1 INTRODUCTION

1.1 Need of Sustainable Cost Effective Rural Structures in India

Since 70% of the country's population belongs to rural India, the need of designing sustainable rural structures is of paramount importance. But to provide the rural people with an engineered housing at an affordable price, the cost of such a unit needs to be lowered by application of proper technology giving due considerations suitable to its importance, stability, life expectancy, repairs, maintenance etc.

Therefore, the following three points have been considered:

- Fast-track construction
- Lightweight steel members
- Precast Ferro-Cement panels as walls.

While carrying out the design, it is kept in mind that steel as a framing material will provide the necessary strength to the building against all types of normal and abnormal loading conditions. So, steel Square Hollow Sections have been selected as the structural members of the frame built in grids measuring about 1 metre x 1 metre and the frame has been analysed in a 3D model by software package STAADProV8i for different loading possibilities. The building has been checked for its stability against an earthquake tremor equivalent to Zone V and against a wind gust having a basic speed of 50 m/s as in the coastal regions of India. It has been observed that earthquake loads are not at all predominant in the design. Since there are no Codal stipulations in India to assess the possible loads from hydro-splashing during flood, it is assumed that the building, which withstands such an earthquake and wind effect, will also be durable during flood if the foundations are not scoured off.

Precast Ferro-Cement panels have been used as cladding materials at walls considering its ease of construction, durability and cost. Moreover it is also expected that given some training, the dweller of the house will be able to construct these panels very easily. The connections between the steel and these panels have been so designed that much skill will not be required for erection / connection of such panels on the steel grid. The connections of steel to steel members are also detailed in such a way that the villagers after developing some skill can erect such steel grids making fillet welding with the help of only a 1000-Watts portable generator set.

1.2 Scope of the Design

The design has covered the followings:-

- Collection of local data with respect to the use-habits and living conditions both existing and expected usages with respect to each dwellings.
- Design basis of structural design
- Load calculations
- Analysis of the structural frames
- Design of structural members
- Detailing of connections between steel-steel and steel-Ferro-Cement panels
- Preparation of general structural drawings
- Quantity estimation
- Cost estimation
- Major observations
- Erection methodology
- Conclusions

1.3 Advantages of Use of Steel In Frame of Structure Over RCC

- High ductility of steel leads to better seismic resistance of the frame. Steel component can be deformed in a ductile manner without premature failure and can withstand numerous loading cycles before fracture.
- Steel component has the ability to absorb the energy released due to seismic forces.
- Faster construction - by utilizing prefabricated components. Also, speedy construction facilitates quicker return on the invested capital.
- Quality of steel is assured since it is produced under controlled condition in the factory. Fabrication of the major parts at the shop floor also ensures quality control of the fabrication work. So, larger use of steel in construction ensures controlled quality of the structure.
- Cost effectiveness based on life cycle cost analysis because steel structures can be maintained easily and less frequent repairs will be required for steel structures.
- Steel is more durable, highly recyclable and hence environment friendly.
- Cost of formwork is lower compared to RCC construction.
- Cost of handling and transportation is minimized because major part of the structure is fabricated in the workshop.
- Reduction in overall weight of the structure compared to RCC construction is possible and thereby the foundation cost is reduced.
- The construction of buildings using steel will make the society develop itself with sustainable structures.

2 MAJOR DESIGN CONSIDERATIONS

2.1 Methodology

The designs have been carried out on the basis of data collected from concerned panchayat department of Govt of West Bengal

2.1.1 Collection of data for Planning

Department of Rural Development and Panchayats, Govt of West Bengal has been carrying out various structures like unit house under IAY, health centres under Anganwadi project, meeting halls and school buildings under Sarva Siksha Mission. For comparison all the existing schemes are collected and suitably converted to steel intensive structures. Glass panes have been designed to fit with 1 ft. width so that the wastage of materials is minimized.

2.1.2 Preparation of Design Basis

The design has been carried out with some basic assumptions in design criteria/parameters including i) assumed soil parameters, ii) wind speed, iii) earthquake zone etc.

A net safe bearing capacity of soil at 1.0 m below with respect to the existing ground level is assumed to be 5 t/m^2 for the worst soil and 20 t/m^2 in case of good soil.

Wind load is based on IS 875 (Part 3) for coastal region for a basic wind speed of 50 m/s having k_1=1.0, k_2=1.00 and k_3=1.00 i.e. for a design wind pressure of 150 kg/m^2.

For earthquake loading, the provisions of IS 1893:2002 was considered for Zone V.

For reinforcement in Ferro-Cement panels Fe 250 steel conforming to IS 432has been used. Square Hollow Section (SHS) (conforming to f_y = 210-240 N/m^2 as per IS 2062) has been considered as structural steel.

All reinforced concrete work in foundation has been designed assuming durability requirements suitable for rural application.

2.1.3 Consideration for Stability

In this publication the rural housing units have been designed to be stable against normal loads like dead load and live load as well as abnormal loadings like wind and earthquake loads. RCC foundation has been provided for these units with isolated pad foundations along with a pedestal each, placed at a depth of 1.0 meter below the existing ground level. The stability of the building has been checked against all possible worst combination of loads. The net safe bearing capacity of the soil has been considered varying between 5 - 20 t/m^2. The building has been checked for its stability against a wind pressure of 150 kg/m^2 and earthquake zone V. As per IS stipulations, the maximum wind and maximum earthquake have not been considered to act simultaneously. It has been observed after analysis that no tension has developed under any footing. Moreover the self-weight of soil fill over the footing satisfies the stability requirements of the building foundations against overturning and sliding. The connections between the steel members are all rigid connections, which has been designed to transfer the loads in the form of moment, shear and axial loadings to the supporting members and ultimately to the foundation. The Ferro-Cement panels have been designed to withstand the lateral thrusts and its connection with the steel members have been so detailed that it performs well as a cladding material covering the steel members as well as making the structure laterally stable. From the analyses, it is found that the buildings are well within the stipulated deflection limit of IS code.

2.1.4 Selection of Materials

While selecting the material of construction for the rural structures, due consideration has been given to the durability aspect like termite attack, strength aspect i.e. strength to withstand the thrusts of wind and tremor of earthquake, comfort expected in human habitation like temperature variation within the housing unit with the variation outside and proper ventilation and so on. The finished ground level of the housing units could be kept above the high flood level of a particular area to suit at site. It has been observed from the data collected from villages that during average monsoon the requirement of such elevation is 600 mm.

Steel Hollow Section has been selected as member of the framing system for its strength and lightweight. Ferro-Cement panel of 15 mm thickness has been selected for cladding material because of its capacity to withstand lateral loads due to wind and also because of its durability against weathering actions of nature and attack of termite. Such panels are also lightweight. Therefore an overall benefit in foundation design is possible due to reduced self weight of the materials.

For foundation, conventional RCC of Grade M 20 conforming to IS 456:2000 has been selected with reinforcing steel of Fe500 Grade conforming to IS 1786. Foundation consists of isolated pad footings with pedestals and tie beams around the building tying the top of pedestals.

2.1.5 Design & Engineering

3D frames for these buildings have been conceived as a grid using Square Hollow Section as structural members with all rigid joints (welded). The self-weight of the structural members and cladding panels are considered as Dead Loads. A Live Load of 75 kg/m^2 on the roof has been considered because these roofs are of the category of inaccessible roof conforming to the stipulation of IS 875 (Part 2). The structural frames have been analyzed and designed by STAADProV8i software package. For loadings due to Earthquake the loads have been generated by the computer program itself for an earthquake loading as per Zone V and for Wind, equivalent static loads had been calculated separately and given as input for a wind intensity of 370 kg/m^2 up to 10 m height i.e. the coastal wind in India.

Any additional cost due to protection against corrosion of steel members and fire protection have not been considered because it is assumed that corrosion will be protected by intermittent standard enamel painting and maintenance and in case of fire the dwellers will get sufficient scope to go outside. The aspects of heat insulation and ventilation have been given due consideration because these aspects are directly related to the conservation of human energy. The thickness of Ferro-Cement Panels used in this design being only 15 mm, the insides of the buildings may not be thermally well protected when used in a single layer. But the buildings are designed in such a way that double layer of Ferro-Cement panels could also be provided, one on each side of the Square Hollow Sections, thereby creating an air gap in between the two cladding panels, which will insulate the total building. Thus, during summer the inside of the building will remain comparatively cool with respect to its outside temperature and during winter, the reverse situation will occur. The buildings have been planned and designed in a way that a healthy environment is created inside through proper ventilation and illumination. In the model house the ferro-cement panel was fixed onto the steel members by cross members at the four corners. Thermocol has been placed behind it and sand-cement (1:4) plaster has been laid on it from inside the house having a square net placed on the thermocol. Fixed glass panes at the eave's height have been provided to illuminate the room with sufficient natural light and a skylight, fitted with mosquito net is provided at the overlapping parts of the two sloped roof to provide exhaust of hot air from inside to outside of the room. In case of four sloped roof an aluminum turbo ventilator may be provided at the crown to ensure proper ventilation preventing any ingress of rain water and mosquitoes.

The Steel structural grid is earthed. The connections could be detailed in such a way that the Steel sections remain concealed within claddings. Further, insulated electrical wires may be routed through PVC conduits. Hence there is no chance of electrocution out of short circuit and the effect of thunder is minimized.

2.2 Salient Features of Design & Engineering

2.2.1 Steel in Frame

The 3D computer models of the framing system of the buildings with SHS as structural members have been made in STAAD software package and the Ferro-Cement panels are designed as slab elements over these frames.

The slab is modeled as an element to carry the live load as distributed pressure load. The structural members of the frame have been designed by STAAD package which have been verified manually following IS 800:2007.

Different loads and the load combinations considered for analyses are:

1. DL (Dead load including the wall and roofing panels)
2. LL [Live Load as in IS 875(Part 2) for inaccessible roof]
3. WLx [Wind Load in X-direction as per IS 875(Part 3)]
4. WLz [Wind Load in Z-direction as per IS 875 (Part 3)]
5. For load combination with DL & LL, factored load=1.5x (DL+LL)
6. For load combination with DL, LL & WL, factored load=1.2x (DL+LL+WLx) or 1.2x (DL+LL+WLz)
7. For load combination with DL & WL, factored load=1.5x (DL+WLx) or 1.5x (DL+WLz)

2.2.2 Ferro-Cement Cladding

A typical panel size of 1m x 1m for the cladding materials has been chosen. Each panel is made of a 15 mm thick Cement-Sand mortar (1:1) skin with 1 layer of 0.265 mm diameter galvanized chicken mesh under a layer of 2.65 mm diameter reinforcement @ 25 mm c/c both ways as welded mesh placed centrally. The typical details of the connection of these panels are given in Chapter 5. The gaps (approx. 2 mm) between the panels and SHS sections will be sealed with waterproof grouting using SIKA / Accoproof or equivalent, to make the connections leak proof.

2.2.3 RCC Foundation System

The foundation type and pattern for all of the housing modules has been conceived as a frame work of RCC peripheral beam at plinth level supported over RCC pedestals and RCC isolated footings. For partition walls, intermediate supports have been considered supported over tie beams.

3 DESIGN OF STEEL INTENSIVE BUILDING

3.1 Some of the Building Components for Rural Houses

3.1.1 Roofing

Roof sheeting is done with 0.5 mm thick Corrugated Galvanised Iron Sheets spanning over purlins supported on steel portals or trusses made from Square Hollow Section/ Rectangular Hollow Section.

3.1.2 Structural Framework

The entire framework for the building has been conceptualized using Square Hollow Section with idealized panels approximately 1.0mx1.0 m. The members are connected with the SHS or RHS sections by insert plates.

3.1.3 Flooring

Brick on-edge flooring placed over rammed earth at locations of rooms. For water-tightness flooring is placed over 50 mm thick 1:2:4 Plain Cement Concrete.

3.1.4 Doors and Windows

Steel framed doors and windows are assumed to be used. Depending on the local site condition other material can be used also to make it cost-effective.