# Modular building – A cost effective solution

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**ABSTRACT**

*Our project aims in reducing the problems acknowledged by labour accommodation for construction purposes. Thereby adopting the method of Modular Building construction. Our model design is a single room for labours at site. We have selected a Cellular Light weight concrete panels as a wall material and cold formed rolled steel as a secondary structural member and Hot rolled steel as primary structural member. The need for modular building is bringing a change in the way the world builds. The following points emphasizes on why modular building can be used. 1. Greener-Less site disturbance, Greater flexibility and reuse, less material waste, improved air quality, Factory controlled process, 2.Faster-Reduced construction schedule, Built to Code with Quality materials. Elimination of Weather Delay. 3. Smarter- Safer Construction, Better Engineered Building, Limitless designed opportunities. 4. Sustainability- Energy efficient, Minimizing transport, health and wellbeing. This structure can also be used in residential, school and hospital buildings making it cost effective.*

## INTRODUCTION

‘’Modular Construction” is a term used to describe the use of factory-produced pre-engineered building units that are delivered to site and assembled as large volumetric components or as substantial elements of a building. The modular units may form complete rooms, parts of rooms, or separate highly serviced units such as toilets or lifts. The collection of discrete modular units usually forms a self-supporting structure in its own right or, for tall buildings, may rely on an independent structural framework.

our project focuses on a basic modular structure which can be used by labors at construction site. Our main focus has been to achieve a design that is economical and cheap. To ensure that the structure can be Reusable for various projects is also kept in account for.

Ours is a Relocatable modular building which can be utilized for schools, construction site offices, medical clinics, sales centers and in any application where a relocatable building can meet a temporary space need. These buildings offer fast delivery, ease of relocation, low-cost reconfiguration, accelerated depreciation schedules and enormous flexibility.

## LITERATURE REVIEW

Types of modular building

The following type of modules may be used in the design of buildings using either fully modular construction or mixed forms of steel construction:

1. 4-sided modules
2. Open sided (corner supported ) modules
3. Modules supported by a primary structural frame
4. Non-load bearing modules
5. Mixed modules and planar floor cassettes

