A COMPARATIVE STUDY OF CONSTRUCTION USING SCHNELL CONCREWALL® PRE-CAST SANDWICH COMPOSITE PANEL AND RC MOMENT FRAME WITH BRICK INFILL

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Abstract— Developing countries especially those in Asia (India), are facing the challenge of a growing middle class with greater demand for housing facilities. Faster and more affordable methods of construction are being sought after it, more than ever before as the action of emergency response. Increased innovation aimed at reducing the cost of construction, and creating affordable housing, is being integrated into methods of building and construction. This has led to introduction of components pre-fabricated using assembly line methods, in the construction process, which reduces the negative aspects of in-situ construction such as theft, unreliable supply of labor, unpredictable weather conditions, unprecedented fluctuations in prices of materials and plenty of energy consumption.

A comparative analysis is conducted based on Discrete event Simulation and Scheduling integration methodology in order to calculate duration of each activity of construction process by EZStrobe and determine the resource utility, productivity of resources for Schnell Concrewall and RC moment frame with brick infill construction technologies. This research paper will utilize time study method to determine the time taken by manpower and equipment to perform each task and show advances in technology that are making management of productivity, resource utility, cost, time which are more predictable. Two case studies were taken in order to have a comparative analysis.

Keywords— Schnell Concrewall panels, Discrete Event Simulation, Time study, Productivity.

I. INTRODUCTION

Use of Expanded Polystyrene Panels (EPS) introduces a pre-manufactured technology in the construction of reinforced concrete buildings. This industrial system entails production of a panel of wavy/undulated shape of polystyrene which is covered on either side with electro welded zinc coated square mesh. There are 33 connectors of the square mesh per m² to form a three dimensional reinforcement steel. There are two kinds of polystyrene panels, single and double. A single panel has a polystyrene sheet sandwiched between welded wire mesh on either side while a double panel is made of two single panels which are joined with an intermediate cavity.

Building Materials and Technology Promotion Council, New Delhi described Concrewall® construction system as a factory made system based on expanded polystyrene panels (corrugated) reinforced with double mesh of galvanized cold steel wires, interconnected to each other. To form the walls, the mesh is covered with a coat of shotcrete applied under pressure using a pneumatic system. A building can go up to four floors with a single panel and fifteen floors in double panel. Assembly of the finished panels is done on site. A single operator can lift and place the panels at their respective design positions creating labor savings compared to traditional construction techniques which requires several workers to put up a wall using masonry stone and plaster.

A. Expanded Polystyrene Schnell® panels

Schnell Home machines produce a panel that consists of a polystyrene sheet assembled together with welded wire mesh. A single facility can produce all the elements for building according to customer needs and can vary the thickness, length and density of the polystyrene core as well as the diameter of the mesh and number of connectors between the mats. The machines produce the following panel models:

Single / Double / Floor-Roof.

A single panel has a polystyrene sheet sandwiched between welded wire mesh on either side while a double panel is made of two single panels which are joined with an intermediate cavity. There are 33 connectors of the square mesh per m² to form a three dimensional reinforcement steel.

B. Expanded Polystyrene panel sheet as Green material

Expanded polystyrene sheets (EPS) which are made from small beads of polystyrene mixed with pentane as the blowing agent are best suitable for our purpose. Therefore EPS can be used to minimize the production of cement and to benefit the environment.

C. Activities where Cost and time can be reduced

1) Foundation: In Concrewall building system, type of foundation is strip/slab foundation which reduces excavation and material cost.

2) Wall panel erection: EPS panels are erected in place of brick masonry leading to reduction in time.

3) Roof: Roof panels are used for building slab and shotcreted.
D. Time study analysis

Time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions and for analyzing data so as to determine the time necessary for carrying out the job at a defined level of performance [3].

II. AIM

- To differentiate construction sequence or methodology of Concrewall building systems and RCC structures.
- To compare the time and cost incurred when constructing a Residential building using expanded polystyrene panels and conventional (traditional) method using RC moment frame with brick infill.
- To develop an approach that enables use of discrete event simulation in scheduling of construction operations i.e. simulation based scheduling.

III. SCOPE

The study is focused on a single story residential structure. The construction of an RC & Schnell Concrewall® structure with identical floor plan and dimensions is studied and compared to determine process of construction, resources required, constraints as well total cost of construction. Major task of the project is to effectively utilize time study as well as discrete event simulation technique for determination of duration of task, unit productivity and through detailed estimation of quantities cost analysis is done for both systems.

