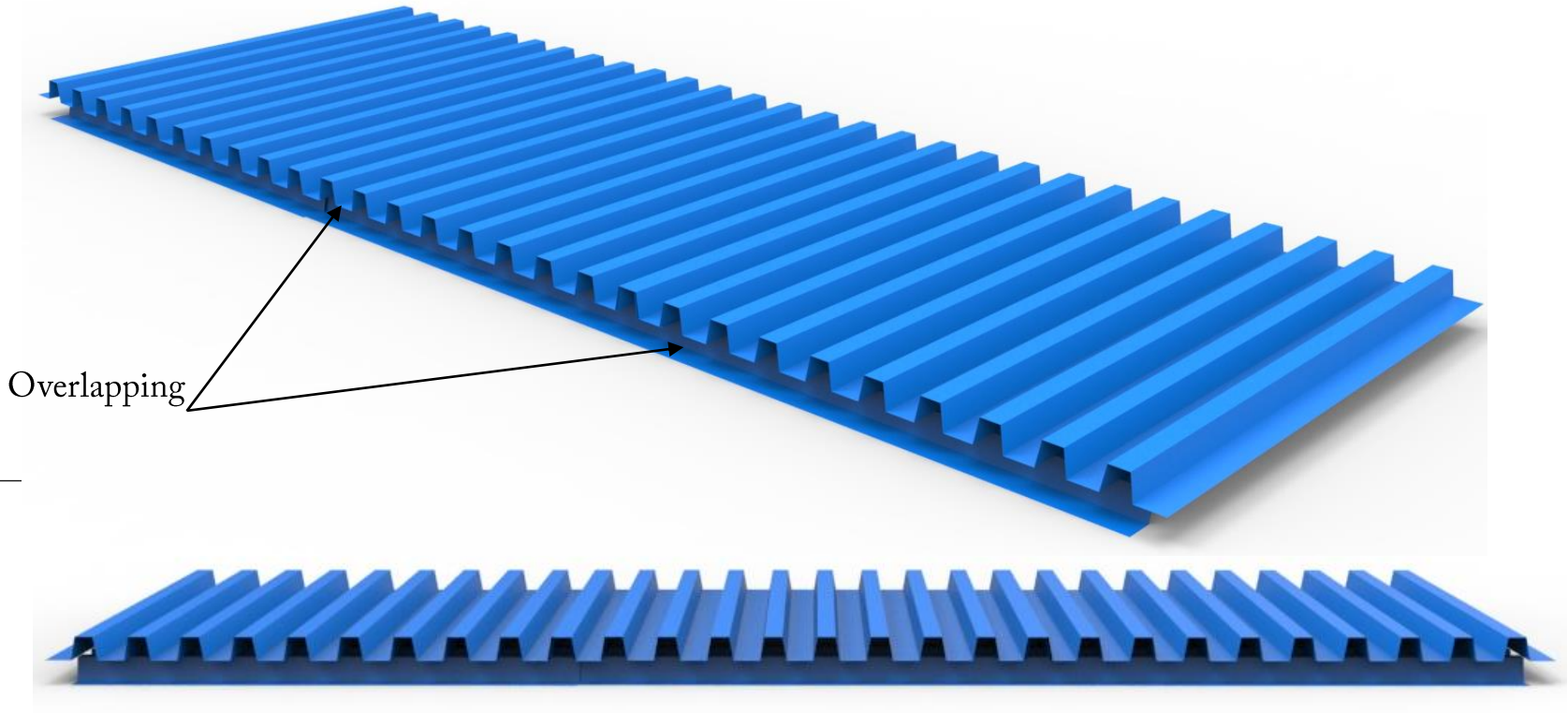
Scenario 1. CCC Structure





Total 6 corrugated sheets (3 above and 3 below) in a criss cross manner are used to made 1:1 size model. The arrangement provides gaps which can serve as ducts for number of piping, wiring, etc.