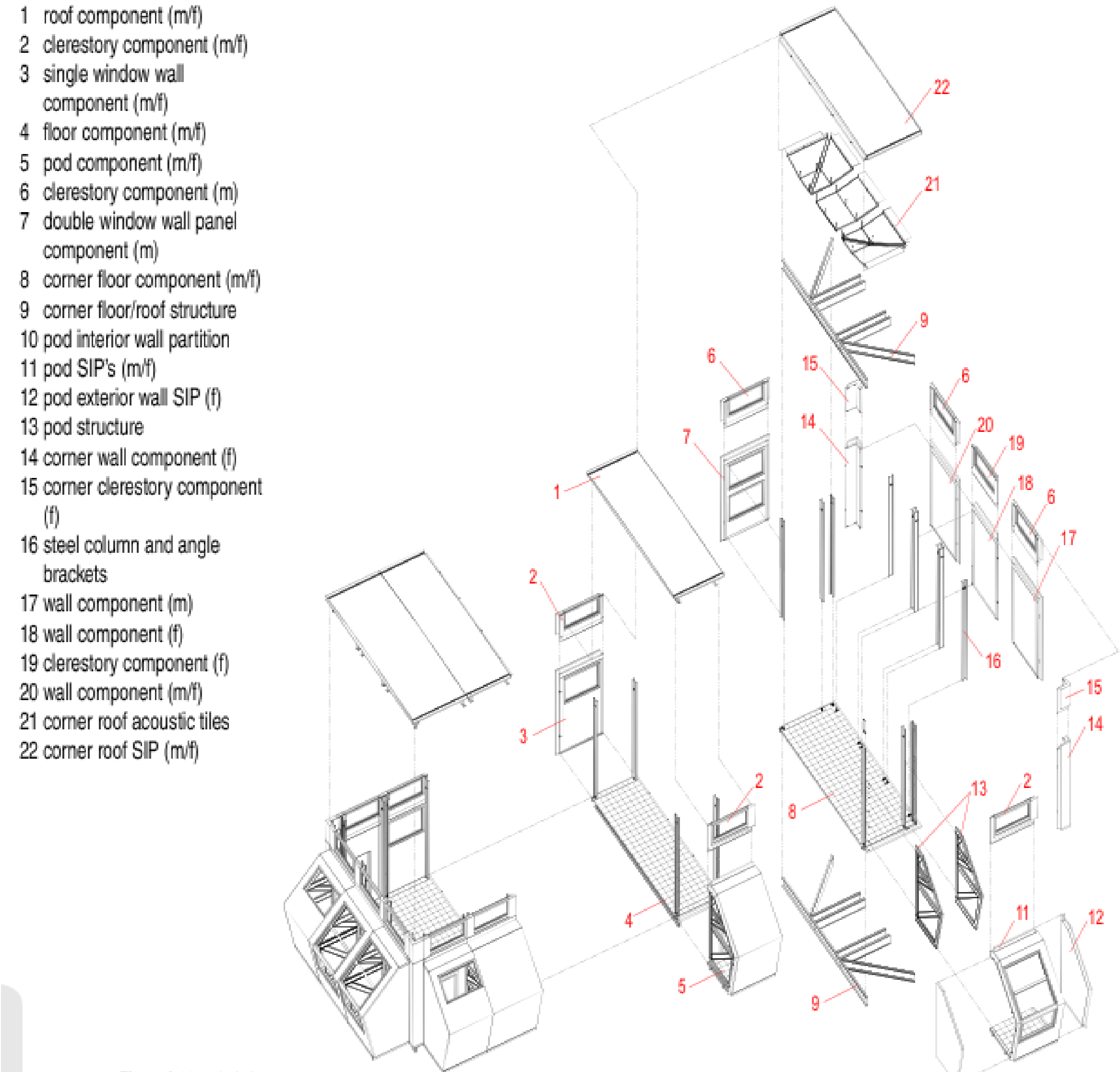


*Figure A.21* exploded axonometric

Different material used construction of modular building -
1. Structural insulated panels
2. Insulating concrete forms
3. Colour coated Galvalume sheets
4. Zincalume steel
5. Colourbond steel
6. PUF panel
7. Sandwich panel
8. Aerocon panels
9. Cold form steel frame
10.Hot rolled steel frame
11. Light steel framed infil walls
12.Cellular light weight concrete

## METHODOLOGY

To select a most cost effective,reliable,efficient modular building we studied different types of modular building above and from that we have chosen four side module.for a strong design of module we have considered following loads,material,manufacturing process as following -

**DESIGN**:

Load considerations –dead load
Connection details –bolted
Fire resistance
Spacing
Acoustic

**MATERIALS:**

Square hollow section
Cellular hollow light weight concrete panels
C Section
Corrugated sheets
Mineral wool

**EQUIPMENTS[3]:**

CNC plasma cutting machine with cutting bed 8 x 40 feet
CNC Roll forming line 20 stations for roof sheet profiling
Submersible arc welding (SAW) line & Co2 / arc welding Machines
Powder Coating unit with 25 x 6 x 6 feet oven
Hydraulic press break, shearing machine, Power press machines
Drilling , punching machines
Polyurethane foam wall panels unit with 5 x 12 feet press
Latest design & detailing software
Skilled Man power and Engineers

**3.1 DESIGN CONSIDERATIONS**

The different loads have to be accounted for while designing different components of the modular building. The loads have been taken into consideration as per the standards. Depending on these loadings, the member specifications have been finalised and tested for bending, shear etc. The loads accounted for are as follows:

**3.1.1 Dead loads for various building components[14]**

For dead loads coming on the building, the following values have been taken into account according to the structural element.