IV. METHODOLOGY

A. A brief introduction to Schnell houses in Jindal Steel power plant

Jindal Steel and Power Limited (JSPL) is one of India’s primary & integrated steel producers with a significant presence in sector like Mining, Power Generation and Infrastructure. National wide it had two branches in Odisha and Chhattisgarh. During the site visit to Angul, Odisha the following information is collected:

- Schnell is a manufacturer of machinery for the production of innovative building elements
- Schnell machinery for manufacturing EPS panels was installed within JSPL Company, Angul. Polystyrene balls get imported from New Delhi for making EPS sheets.
- JSPL Township consists of G+3 storey residential houses with Single panel structures constructed for employees working with in industry shown in figure.

- There are other structures made of Schnell EPS panels integrated other building systems :
  i. RCC + EPS Partition Wall Buildings
  ii. EPS Wall Panel Buildings
  iii. Combination of Hot Rolled Sections, Speed floor, EPS wall panel buildings

B. Data collection and analysis

(a) Single panels

(b) Shotcrete

i. Cement, quarry chippings (dust) and sand are mixed in the ratio of 1:1:1 respectively. A water cement ratio of 0.55 is used to realize a workable mix.

ii. Quarry chippings of 6mm size are used allowing the use of a turbo pump to spray the shotcrete on the wall panels. Shotcrete is applied to a thickness of 17-20mm.

(c) Concrete

The ratio of concrete mix used as the cover for the floor slab is 1:1.5:3, being the ratio of cement to sand to ballast (20mm). The concrete is corrugated to make a cover of 40mm for the slab

(d) Wire mesh reinforcement

14 gauge galvanized steel wire mesh is used as reinforcement for the prefabricated panel elements. Cold drawn and galvanized metallic wire with low carbon content, stress tension up to 700 N/mm² and a constant diameter of 30 mm is used.

i. Angular meshes
ii. Flat Meshes
iii. U Meshes
Building Procedure

1) Foundation
- Foundations for the Concrewall system whether strip or slab are conventional. In this research slab foundation is considered.

2) Wall panel erection
i. Anchoring rebar’s to foundation
Mark out and profile line wall positions
- Starter bars should be either φ6mm or φ8mm, 500mm long with 100mm drilled into the foundations and 400mm above.

3) Single panel roof installation
When the vertical panels are assembled on site, the verticality of the walls checked and the bending meshes positioned on all the corners, it’s time to put the horizontal bending meshes to connect the floor/roof to the vertical panels. The bending meshes must be fixed in whole the perimeter of the floor/roof, at level of the intrados.

- All corners and wall joins must be reinforced with right angled wire mesh to the full height of the walls
- Once the panels are plastered on one side the wall braces can be removed 24 hours later. The panels are now sufficiently ‘stiff’ that plastering on the other side can be done without bracing.

4) Window and door fitting
- To cut panels to fit and for door and window openings the wire must first be cut with a wire cutter or angle grinder.
- Reinforcement around wall openings. Added steel mesh reinforcement is needed around window and door openings to ensure no plaster cracks form in these areas. Mesh reinforcement strips of must be wire tied diagonally (45°) around openings before plastering.
- Fix a metal angle iron or hollow tube sub frame into the openings before plastering. Fix and plaster these in place and then secure the frames to the sub frame.

5) Electrical and plumbing installations
- A hot air gun or torch is used to create channels in the polystyrene for the placement of switch boxes, electrical conduits, cables or pipes.

C. Comparative Study

- The concrete casting on the floor/roofing panels (after placing the additional reinforcing bars, if needed) must to be done after the walls are plastered and it requires a series of props to limit the deformation of the panel.

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- A hot air gun or torch is used to create channels in the polystyrene for the placement of switch boxes, electrical conduits, cables or pipes.

5) Application of shotcrete
Application of shotcrete is done on both sides of the single or double panel till a thickness of 17-20mm is achieved. After about 30 minutes, mortar of 15mm thickness is applied.

C. Comparative Study

- Plan
In order to have a comparison between the RCC and Schnell Concrewall panel buildings in terms of cost and time, a residential 2BHK building plan satisfying all the vasthu norms is drawn in Auto cad and
analyzed in terms of cost and time incurred during construction.