Scenario 2. CCC to CCC Joinery

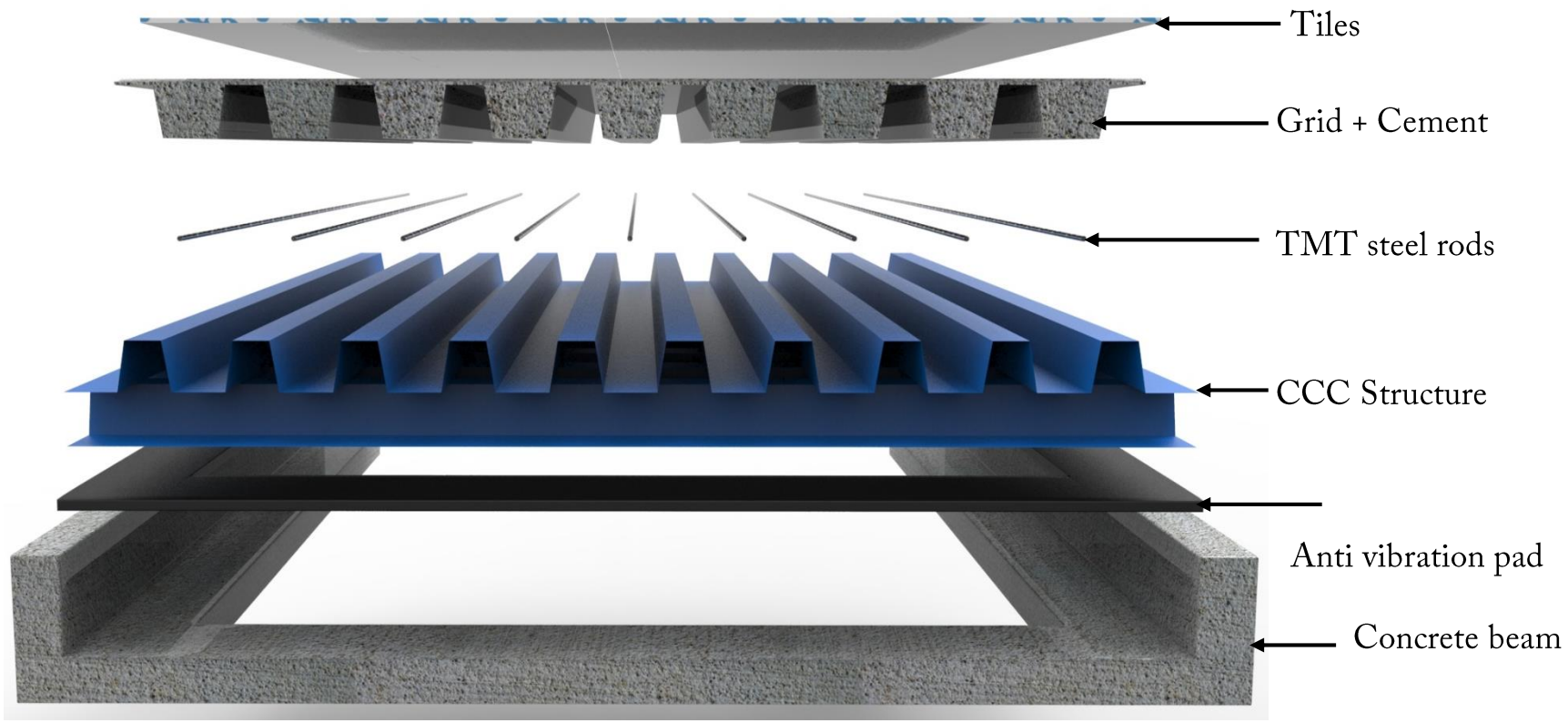


The overlapping criss cross structure acts as a beam itself. The innovative use of cross corrugation unable increased strength by use of minimal inventory. The structure is light weight in itself. It can be adapted to any dimensions and can be assembled to house itself in precast cement concrete grids of various dimensions. Since the upper and lover sheets are similar the no of items in the bill of materials remains the same. Riveting can be done to provide additional support. The beam thus formed can grow in both directions. Riveting can be done to provide additional support.