Table 3 Dead load considerations for building

| Element | Dead load (kN/m$^2$) |
|---|---|
| Flooring grade chipboard | 0.1 to 0.2 |
| 65mm concrete screed | 1.50 |
| 75mm concrete screed | 1.75 |
| 100mm concrete floor slab | 3.50 |

3.1.2 Imposed loads[14]

Table 4 Imposed load considerations for building

| Element | Loading |
|---|---|
| Roof | Distributed load 0.75kN/m$^2$ or concentrated load of 0.9kN |

| | |
|---|---|
| Floors<br>Above ground storey<br><br>Communal areas<br><br>Corridors, staircase, etc | <br>Distributed load 1.5kN/m$^2$ or concentrated load of 1.8kN<br>Distributed load 2.0kN/m$^2$ or concentrated load of 2.7kN<br>Distributed load 3.0kN/m$^2$ or concentrated load of 4.5kN |
| Ceilings | Distributed load 0.25kN/m$^2$ or concentrated load of 0.9kN |

**3.2 Design of the various member**

Here actual design process starts where we first calculated loads coming on the members. Trials were conducted on various sections by using the software STAAD.PRO. By analysing the various results, the most economical section was selected and the manual calculation for the design in terms of shear, bending etc was compared with the software results. The various steps of manual calculation are as shown below:
The design loads considered were:

1. DL of roof-210N/sq.m
2. Purlin -70N/sq.m
3. Fixing-25N/sq.m

**3.2.1. Joist**

Problem statement-check for Moment of resistance, shear strength, web crushing strength at end support.

Selected section 30x15x1.25[6]
Analysis of section under compression

Shear force = 0.225kN
Bending moment=0.056kN.m

Material properties
T=1.25mm
D=30mm
$R_{yy}$=49.9mm
$I_{xx}=0.916\times10^4\ mm^4$
$Z_{xx}=0.611\times10^3\ mm^3$

$$P_y = \frac{240}{1.15} = 208.7\text{MPa}$$

$F_y$=240MPa
Only compression flange is subjected to local buckling.
Limiting stress for stiffened web in bending

$$P_o = \left\{1.13 - 0.0019\left(\frac{D}{t}\right)\left(\sqrt{\frac{Fy}{280}}\right)^{0.5}\right\} \times P_y$$

$$P_o = \left\{1.13 - 0.0019\left(\frac{30}{1.25}\right)\left(\sqrt{\frac{240}{280}}\right)^{0.5}\right\} \times 208.7$$

= 227.69MPa
Which is equal to the maximum stress in compression flange ie Fc=227.69MPa
Effective width of compression flange

$$H = \frac{B_1}{B_2} = \frac{15}{30} = 0.5$$

$K_1 = 5.4 - \left(\frac{1.4 \times h}{0.6+h}\right) - (0.02h^3)$ =4.76

$P_{cr} = 185000 \times k_1 \times \left(\frac{T}{b}\right)^2$ = 1528.8MPa

$\frac{F_{cr}}{(P_{rc} \times \gamma_m)} = 0.136 > 0.123 \ldots . OK$

Beff/B=((1+14((Fcr/Pcr)^0.5)-0.35)^4)^(-0.2))
=1
Beff=30mm=B
i.e. full section is effective in bending

The moment of resistance=$M_{cx} = \left(Z_{xy} \times P_y\right) = (0.611 \times 10^3) \times \left(\left(\frac{240}{1.15}\right) \times 10^6\right)$
$= 0.127\ kN.m > 0.05kN.m \ldots\ldots$ OK

Shear resistance:
Shear yield strength,

$P = 0.6 \times P_y = 0.6 \times \left(\frac{240}{1.15}\right) = 125.2$Mpa

Shear buckling strength

$q_{cr} = \left(\frac{1000 \times T}{D}\right)^2 = 1736MPa$

Max shear force = 0.225 kN
Average shear stress ,

$f_v = \frac{shear\ force}{area} = \frac{(0.225 \times 10^3)}{(30 \times 1.25)} = 6Mpa < 1736Mpa \ldots \ldots OK$

web crushing strength at end support ,

$\frac{D}{T} = \frac{30}{1.25} = 24 < 200 \ldots \ldots OK$

**3.2.2 Stud design :**
Check for axial buckling resistance**.**
L = 2.5m

$L_{effective} = \frac{0.85}{2.5} = 2.125$ m

Select 50 X 25 X1.6[6]

$F_{y=}$ 240n/mm$^2$

$P_y = \frac{240}{1.15} = 208.7$ MPa

Properties
A = 1.49 cm$^2$
$I_{xx}$= 5.70 cm$^4$
$I_{yy}$= 0.923 cm$^4$
$R_{min}$ = 0.787m

Load factor ,

$Q = \frac{A_{effective}}{A}$
$= \frac{1.41}{1.49}$
= 0.95

The short strut resistance

$P_{CS=}\ 0.95 \times 1.49\ \times\ 10^2\ \times (\frac{240}{1.15})$

$= 29.5$ kn

$P_u = 0.225$ kn < 29.5 kn…... OK

Axial buckling resistance

Check for maximum allowable slenderness

$\frac{L_e}{r_y} = \frac{2.12 \times 10^3}{0.787 \times 10^2}$

= 26.93 < 180 …… OK

To find member forces :

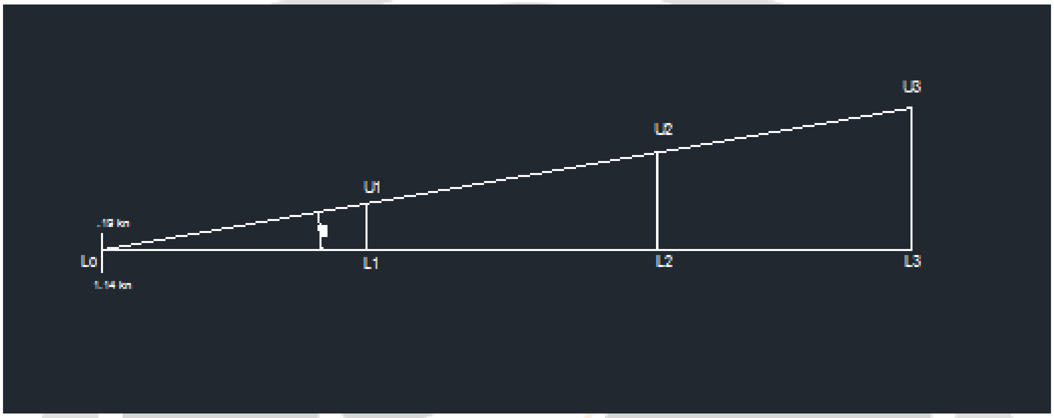


Fig.17 Member force

∑Fy=0

$FL_0U_1 \times \sin(10) + 1.4 - 0.19 = 0$

$FL_0U_1$= -5.47KN

∑Fx=0

$-5.47 \times COS(10) + FL_0L_1 = 0$

$FL_0L_1$ = 5.38KN

Top chord

Pu= - 8.20 kn

Bottom chord

Pu= 8.07 kn

3.2.3 Connection design[13]

$\emptyset = 10\text{to}12\text{mm}\ \ (6.05 \times \sqrt{\text{t}})$

P=2.5x(d)=25mm

e=1.5x(dh)=18mm

To find shear capacity of bolt-

$V_{dsb} = ((\frac{f_b}{\sqrt{3}}) \times \gamma) \times (1.8 \times (\frac{\pi}{4}) \times d^2)$

$V_{dsb} = ((\frac{400}{\sqrt{3}}) \times 1.25) \times (1.8 \times (\frac{\pi}{4}) \times 10^2)$

=26.11KN

Bearing strength of bolts-

$V_{dpb} = 2.5 \times K_b \times d \times t \times (\frac{f_u}{\gamma_{ml}})$

Where,
$f_u$ = smaller of the ultimate tensile stress of the bolt and the ultimate tensil stress of the plate
d = nominal diameter of bolt
t = summation of thickness of the connected plates experiencing bearing stress in the same direction
$K_b$ = lesser of the following four cases

$K_b = \frac{e}{3\times dn} = \frac{20}{3\times 11} = 0.6$

$= \left(\frac{p}{3\times dn}\right) - 0.25 = \left(\frac{25}{3\times 11}\right) - 0.25 = 0.5$

$= \frac{Fub}{Fu} = \frac{400}{410} = 0.97$

$= 1$

Therefore, $K_b$ =0 .5

$V_{dpb} = 2.5 \times 0.5 \times 6 \times 1.6 \times \frac{410}{1.25}$ =7.216 kn

No. of bolts= (8.2/7.216)=2 bolts (minimum requirement)

Staad o/p for section of dimensions (2.2 X 2.2 X 2.5m)

Table 5[6] STAAD.PRO Output

The software used for finding out different quantities of materials required is STAAD.PRO and the following table indicates the same

| Profile | Length(m) | Weight(kN) |
|---|---|---|
| ST $50_{cu}$ 25x1.6 | 8.80 | 0.102 |
| ST $30_{cu}$ 15x1.25 | 8.80 | 0.047 |
| $ST_{LU}$ 15x1.6 | 4.40 | 0.015 |
| | Total | 0.163 |

Hence both manual calculations and software design are same.
Here we checked the different sections on software and hence a lot of time was saved on design calculations as there was no failure of design while checking for bending, shear, buckling etc.

## OUR MODEL DETAILS

Costing of the model
Material used
Material used CLC panel[15] (0.550x0.625x0.03)
Cold form vertical C Channel[6] (0.04x0.025x0.0016)
(stud)

Clc panel –

Cost of panel:
Size 0.550x0.625x0.03
Cost/panel= Rs.30
$1m^2$ requires 3 panels
Cost= Rs.90
$1m^2$ requires= 2 C channels of 0.04x0.025x0.0016
= Rs.45/channel
Total cost with grout filling, adding wastage cost etc= Rs.200/$m^2$

**Manufacturing process-**

It is mixture of cement+fly ash+crushed sand+water+foaming agent(our is protein base foaming).and 2 layers of chicken mesh is layered on both faces.

After proper mixing time in mixture, it is put in a mould and after 12 hours panel is removed and cured for 12 days as wet curing and 16 days of dry curing.

**Advantages-**

1. It is cellular light weight concrete has density range of 400-1800 kg/$m^3$

2. Our CLC panel is of density 800 kg/$m^3$

3. Its water absorption is less than 14%

4. Fire resistance is 20 to 30 minutes

5. It has better acoustic performance over conventional patra room.

6. Excellent thermal insulation, and this material is already use by many builder on roof floor to increase thermal insulation of structure

## CONCLUSION AND FUTURE SCOPE

### Conclusion

From the study conducted in this project, we can conclude that speed of construction, waste reduction, fire , thermal , acoustic performance, relocation etc can be achieved from modular structure. So after reviewing the project we came to a conclusion that when work is to be done in bulk or great volume modular structures are more economical than conventional structures .After visiting Poojary prefab and observing their production line and finding out rates per unit material used in modular building, we can conclude that if rate of production is less,then modular buildings are an expensive option for labour housing. Therefore we manufactured CLC panels as they were more economical than other materials and satisfied all the specifications and requirements of modular structures.

- Labour can have thermal resistance,water proof accommodation.
- As cost of our CLC module is less than patra room.
- Therefore our module is most economical, safer and comfortable accommodation.

### Future scope

- As builder gives sub contracts of work in many areas, contractor is willing to have most economical accommodation for labour.
- Contractor will prefer CLC module instead of current patra room to have a better accommodation and increase labours standard of living.
- Number of labours required are less to set up modular buildings on site.
- Set up time of module is very less.

We conducted a survey and interviewed many contractors and conveyed the above advantages to them about modular structures, and the response was very positive and modular structures will definitely come into use in near future

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