Plan shown below consists of

![Figure 9: Single storey Residential house plan](image)

![Figure 10: Wall and roof panels plan](image)

![Figure 11: Wall and roof panels alignment](image)

- **Cost analysis of buildings**
  The main savings in cost when building using the expanded polystyrene are achieved through reduced transport, labor and running and maintenance costs. The costs involved in construction were analyzed by detailed estimation of material quantities and labor charges involved in construction of both buildings. The following notes below were used to compute the material costs of the building

  **Notes**
  - RCC Brick infill structure:
    - Perimeter of house 1015sf (35’x29’2”)
    - Height of the storey is 10’6”
    - Density of cement 1440 kg/m$^3$
    - Quantity of cement used for 1m$^3$ of concrete (1:1.5:3), generally it is assumed that percentage of voids occupied for a given quantity of concrete is 57 percent.
    - Cement: 1/5.5x 1.57x1440=8bags
    - Steel: Conversion factor for 1meter length of Fe415 steel in terms of kilograms if $d^2/162.2$, where ’$d$‘ is the diameter of steel rod.
    - Brick: Common burnt non modular clay bricks of size 23x13x10 cm size are used whose dimensions with cement mortar are 24x14x11cm
    - Depth of reinforced slab of 6”
  - Schnell EPS building:
    - Panel area (1.2m by 3m) = 3.6 m$^2$
    - Cost of a wall panel including transportation cost per m$^2$ = 110 rupees
    - Cost of a wall panel including transportation cost per m$^2$ = 160 rupees
    - Number of labors in a team = 7members

**Table 1: Material Cost estimation for RCC Moment frame with brick infill structure [4]**

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Unit</th>
<th>Price per unit</th>
<th>Net amount in rupees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bricks non modular</td>
<td>8880</td>
<td>No’s</td>
<td>3.50</td>
<td>30880</td>
</tr>
<tr>
<td>45 grade Cement required for sub structure and super structure including brick work mortar</td>
<td>620</td>
<td>Bags</td>
<td>330</td>
<td>204600</td>
</tr>
<tr>
<td>Reinforcement bars of various diameter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. 8mm diameter bars</td>
<td>2669</td>
<td>kgs</td>
<td>45</td>
<td>122774</td>
</tr>
<tr>
<td>ii. 12mm diameter bars</td>
<td>1725</td>
<td>kgs</td>
<td>11</td>
<td>75900</td>
</tr>
<tr>
<td>iii.16mm diameter bars</td>
<td>400</td>
<td>kgs</td>
<td>11</td>
<td>17600</td>
</tr>
<tr>
<td>4mm aggregate/stone ballast for RCC</td>
<td>160</td>
<td>cft</td>
<td>23</td>
<td>3680</td>
</tr>
<tr>
<td>20mm stone ballast for columns, slab, stairs</td>
<td>2102</td>
<td>cft</td>
<td>25</td>
<td>54600</td>
</tr>
<tr>
<td>Course sand for sub and super structure</td>
<td>1237</td>
<td>cft</td>
<td>45</td>
<td>55665</td>
</tr>
</tbody>
</table>

A Comparative Study of Construction Using Schnell Concrewall® Pre-Cast Sandwich Composite Panel and RC Moment Frame With Brick Infill

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Table 2: Material Cost estimation for Schnell EPS Panel structure

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Price per unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp. Polystyrene Panel</td>
<td>822</td>
<td>kg</td>
<td>45</td>
<td>370,085</td>
</tr>
<tr>
<td>Concrete Block</td>
<td>745</td>
<td>kg</td>
<td>10,066</td>
<td></td>
</tr>
<tr>
<td>Reinforcement</td>
<td>250</td>
<td>kg</td>
<td>11,000</td>
<td></td>
</tr>
<tr>
<td>Schnell Panel</td>
<td>1000</td>
<td>sq ft</td>
<td>100</td>
<td>100,000</td>
</tr>
<tr>
<td>Roof Panel</td>
<td>1000</td>
<td>sq ft</td>
<td>160</td>
<td>160,000</td>
</tr>
<tr>
<td>Normal for M30 grade concrete</td>
<td>500</td>
<td>bags</td>
<td>320</td>
<td>160,000</td>
</tr>
<tr>
<td>Course sand for M30 grade concrete</td>
<td>540</td>
<td>cft</td>
<td>250</td>
<td>135,000</td>
</tr>
<tr>
<td>Course aggregate for M30 grade concrete</td>
<td>1220</td>
<td>cft</td>
<td>800</td>
<td>976,000</td>
</tr>
</tbody>
</table>