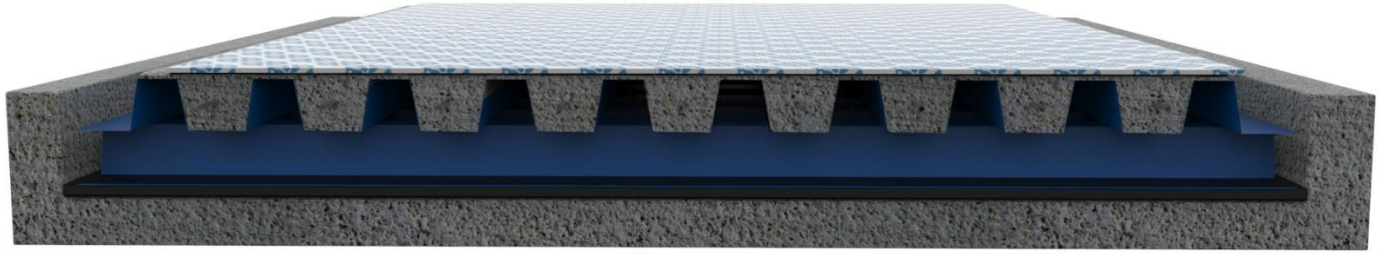
The rigidity of cross corrugation can be increased by riveting the two panels together. By doing so, the structure become suitable to dynamic loading.

Nut bolting is a reversible method of bringing the two panels together. It is more suitable over adhesive bonding and riveting due to its reversibility. This feature is much required in an application as ours , where quick assembly and forgivance are a quality that the unskilled worker might appreciate. .

Concept 1's Exploded View

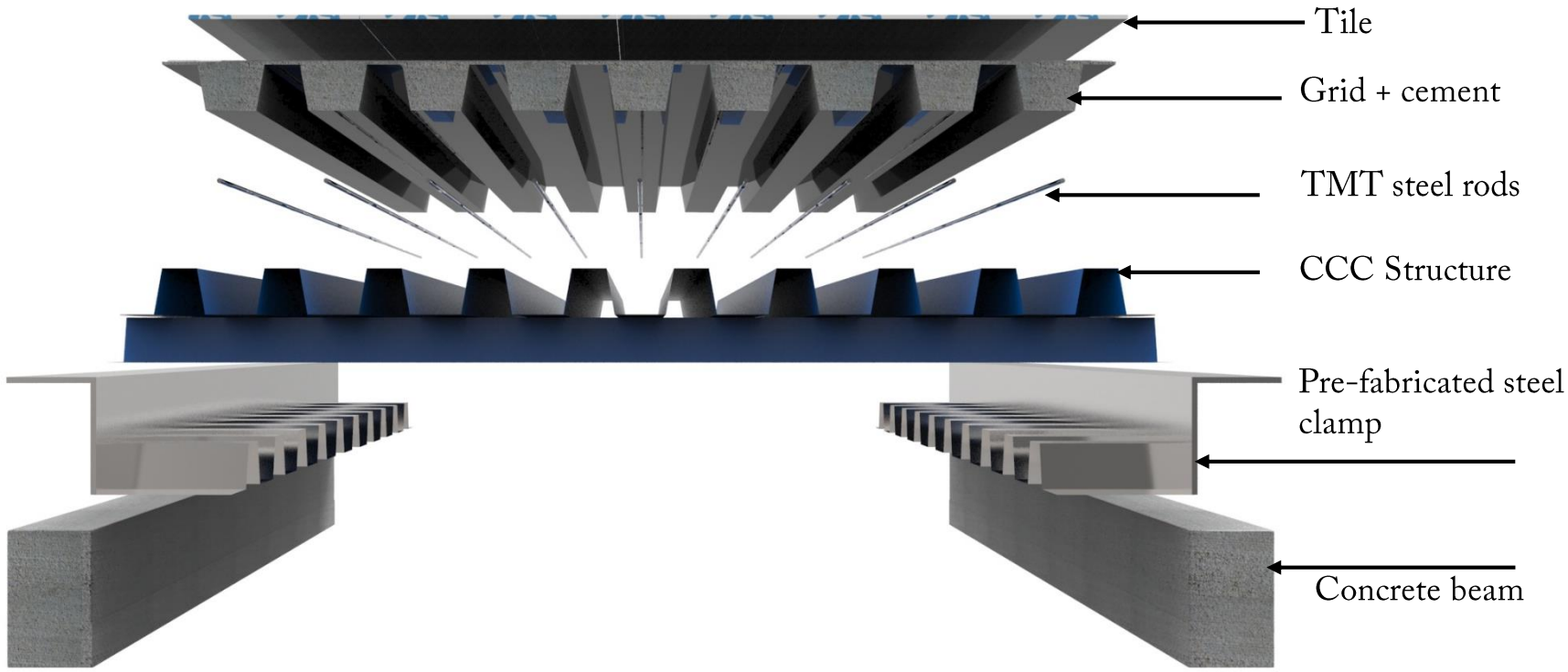


Concept 1 : Final front view

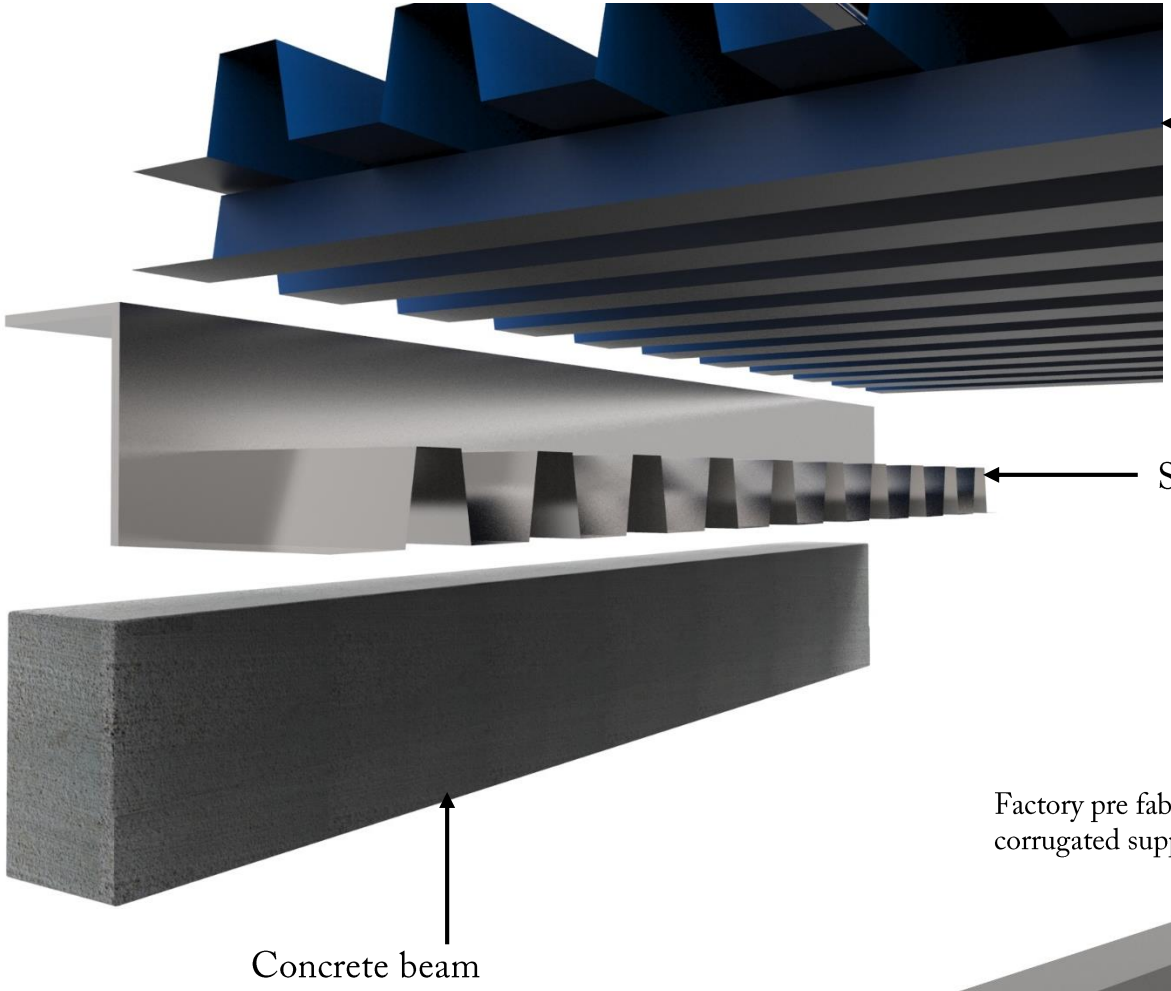


Precast concrete beams with slots to allow corrugated sheets to rest on vibration dampers. For further strengthening the composite structure, TMT rods can be laid in the gaps filled with cement. After levelling, the final finish can be done.

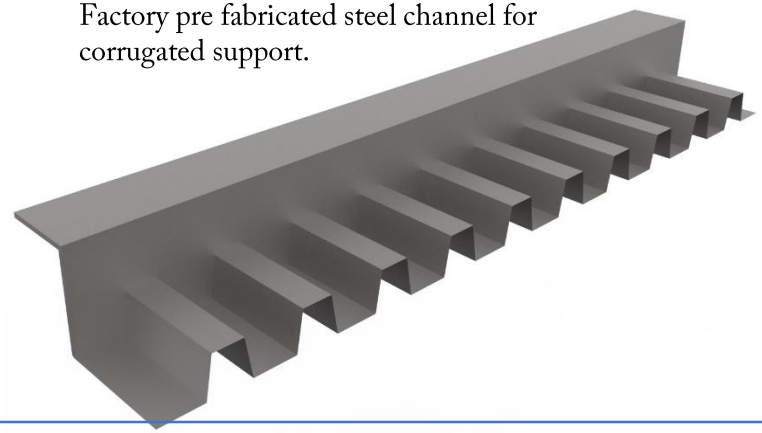
Concept 2's Exploded View



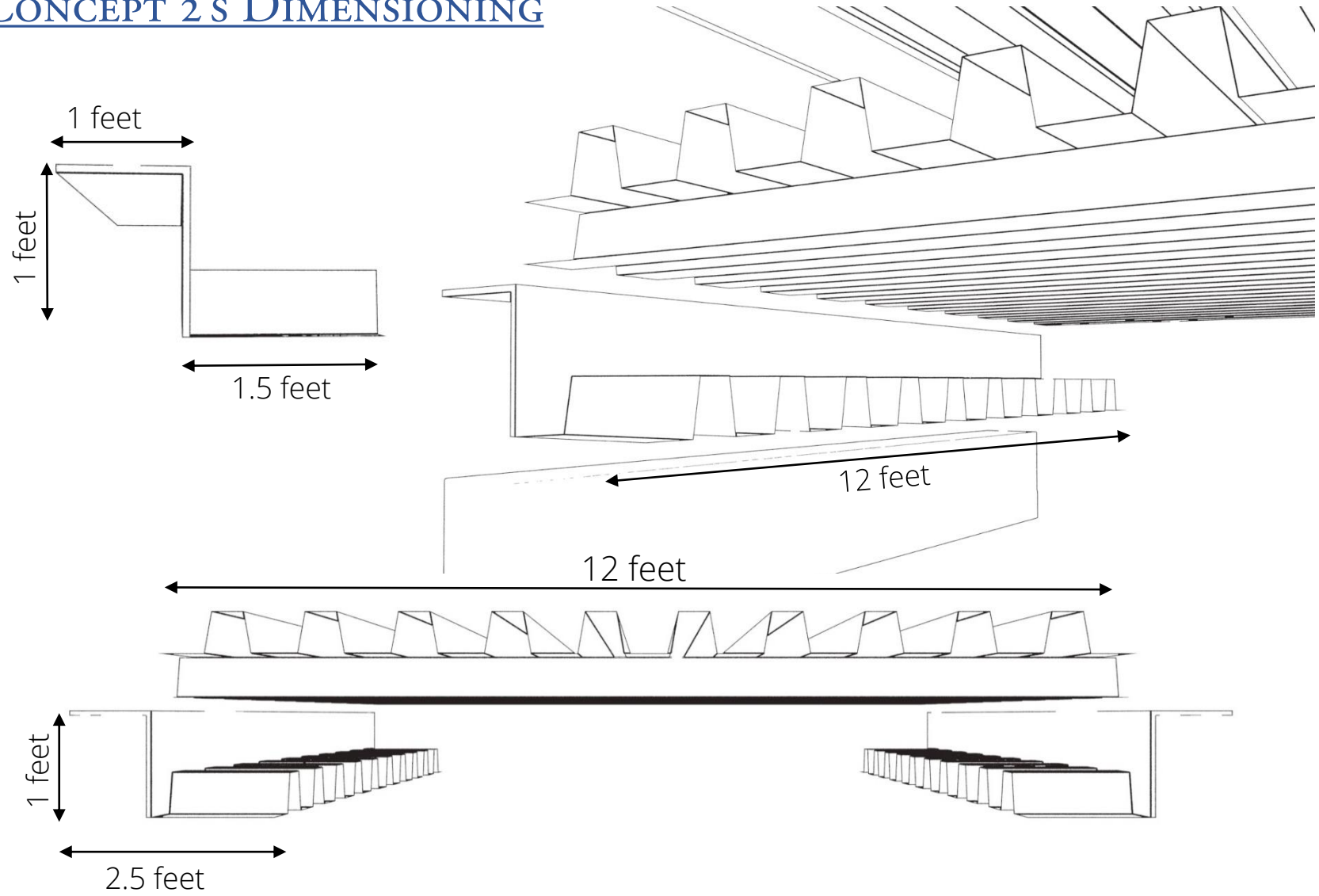
Here, the steel clamps that are anchored to concrete beams to support the corrugated sheets are shaped in the profile of the sheet itself. This ensures total contact and uniform distribution of load thus preventing buckling of the sheet in case of dynamic or excessive loading. (Details of clamp profile on the following page)



Factory pre fabricated steel channel for corrugated support.



Concept 2's Dimensioning



4. Size, Volume and Weight

Technical specifications selected

Reference Corrugated sheet
http://www.china-geoffering.com/corrugated-steel-sheets/images/steel-painted-corrugated-sheets.jpg as seen on 14/11/2014

Approximate Weight Per Sheet (for 120 gsm coating)

Size (Thickness X Width)	Approximate Weight per Piece for Various Lengths of Sheet (in Kg)							
(mm)	6ft (1830mm)	7ft (2135mm)	8ft (2440mm)	9ft (2740mm)	10ft (3050mm)	12ft (3660mm)	14ft (4270mm)	16ftm (4880mm)
0.30 x 800	3.66	4.3	4.88	5.49	6.14	7.33	8.59	9.77
0.35 x 800	4.34	5.01	5.79	6.51	7.15	8.68	10.02	11.57
0.40 x 800	4.94	5.77	6.59	7.41	8.24	9.88	11.53	13.17
0.45 x 840	5.58	6.51	7.44	8.37	9.3	11.15	13.02	14.87
0.50 x 840	6.2	7.24	8.27	9.3	10.34	12.43	14.52	16.54
0.55 x 840	6.86	8.01	9.15	10.29	11.45	13.72	16.03	18.3
0.60 x 840	7.5	8.75	9.99	11.24	12.5	14.99	17.51	19.9
0.63 x 840	7.88	9.21	10.51	11.82	13.15	15.76	18.41	21.02
0.80 x 840	10.05	11.74	13.4	15.08	16.77	20.1	23.47	26.8
0.30 x 910	4.05	4.72	5.4	6.07	6.75	8.1	9.45	10.79
0.35 x 910	4.84	5.66	6.45	7.26	8.08	9.67	11.31	12.9
0.40 x 910	5.56	6.5	7.42	8.35	9.28	11.13	13	14.84
0.45 x 910	6.28	7.32	8.38	9.43	10.46	12.57	14.65	16.76
0.50 x 910	6.99	8.17	9.32	10.49	11.67	14	16.33	18.68
0.60 x 910	8.49	10.01	11.31	12.73	14.3	16.98	20.03	22.63
0.63 x 910	8.96	10.39	11.95	13.44	14.84	17.92	20.77	23.9

http://www.china-geoffering.com/corrugated-steel-sheets/images/steel-painted-corrugated-sheets.jpg as seen on 14/11/2014

From above specification chart and some field study, Sheets having thickness 0.50mm and having 3feet*12feet are selected

5. Transportation

Eicher 11.10 has been specifically designed for heavy-duty applications. A strong built combined with high fuel efficiency add up to make this a Heavy duty Profit machine for its owner. This model is an ideal long distance load carrier owing to its high capacity fuel tank, high speed, better manoeuvrability and faster turnaround. It has an unbeatable lead in rated payload w.r.t similar GVW vehicles. With highest mileage in its category and only option of 20ft in its category, it is the best selling – value for money truck.[3]

EICHER 11.10

Typical Transport truck
http://www.adpost.com/classifieds/uploadt/in/vehicles/in_vehicles.12103.1.jpg as seen on 14/11/2014

APPLICABLE SEGMENT

- Cement
- Food Grains
- Furniture
- Gas Cylinder
- Hardware
- Low density volumetric loads 2/3 wheeler carrier
- Low end users of HCV
- Market Load
- Poultry Feed
- Sugar
- White Goods

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[1] (12 November 2014 at 22:12.) *Concert slab,* Available at: *http://en.wikipedia.org/wiki/Concrete_slab* (Accessed: 12/11/2014).

[2] (28 September 2014 at 01:19.) *Flooring,* Available at: *http://en.wikipedia.org/wiki/Flooring* (Accessed: 12/11/2014).

[3] *Eicher truck* , Available at: *http://eicher.in/etb/Products/Haulage/Eicher11.10* (Accessed: 14/11/2014).

[4] (11 October 2014 at 09:25.) *Fastener,* Available at: *http://en.wikipedia.org/wiki/Fastener* (Accessed: 12/11/2014).

[5] (11 October 2014 at 20:54.) *Steel Building,* Available at: *http://en.wikipedia.org/wiki/Steel_building* (Accessed: 14/11/2014).

[6] Jeff, Yatheesh Raju, Loni_lings *Concrete,* Available at: *http://www.wikihow.com/Place-and-Finish-a-Concrete-Floor* (Accessed: 12/11/2014).

[7] Leslie Struble and Jonathan Godfrey () *Footpint* , Available at: *http://www.greenrationbook.org.uk/resources/footprints-concrete/* (Accessed: 14/11/2014).