- **Duration analysis by Simulation**

  Time study analysis is conducted in order to obtain durations taken by each task in the activity. The activities are captured in the video so that series of durations can be noted for each task at different locations on construction site. Then distribution fitting using Easy Fit software is used to obtain the best fitting curve for the continuous duration points of tasks noted from video.

- **Schnell EPS panel Building**
  - **Activity 1: Earthwork Excavation**

  Soil of 600 cubic feet has to be excavated by a hydraulic excavator of bucket capacity 9.2 cft and excavated soil is carried to some distance and dumped by a tractor whose truck capacity is 55 cft. The activity is captured by video and durations for each task for multiple cycles are noted. The best fitting curve is obtained from each task duration points and that distribution is inserted into model using ACD elements in Microsoft Visio with EzStrobe.

In the similar manner, activity cycle diagram for each of the construction activities is created in Ezstrobe and through simulation durations for all the sub tasks and tasks of those activities are determined.

For an idea, ACD of Earth work excavation which was made in Ezstrobe is shown in figure 12.

- **Cost**: On comparison from Table 1 and 2, the material cost when using the expanded polystyrene panels (Rs.4,32,088.00) is about 16% less than cost of the same when using the conventional method of construction using RCC frame with brick infill (Rs.5,83,859.00) for a single-storey residential dwelling. An overall reduction of about 35.7% in the total cost of materials, labor and equipment using cast in-situ concrete panels with EPS core and shear connectors was estimated for the project.
Material cost analysis

Duration: The time taken by each activity in Schnell Concrewall construction technology is much less than RCC which has been analyzed through simulation using EZ-Strobe, table 4.

Table 4: Duration analysis for both Schnell and RCC structure

<table>
<thead>
<tr>
<th>S.No</th>
<th>Activity</th>
<th>Duration (Hours)</th>
<th>Activity</th>
<th>Duration (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Excavation</td>
<td>1.01</td>
<td>Excavation</td>
<td>10.4</td>
</tr>
<tr>
<td>A2</td>
<td>Reinforcement in supporting beams</td>
<td>8</td>
<td>Reinforcement up to plinth level</td>
<td>3.7</td>
</tr>
<tr>
<td>A3</td>
<td>Slab foundation casting</td>
<td>15</td>
<td>Concrete casting up to plinth level</td>
<td>32</td>
</tr>
<tr>
<td>A4</td>
<td>Wall panel erection</td>
<td>19.6</td>
<td>Plinth beam</td>
<td>23.3</td>
</tr>
<tr>
<td>A5</td>
<td>Roof panel erection including stairs</td>
<td>9</td>
<td>Column raising to Slab reinforcement</td>
<td>83</td>
</tr>
<tr>
<td>A6</td>
<td>Shortcreteing</td>
<td>16.05</td>
<td>Slab casting</td>
<td>10</td>
</tr>
<tr>
<td>A7</td>
<td>Slab/roof casting</td>
<td>17.1</td>
<td>Brick wall</td>
<td>52</td>
</tr>
<tr>
<td>A8</td>
<td>Electrical fixtures</td>
<td>0.67</td>
<td>Electrical fixtures</td>
<td>1.57</td>
</tr>
</tbody>
</table>

The labors working under Schnell panel system are more productive because of the simplicity of the construction technology, table 13 which can be observed in bar chart provided below:

Table 13: Work done by manpower

<table>
<thead>
<tr>
<th>S.no</th>
<th>Schnell house productivity rate (per hr)</th>
<th>RCC structure productivity rate (per hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wall panel erection 66</td>
<td>3 brickwork 52</td>
</tr>
<tr>
<td>2</td>
<td>Reinforced installation 52</td>
<td>4 slab floor installation 10</td>
</tr>
<tr>
<td>3</td>
<td>Electrical fixtures 15</td>
<td>6 electricians 8</td>
</tr>
</tbody>
</table>

PRODUCTIVITY:

Figure 15: Bar chart showing the productivity analysis

REFERENCES: