Background

A house is more than a shelter. It is the key for leading a productive life as housing is one of the core needs of human existence. The problem of providing housing to all especially the poor living in slums, pavements, huts, illegal settlements and those living in temporary and unsafe shelters has been a challenging task for the Government requiring huge quantity of building materials, labour both skilled and unskilled, time and huge investment. While there has been an impressive growth in the total housing stock from 65 million in 1947 to 187.05 million in 2001, and as estimated that 26 million homes are required by 2012. There continued to be increasing gap between the demand and supply of housing units. The shortage of housing is acutely felt in all towns and cities. In order to bridge the gap, the Government agencies need to go for speedy and cost effective safe housing by adopting innovative technology that provides solutions to huge housing demand. In this effort, the Slum Development Board has initiated “Cost Effective Monolithic Concrete Technology” for the first time in the State for Construction of 6000 multi storied dwelling units with ground and ground plus three floors. About 4800 ground plus three units are taken up by adopting Monolithic Shear Wall Design.

The building construction cost can be divided into two parts comprising building material cost of 65 to 70% and labour cost of 30 to 40%. Cost reduction is achieved by selection of more efficient material or by an improved design or by innovative construction technology. With growth in information technology and retail economic activities, young unskilled, unemployed youths are attracted more towards such opportunities and show least interest in construction jobs where one has to sweat very hard to earn his wages. With this, huge shortage of skilled/unskilled labour, construction of quality houses becomes difficult leading to abnormal delays in completion of projects with cost overrun. The conventional method of construction, labour availability & labour cost is going to be very critical & challenging for housing in coming days, considering the large financial allocation by the State and Union Governments in social housing schemes towards improving the quality of life of the poor people in the state. In order to initiate mass housing projects, it is necessary to have less labour dependency, innovative construction technology with mechanization, which could deliver speedy, qualitative and durable house in a cost effective manner.

The Monolithic Concrete Technology is a rapid and disaster resistant construction with aluminum formwork is an upcoming technology which is enabling the cost-effective and rapid mass housing projects. In this action research, the housing project under JNNURM scheme implemented in Mysore city by the Karnataka Slum Development Board in collaboration with Private agencies has been studied with respect to its practical application, cost-effectiveness, affordability, time saving in construction, safety against disasters and functional aspects. A
comparison of other conventional and traditional technology with monolithic concrete technology was also felt necessary to take up this study.

In this background, there is an urgent need to fulfill the housing and infrastructure requirements. The challenge can be met by adopting Innovative paths and employing alternative technologies to build and deliver houses faster. Fortunately one such promising technology offering total solution to housing construction is available – Monolithic Concrete Construction.

**About Monolithic Concrete Technology**

Monolithic construction is a method by which walls and slabs are constructed together. In this method, fresh cement concrete is poured in light weight aluminum formwork system having required reinforcement bars for needed strength. As the walls and slabs are cast in one go, the operation is very fast. This is ideal for multi storied construction, allowing speedy construction on mass scale. This technology offers speedier solutions to rapidly increasing housing shortage in urban areas by optimal use of time, money and building materials like steel and cement. It promises accelerated construction at optimized cost and time when we go for mass housing especially for economically weaker sections and low income groups who are large in number without houses. It is a highly efficient technology which facilitates concreting of all the components like walls, roof etc. simultaneously, resulting in a structurally very sound monolithic construction.

- The technology requires unskilled and semi-skilled labours (hand-held) and does not require the use of expensive construction equipments. Hence cost effective.
- Modular designs of mass housing schemes provides excellent opportunity for reuse of form work which makes the technology very cost effective.
- The material of formwork (either aluminum or HDPE) is recyclable and completely eliminates the use of precious natural resource wood. Hence the technology is environmental friendly.
- This technology helps excellent quality control of the entire structure as per BIS and all the international standards.
- No need of bricks, blocks and plastering.
- Because of reduced dead load of about 50%, superstructure and foundation cost can be minimized without compromising on strength.
- Its box-like behavior gives the building very high structural strength, against vertical and horizontal forces thereby making it earth-quake and wind/cyclone resistant.
- Excellent finished surface avoids expensive plastering and enhances a relatively water resistant surface.
- Due to reduced wall thickness for a given Plinth area more Carpet area is available.
- Monolithic concrete construction helps in precise scheduling and assured quality control.

Monolithic Reinforced Concrete Construction System uses a formwork system that allows casting walls and slabs according to a pre-defined cycle. It combines the speed; quality and accuracy in production with the flexibility and economy of in-situ construction. The result is a
reinforced concrete structure, the surfaces of which are of sufficiently high quality to require only minimal finishing while the end walls and facades are easily completed. Since footing, wall and slab are designed as an integrated unit and Reinforcement is continuous and interlocks with all the structural components of the building viz., foundation, walls and slabs. Hence Columns and beams are not required which leads to Slender sections thereby providing high resistance to earth quake, cyclone, wind and flood.

Objectives of the Study

It was necessary to assess the performance of Monolithic Concrete Technology adopted in JNNURM Housing Project for Slum Dwellers in Mysore City. The applicability and feasibility of the technology vis-à-vis other conventional construction was to be evaluated.

Need for the Study

The survey indicated the fact that there are about 10 per cent of the people living in temporary shelters either on illegal or own land with little or no access to basic infrastructure services. Affordable housing enabled by appropriate technology would be the only solution to housing need of the urban poor. The rising urban population has also given rise to increase in the number of urban poor and shelterless. Therefore, there was a need to study the Monolithic Concrete Technology adopted in JN NURM Housing Project for its safety, durability, affordability and other housing parameters.

Methodology of Study

The survey was carried out at the site of the projects and discussions were held with the Officers and Engineers of Karnataka Slum Development Board, MCC, Beneficiaries of housing, Contractor and the construction workers. The data was compiled, analysed and reported.

Scope of the Study

The study covers the housing projects under JnNURM scheme using Monolithic Concrete Technology.

Housing Status in Mysore City

Out of total 9.50 lakh Mysore city population as per 2011 Census, 10% of Population is residing in slums. A total 82 slums have been identified and out of which 49 slums are in the Mysore City Corporation limits. The ever increasing number of slum dwellers and shelterless population has placed tremendous pressure on housing and infrastructure. Mysore City, one of the historical tourist places in India, well known all over the world for its rich heritage, culture and tradition. Due to rapid urbanization of Mysore, there is increasing number of dwellers causing tremendous pressure on housing, urban basic services and infrastructure. The gap between demand for and
Supply of houses is widening among the backward areas. The speed of providing housing and infrastructure facilities is not up to the benchmark which we need to achieve because if we fail, housing shortage will worsen resulting in increasing growth of slums.

Due to the constraints of financial resources in Mysore City Corporation, the development of backward and revenue areas have not improved. Hence, The Karnataka Slum Development Board and Mysore City Corporation have taken up rehabilitation of 65 slums in the city under the JnNURM Scheme and some the housing projects by adopting monolithic construction technology.

Planning for Slum Housing in Mysore City under JNNURM Scheme
The basic house is designed so that each flat has an overall area of 225 sq.ft. This has been divided into a living room, a bedroom, a kitchen and a toilet. The area for each house is designed as follows:

Houses in G+1 or G+2 configuration
1. Living Room - 81 sq.ft.
2. Bed Room - 54 sq.ft.
4. Bath Room - 17 sq.ft.

The type of construction is based on several factors such as soil conditions, local requirements and cost of the land. In Mysore, the pressure on land is high and the acceptance of multi-storeyed dwellings is more common. Further the beneficiaries usually consist of construction workers, housemaids or factory workers and therefore the need for open space is limited. Keeping these in mind generally three storied building (ground + two floors) is considered as the optimum design. Drinking Water is the most important service provision, and it is proposed to supply piped drinking water to each house. In addition, there will be a bore well with enough capacity to provide drinking water to all the flats. The bore well will pump the water into a surface tank from which it will be again pumped to individual overhead tanks. From the individual overhead tanks the water will be piped to each apartment with one connection to the bathroom, toilet and kitchen respectively.

In some areas where a large number of houses are coming up a overhead water tank is also considered. Underground Drain The sewerage drain water from each house will be fed to the under ground drain and all the branch drains will join a main drain from where it will be let to the city's sewerage treatment plants. In case such a central system is not possible to be provided, either a soak pit design or a sewerage treatment plant has to be considered. However, this cost has not been considered in this project. Storm water drains are running on either side of the road in the direction of the natural slope. These branch drains are then connected to a main storm drain (of larger dimension), which lead the water safely into a storm drain. The rain water existing outside the project area will also flow into the project boundaries and in such a case a suitable storm water drain also has to be laid to collect such overflow from surrounding areas.

Under JnNURM scheme, the norms for housing have different sites and area with dimensions 10x20 feet -1230 Nos., 15x20 feet-1152 Nos., The site with dimensions of 20x30 feet are 1336 nos. while dimensions of 25x30 are 587 nos. Type design-1 has been proposed for
site dimensions namely 10x20 feet and 15x20 feet together totalling to 2382 nos and the balance of 1923 nos with type design-2.

The cost of conventional RCC multi-storeyed building in cities has gone up significantly in the last few years due to sharp increase in the price of steel and cement. In ground + two type of design the building loads are taken by reinforced concrete columns and beams. Therefore the steel and cement usage is significantly more leading to high cost. The walls are built of hollow concrete blocks with the main walls of 9" width and patrician walls of 4" width. These walls will be plastered and painted both internally and externally. The Slum Development Board and MCC have considered the Monolithic Concrete Technology in some projects as an alternative to such multi-storeyed construction. The infrastructure cost is relatively lower in urban dwellings due to the compactness of the design.

The first phase of the slum rehabilitation project in Mysore City was estimated at Rs. 38.11 Crores. The administrative cost would be 5% of the project cost. The endeavour would be to provide an appropriate and comfortable dwelling at an affordable cost. The beneficiary contributions would be as applicable under the JNNURM guidelines.

**Project Implementation under JNNURM Scheme**

The duration of the project was 18 months from the date of awarding the work to the qualified bidder. This will spanned in the year 2009-10 and 20010-11. All the selection of the agencies and construction contractors was be done by the procedure of tendering, as per the Karnataka Transparency for Public Procurement Act 1999.

The time frame for each activity is given below:

i) In house Expertise – The in-house engineers together with revenue official have done door to door survey and generated documentation of the urban poor. This process is complete and has finally listed 4305 No. of beneficiaries for housing scheme.

ii) Selection Construction Contractors

iii) Project completion - 18 months from the appointment of construction contractors.

State level – The contribution from the state is 10% for housing and 20% for infrastructure works. This would be released after the submission of the DPR and the also against sanction of the project under the JNNURM. All the land is within the ambit of Mysore city corporation limits, no clearance is required from any agency excepts for shifting of utility lines from the concerned agencies. This inter–departmental activity will be absorbed within the time frame of the project duration.

In some projects, as the beneficiaries are owners of the sites, the dwelling units proposed are of ground floor only. However, as the site dimensions of 10x20 feet did not permit for 25 sqm of carpet area, ground plus first floor dwelling unit with carpet area of 25.74 sqm been proposed. In these projects, construction of load bearing walls with precast concrete blocks on size stone masonry is proposed. Both sides of the wall shall be plastered and painted–external surfaces with
cement paint and internal surfaces with distemper. Upon approval of this project, a mechanism will be evolved to prevent resale of land from the beneficiary at least for a reasonable time period of 10-15 years. However, guidelines will be drawn to mortgage the patta (kathe) granted to the beneficiary in banks in case the beneficiary likes to draw loans. Biometric identification of the beneficiary could be subsequently carried out for proper identification and for proper control of resale of land after a period of 10-15 years.

**Funding pattern under JnNURM in Mysore city**

<table>
<thead>
<tr>
<th>Category of Cities/Towns/UAs</th>
<th>Grant Centre</th>
<th>Grant State</th>
<th>Beneficiaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable to Mysore City</td>
<td>80%</td>
<td>10%</td>
<td>10%</td>
</tr>
</tbody>
</table>

**Case Study: Monolithic Concrete Technology in Sathagally housing project**

The survey and discussions with the beneficiaries and Officers and Engineers of the Karnataka Slum Development Board, MCC and Construction Company(Contractor) in charge of the project were conducted to seek the data and reactions of the beneficiaries on the housing project.

- **Name of the Project**: Construction of 448 houses at Sathagally Behind VTU Regional office Mysore
- **Technology Used**: Monolithic Concrete Technology
- **Extent of Land**: 5 Acres
- **No of Floors**: G+3 - 14 blocks (32 houses per Block)
- **Project Cost**: Rs 1350.72 lakhs
- **Agency**: M/s P G SETTY Constructions Pvt Ltd, Mysore
- **Date of Commencement**: 4/2/2010
- **Scheduled date of Completion**: 3/2/2011
- **Beneficiaries**: Kesare 2nd stage, Kesare 3rd stage, Chamundi bettada pada, Kalyangiri, Usmania block, Yellamma slum, Gopika gudisalu.
- **External Electrification**: CESC submitted for Rs 22.03 Lakhs
- **UGD Lead Off**: DEWATS proposed at a cost of Rs. 60.00 Lakhs
- **Water Supply**: Two Bore wells for temporary supply & Two sump tank of capacity 1 lakh litres and 65000 litres respectively.
- **No of houses Sanctioned**: 448 houses
- **Financial Progress**: Rs 1350.72 lakhs
Comparison of Monolithic Concrete Technology adopted in the Housing Project

<table>
<thead>
<tr>
<th>Component</th>
<th>Items</th>
<th>Conventional</th>
<th>Monolithic Concrete Technology</th>
<th>Savings in Monolithic Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation</td>
<td>Thickness (Min) in mm</td>
<td>450mm</td>
<td>200mm</td>
<td>7 cum</td>
</tr>
<tr>
<td></td>
<td>Volume in cum</td>
<td>13</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Superstructure</td>
<td>Wall thickness (Min.) in mm</td>
<td>175mm</td>
<td>110mm</td>
<td>9 cum</td>
</tr>
<tr>
<td></td>
<td>Volume in cum</td>
<td>24</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Wastage</td>
<td></td>
<td>2</td>
<td>0.2</td>
<td>1.8 cum</td>
</tr>
<tr>
<td>Total saving in volume</td>
<td></td>
<td></td>
<td></td>
<td>17.8 cum</td>
</tr>
</tbody>
</table>

Considering a building of G+3 floors with 8 houses in each floor having a built up area of about 37.5 Sqm per house, the man power requirement per house is as given below

<table>
<thead>
<tr>
<th>Component</th>
<th>Conventional</th>
<th>Monolithic</th>
<th>Savings in Monolithic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation</td>
<td>Man power in man-days</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Superstructure</td>
<td>Man power in man-days</td>
<td>71</td>
<td>20</td>
</tr>
<tr>
<td>Total Savings</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dependability on Skilled Labours

<table>
<thead>
<tr>
<th>Conventional Method</th>
<th>Monolithic Structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skilled Labour - 60%</td>
<td>Skilled Labour – 20%</td>
</tr>
<tr>
<td>Unskilled Labour-40%</td>
<td>Unskilled Labour – 80%</td>
</tr>
</tbody>
</table>

Parameters considered for beneficiaries selection

As discussed, the list of beneficiaries was approved by the Committee formed for this purpose headed by the Dy. Commissioner and other Members. Whereas the Karnataka State Slum development board has taken up the projects to rehabilitate the entire Slum population to the place identified for this purpose.

The Government of Karnataka has stipulated an annual income of less than Rs. 11,200/- as one of the criteria along with non economic factors like individual toilets, individual water supply connection, house hold internal electricity for selection of beneficiary under this scheme. In the present proposal, urban poor with an annual income of less than Rs. 11,200/- who owned a piece of land either vacant or constructed with thatched roof in a dilapidated condition are selected.
Physical Indicators
- Quality of houses being built of thatched roof or AC sheet found in dilapidated condition
- Living areas / spaces.
- No access to sanitation facilities such as open air, street drain, public toilet.
- No access to water supply such as individual piped network, stand post, hand pump, well and others.

Economic Indicators
- Income levels
- Security of tenure
- House ownership

Social Indicators
- Literacy level
- BPL / APL, SC /ST/OBC/Others

Field Findings of the Monolithic Concrete Technology in the Housing Project
- There is a saving in the quantity of materials in foundation to the extent of 7 cum
- The thickness of the wall is 110mm as compared to 175mm in conventional construction thus saving in the materials to the extent of 9 cum
- Wastage has been reduced by 1.8cum
- The total saving in the quantity of materials is approximately 17.8cum
- In each house, the saving in terms of labour/man days is about 51 man days for a house of 37.5 Sqm with Ground+3 floors with 8 houses in each floor
- Skilled Labour required in case of monolithic structures is 20% as compared to 60% in case of conventional construction
- Unskilled Labour requirement in case of monolithic structures is 80% as compared to 40% in conventional method
- Thus, there is a saving in the cost skilled labour to the extent of 40%

The system of construction in monolithic technology followed a 4 day cycle as follows:

Cycle time for completion of single unit:
Cycle time for completing single ground floor unit with one set of formwork:
- Foundation: 4 days
- Walls and roof and finishing works: 8 days

Total time for completion: 12 days.

Hence by deploying four set of form work one house can be delivered in Every 3 days.

Cycle time for completion of single unit under G+ 3 constructions
(4 x 4 = 16 units) is also 3 days per unit.
Day 1 - The first activity consists of erection of vertical reinforcement bars and one side of the vertical formwork for the entire floor or a part of one floor.

Day 2 - The second activity involves erection of the second side of the vertical formwork and formwork for the floor (roof slab)

Day 3 - Fixing reinforcement bars for floor slabs and casting of walls and slabs

Day 4 - Removal of vertical form work panels after 24 hours, leaving the props in place for 7 days and floor slab formwork in place for 2.5 days.

Monolithic technology is 3.5 times faster compared with Conventional Brick/Block masonry work. This can go upto 5 times for 4 days cycle time. If formwork per floor made available (single repetition), then the speed will increased to 8-9 times.

### Comparison of Speed of construction

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Description of Activity</th>
<th>Conventional</th>
<th>Monolithic technology</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Foundation</td>
<td>30</td>
<td>16</td>
<td>Excluding excavation 4 repetition</td>
</tr>
<tr>
<td>2</td>
<td>Plinth</td>
<td>10</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Columns</td>
<td>15</td>
<td>0</td>
<td>Includes curing</td>
</tr>
<tr>
<td>4</td>
<td>Beams</td>
<td>10</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Slab</td>
<td>15</td>
<td>0</td>
<td>Includes curing</td>
</tr>
<tr>
<td>6</td>
<td>Walls</td>
<td>30</td>
<td>24</td>
<td>6- day cycle-4 repetition</td>
</tr>
<tr>
<td>7</td>
<td>Plastering</td>
<td>30</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>140 days</strong></td>
<td><strong>40 days</strong></td>
<td>3.5 times (1/3 of conventional)</td>
</tr>
</tbody>
</table>

Note: In the above case Form work procured only ¼ of Plan area (4- repetitions per floor area)

(Data obtained from the P.G. Shetty's Constructions worked as contractor of the housing project)

The above calculation does not include the additional cost-benefits such as the increased carpet area cost (5-8%), early occupational cost (4-5 months), and saving in interest cost, resources holding charges (4-5 months) etc., as in case of conventional construction. The wastage of materials at site not accounted (3-5%). Also not considered the scrap value of Aluminium forms after 100 repetition (generally scrap value is higher compared to steel). Considering above, about 15-20% of overall cost shall be saved. It is seen from the field that the following saving in cost was observed.

### Comparison of Cost

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Description of Item</th>
<th>Conventional</th>
<th>Monolithic Technology</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Initial investment on Aluminium Form- work</td>
<td>Nil</td>
<td>Rs 300 / sqm</td>
<td>Rs 10000 per sqm -life of 100</td>
</tr>
<tr>
<td></td>
<td>Handling charges</td>
<td>Nil</td>
<td>Rs 100 / sqm</td>
<td>repetition</td>
</tr>
<tr>
<td>---</td>
<td>-----------------</td>
<td>-----</td>
<td>--------------</td>
<td>------------</td>
</tr>
<tr>
<td>3</td>
<td>Solid Block work for Wall(8” thick)</td>
<td>Rs 850 / sqm</td>
<td>Nil</td>
<td>Market price</td>
</tr>
<tr>
<td>4</td>
<td>Plastering for walls(Both side)</td>
<td>Rs 175 / sqm</td>
<td>Nil</td>
<td>Market price</td>
</tr>
<tr>
<td>5</td>
<td>M25 grade- Ready mix concrete</td>
<td>Nil</td>
<td>Rs 500 / sqm</td>
<td>Rs 3800/cum</td>
</tr>
<tr>
<td>6</td>
<td>Steel for Shear walls</td>
<td>Nil</td>
<td>Rs 200/sqm</td>
<td>Rs 40000/MT</td>
</tr>
<tr>
<td>7</td>
<td>Miscellaneous</td>
<td>Rs 100 /sqm</td>
<td>Rs 100 / sqm</td>
<td></td>
</tr>
</tbody>
</table>

(Data obtained from the P.G. Shetty’s Constructions worked as contractor of the housing project)

The Engineers and the contractor have explained the general advantages of this technology as compared to other traditional and conventional construction techniques. As also the construction labourers find it easy to work with as there is relatively less manual hard work. The lifting of bricks, stones, sand etc., is avoided as only pumping of concrete in the form work is done. Once the formwork is set out, the work becomes easy. The requirement of highly skilled labourers is not felt in this construction.

### Comparison of Monolithic construction with Conventional construction

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Monolithic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less Structural Stability against non-gravity loads.</td>
<td>High Structural Stability against non-gravity loads.</td>
</tr>
<tr>
<td>Requires more construction activities, time and labor</td>
<td>It is speedy and requires fewer work forces.</td>
</tr>
<tr>
<td>Higher construction cost.</td>
<td>Cheaper by 10% than conventional methods. Lower construction cost.</td>
</tr>
<tr>
<td>More number of skilled masons are required.</td>
<td>This technology requires only trained and unskilled workers</td>
</tr>
<tr>
<td>No consistency in shuttering. Irregular shape may spoil the final finish.</td>
<td>The Monolithic technology has simple modular light weight formwork system which gives a defined shape.</td>
</tr>
<tr>
<td>Wall surfaces are too rough. Inner and outer surfaces require plastering</td>
<td>The form finish concrete surface is smooth. Needs no plastering</td>
</tr>
<tr>
<td>Periodic and regular maintenance required.</td>
<td>The cement concrete monolithic structure once built will always be Maintenance free</td>
</tr>
</tbody>
</table>

### Comparison of Aluminum Form Work with the Conventional materials

<table>
<thead>
<tr>
<th>Type of Formwork</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>Lightweight</td>
<td>Non-Recyclable, Consumes Natural resources, More Human Resource, Needs</td>
</tr>
<tr>
<td>Material</td>
<td>Characteristics</td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Steel</td>
<td>Heavy in Handling, More Human Resource.</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>Recyclable, Light Weight, Less Human resource, Less Time Consuming, Plastering not required.</td>
<td></td>
</tr>
</tbody>
</table>

**Man power comparison**

<table>
<thead>
<tr>
<th>Component</th>
<th>Conventional</th>
<th>Monolithic</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation</td>
<td>6</td>
<td>6</td>
<td>Excess of 51 man days in conventional</td>
</tr>
<tr>
<td>Superstructure</td>
<td>71</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>Total excess</strong></td>
<td></td>
<td></td>
<td>51 Man days</td>
</tr>
</tbody>
</table>

In this housing project using monolithic construction, all the elements are cast together with RCC by using aluminium form work, which supports wall, beam, column, roof slab and other elements together for concreting in one go. This ensures absolutely no joints (monolithic) between the elements with great surface finish, hence highly durable & earthquake resistant.

By virtue of its construction, the building is resistant to earthquake forces as the RCC walls provide adequate ductility and shear resistance. Since, all elements are cast together, proper anchoring and connections are automatically ensured. The construction process which involves minimum number of activities which can be simultaneously carried out with less time, exhibits highest quality and brings most durable, disaster resistant, and cost effective housing.

**Field Observations**

- The formwork does not depend upon heavy lifting equipment and can be handled by unskilled labors.
- Speed can be achieved due to light weight of forms, and less labour required for carrying the formwork.
- Good quality with accurate dimensions for all openings to receive windows and doors, right angles at meeting points of wall to wall, wall to floor, wall to ceiling, etc, concrete surface finishes are good to receive painting directly without plaster.
- Smooth surface finish is obtained.
- Higher carpet area, due to thinner shear wall construction.
- Very few construction joints, provides more seismic resistance to structure and highly durable compared to that of conventional column and beam slabs construction with brick or block work.
- The walls do not require plaster, problems associated with plaster cracks, etc. eliminated.
- Uniform quality will be achieved by using uniform grade of concrete for walls & columns.
- This requires only 7 days cycle of casting a floor together with all slabs, as against 40-50 days cycle in conventional method.
- Uninterrupted progress can be planned, 2/3 of construction time in overall project period can be reduced.

Survey findings
- The survey and data collection was done in both Rajivnagar 3rd stage and Sathagalli housing projects in which the Rajivnagar housing project was under construction. This was a project with G+3 storeys and each floor in the block consist of 8 dwelling units. The construction was taken up by using Monolithic Concrete Technology by the construction agency for 552 houses.
- The Total Plinth area of each individual house is 254 Sq ft with an estimated cost of Rs.2.80 lakhs/ Unit. This is about 15% less than the Conventional Construction. During visit to the Sathagalli housing project a Completed project, the beneficiaries expressed that there is no separate water supply. Two bore wells provided for the purpose of water supply to the construction activity are used for supplying water to the residents of 448 Dwelling Units at Sathagalli housing Project.
- The beneficiaries are also complained about delay in electrical service and expressed their anguish against the authorities. It is learnt that this was also one of the main reasons for poor occupation by beneficiaries.
- Beneficiaries have expressed that the housing project is far away from the city which has resulted in lot of hardship for the dwellers for conveyance to work place as most of them worked in city as daily labourers, construction workers who has to travel every day to Mysore city without proper transportation facilities from housing project.
- The physically challenged and senior citizen are accommodated in the Ground floor only as per agreement.
- The construction is taken up considering all building bye-laws and the provision has been made for primary health centre and primary school with Civic amenities.

Principles of Monolithic Concrete Technology
- Rapid and best quality construction
- Customer satisfaction
- Affordable & Competitive price
- Maintaining trust between the Owner & Contractor by way of quality, timely completion with motto in mind: "Cost is long forgotten, but Quality is remembered forever" and "House for all."
The quality of concrete is most important especially when concrete is pumped into the formwork. It is necessary ensure workability without segregation and bleeding by maintaining the quality and density.

Limitations of Monolithic Concrete Technology
As observed from the field, following drawbacks are noticed

- Generally, used only in mass housing project with same plan and the multi-storey structures having same plan area at all floors.
- Huge initial investment for formwork procurement
- About 70-80% of formwork elements shall be useful for new project (new plan) after first project, rest shall be suitably designed and procured for next projects
- Initial setting of formwork at site as per drawing dimension, may take more time
- The training of labor to handle designed formworks at site
- All the utilities, have to lay & embedded in concrete walls/slabs, hence relocation, repair of these will be very difficult.
- Since, structure is monolithic and wall thickness is less, these houses are little warmer than the conventional during summer. However, this problem can be overcome by using suitable thermal insulated paint for external wall or by adopting simple thermal insulation techniques or growing creepers & plants around the external walls.

Merits of Monolithic Concrete Technology
Providing housing for the poor, shelterless and slum dwellers is a gigantic and a complex problem. The Government needs to adopt the technology that provides solution to meet housing needs of millions of people. To do this, faster construction by launching Mass housing projects with monolithic technique is one of the solutions to the overgrowing problem. The speed & quality construction drives this technology;

- Cost effective - average 15% cost saving for load bearing wall over conventional timber/plywood shuttering
- Increased Carpet area/Usable floor space of (5 - 8%) over Conventional Design
- Speedy construction - 1/5th - 1/6th of time required to complete construction against the conventional
- Easy to use, since it’s simplified design
- Monolithic construction-box type strong structures with minimum/ no joints
• Structures are better earthquake and wind resistant
• Highly durable structures - required least maintenance
• Smooth finish of wall/roof/floor- ready to take the paint
• Block/Brick masonry eliminated thus Internal & External Plaster eliminated
• Environment-friendly - no wood/timber used
• Formwork-Lightweight section are used-hence easy to lift and used
• Aluminium shuttering material has higher scrap value compared to plywood/steel

Versatility
The technology makes its possible to cast entire building at one go which includes Walls, columns, beams, floor slabs, staircases, balconies, window hoods, storage lofts requiring no bricks, blocks or plastering.

Speed
• Multi-Storey Housing - structures are completed at the rate of four days per floor - regardless of floor size.
• Single or Double Storey Housing - structures are completed at the rate of one house per day.

Quality
• Precision in fabricating the formwork results in accurate and consistent forming of the concrete.
• The quality of the concrete finish is the same regardless of whether the System is used for low cost housing or luxury housing.

Cost Effectiveness
• Highly reusable formwork.
• Forms all the concrete in a building.
• Unique construction cycling.
• Uses locally available materials - i.e. concrete and reinforcing steel.
• Requires unskilled labour only and no cranes.
• Loadbearing wall structural design.

Defects of Traditional and Conventional Methods of Construction

A few housing projects taken up by housing agencies in Mysore provide enough evidence that the planning, materials including construction were not up to the mark. The planning stage is crucial in any project and at the stage of planning a house, care shall be taken to keep the shape of the plan square, rectangular and symmetric. This would help in reducing the cost and symmetric plan would keep the building resistant against earthquake. Location of openings in the house and materials used for construction should provide natural light, ventilation and thermal comfort all the time to the occupants and must satisfy the dweller needs. Interior of a house be given adequate attention rather than Exteriors. Exterior must be kept simple and protected from rain, flood, wind, cyclone and theft. Time, material & labour intensive components in exterior such as ornamental borders, art work on wall and Sunshades, putting
unsymmetrical and costly elevations in the name of architecture etc., shall be avoided. Following shall be carefully thought of before selection of a particular component for foundation and superstructure;

The local skills could be improved by application technology so that durability and structural safety of houses are ensured. For houses of small to moderate size both in rural and urban areas, Brick/stone or RCC framed structure concept can be replaced by load bearing monolithic construction using since the cost of bricks is rising rapidly. The economy in construction can be achieved by designing the houses/buildings for the need and functional requirements.

It is noticed that many houses built using column-beam structure in rural and urban areas are constructed wrongly without the technical knowledge. Column-beam or framed buildings are constructed even for small houses of ground plus one or two storeys even when the soil is good. Concept of Monolithic Concrete structure is best suited for mass housing through multi storied construction. In many instances housing projects, where conventional RCC framed structure with columns and beams constructed, the columns and beam joints are not cast monolithically due to improper workmanship and as a result, the joints would become fragile. In order that the framing concept become effective they need roof level beams and plinth level beams, other wise transfer of load takes places through wall itself. But sadly without understanding this concept, lot of houses are constructed today using framed structure concept in which we can notice roof load is transferred directly to walls without any beams at Roof level but column are constructed up to roof level. Thus the columns are functionless in such cases. Also dummy column concept is also practiced widely in construction, where column and a footing are constructed up to plinth level. Further effective tying of beams to columns should be made by means proper detailing of steel for realising the concept of framed structure in buildings. This problem can be addressed by adopting Monolithic Concrete Technology.

It is noticed during construction that in many houses being built using beam column construction, the stirrups along column and beam reinforcement are bent straight at 90 deg angle which is defective. The bar benders need to ensure bending of stirrups at 135 deg as otherwise these would lead to opening of ties and failure of columns during earthquake. A majority of rural and urban load bearing masonry buildings are constructed arbitrarily violating minimum safety requirements such as length of wall in room being more than 5 Mts., openings more than 50% of wall length, location of windows exactly at the corner, no space between two windows, no plinth or lintel bands. Today most of our roofs are constructed using RCC as Flat roof where large amount of steel and cement are used. Main function of using steel in any RCC element is to take tension, as concrete is weak in tension. Roof element is designed considering only steel to take tensile force ignoring concrete near the steel and thus the concrete immediately above the reinforcement serve the purpose of only confining the steel. Thus we can avoid concrete for confinement purpose to achieve economy. However if we wish to construct RCC roof we can go in for monolithic concrete technology in mass housing projects which results in substantial savings in time and cost.
The Monolithic Concrete Technology (MCT) imparts stability in the whole structure. Since thickness of wall and slab are less, there is saving in materials. One entire floor can be completed in two days using ready mix concrete. The cost of repairs and maintenance is very less as compared to conventional walls and roof construction. The form work can be repeatedly used and milestones or target of reaching desired physical and financial progress can be achieved without compromising on quality. However, initial investment for form work may be higher.

**Construction Stages:**
- Formwork systems of foundation, wall and ceiling are designed in strict compliance with the architectural plan.
- Footing is cast up to the plinth level using conventional shuttering.
- The components of the formwork system are manufactured in the fabrication plant in accordance with the design specifications.
- The construction site is leveled and compacted according to the project's technical requirements.
- Reinforcement bars and foundation forms of the foundation are installed and then the concrete is poured.
- The wall reinforcement and ceiling reinforcement mesh which has already been put in place is connected to the starter bars of the foundation.
- Electrical conduits are embedded in the walls whereas plumbing lines are laid outside the walls.
- The connectors are provided to hold the aluminum formwork which is covered by foam sheets during concreting. The slots thus formed after removing the shuttering is used for the scaffolding and staging for upper floors.
- A thin vibrator needle is used to compact the concrete and an opening is provided in the shuttering works near window sills which when properly compacted prevents honeycombing.

**Wall Reinforcement as per specification.**

The beginning of formwork process normally starts in a corner or Multiple corners depending on the number of workers. This process Continues until all walls are erected.
Application of Nitto bond between old and new concrete surface. Concrete is placed monolithically in walls and slabs and compacted using a thin vibrator needle.

The formwork is removed the very next day to begin the cycle again and Curing compound is applied to the external walls.

The scaffolding and staging works are done with the help of the connector holes which not only supports the weight of the workers but also supports.

For the next floor reinforcement is tied, forms will be set and concrete will be poured repeating the cycle. All services like electrical, plumbing & sanitary are embedded before concreting which avoids breaking & making of structures.

It demands least quality control on site—which is the greatest advantage for fast track construction. It is suitable when minimum number of units is 1000.

**Earthquake Resistance**

In general, buildings with simple geometry in plan will perform well during strong earthquakes whereas buildings with re-entrant corners, like U, V, H and + shaped in plan will undergo significant damage. In this case monolithic casting of slab along with RC load bearing
wall results in a box type structure, which is very strong in resisting horizontal forces due to earthquake or wind. In view of large depth of walls moment of inertia is very high thus resulting in minimal stresses due to bending moment and vertical loads are smaller and in many cases, concrete alone is capable of resisting these forces.

Fig.1 In conventional building for the direction of earthquake shown wall B tends to fail.

Fig.2 In Monolithic construction for the direction of earthquake shaking shown wall A1 & A2 (loaded in stronger direction) supports wall B1 & B2 (loaded in weaker direction) as it is interconnected.

Fig.3 Earthquake resistant Box type monolithic structure.

This is a Box type of construction where entire building behaves like a box tied together in all corners and joins thereby offering maximum resistance to deformation and bending during earthquakes and cyclones.
Protection of Openings in Walls

The most common damage observed during an earthquake is diagonal X-cracking of wall pier and also inclined cracks at the corners of door and window openings. When a wall with an opening deforms during earthquake shaking, the shape of the opening distorts and becomes more like a rhombus - two opposite corners move away and the other two come closer. Under this type of deformation, the corners that come closer develop cracks. The cracks are bigger when the opening sizes are larger. Steel bars provided in the wall all around the openings restrict these cracks at the corners.

Advantages of Monolithic construction technology:

- Total system forms the complete concrete structure.
- Custom designed to suit project requirements.
- High quality finish.
- Cost effective for repetitive mass construction projects.
- Faster Construction and requires less work force.
- Footing, wall and slab are designed as an integrated unit.
- Reinforcement is continuous and interlocks with all the structural components of the building viz., foundation, walls and slabs.
- Slender sections resulting in light weight structures.
- Monolithic box like structure provides high resistance to earth quake.
- For a given Plinth area More Carpet area.

Disadvantages of Monolithic construction technology:

- Semi-skilled and skilled labour for construction is not available locally.
- Adequate training is required for labour.
- Up gradation /alteration works cannot be done.
- Repairs and Maintenance is tedious.
- Promotion for implementation of this technology is required.
- Thermal radiation is more in concrete walls compared to masonry structures.
- Huge Initial investment, nearly 15-30% of the cost depending on the time of delivery.
- Minimum proposed housing units for optimum usage of technology is 1000nos.
- No flexibility for change in design during construction.
- Formwork is design Specific.
Conclusion

The Monolithic Concrete Technology adopted in Slum Housing Project at Sathagally and Rajivnagar has achieved a cost reduction in the construction to the extent of 15-20%. There was no need for plastering and lintels.

This technology can be conveniently used for all massive housing programmes for poor, the low income groups and luxury housing. The defects that are commonly committed in traditional and conventional construction methods can be avoided in monolithic concrete construction. Unlike load bearing construction using brick and stones which are generally weak against disasters, the monolithic technology provides resistance and safety against earthquake and cyclones. The cost of repairs and maintenance would also be reduced as compared to other constructions. However, the thermal discomfort in summer can be prevented by proper thermal insulation through the method of creepers around the walls and roofs, insulation painting etc. The Conventional and Monolithic Construction technologies are compared in which later is 10 to 15% more economical & 25% faster. Monolithic Construction technology is suitable for mass housing and rehabilitation housing projects. The case study project is implemented outside the developed area which is not easily accessible. However all necessary infrastructure facilities such as Buses, Market center, School, Hospital etc., are to be provided. Rain water harvesting should be adopted as there is vast roof area/built-up area. Solar energy for street lights can be a better option. Most important observation is that all those living in the houses felt that house is comfortable and they were satisfied with the quality. Most of the key components like walls, columns, beams, floor slabs, staircases, balconies, openings, hoods, storage lofts, etc., are monolithically concreted in-situ. No need of bricks, blocks and plastering. Because of reduced dead load, superstructure and foundation cost are minimized without compromising on strength. These structures are efficient against earth-quake due to its single rigid block nature. Amenable to fast-track construction. All services like electrical, plumbing and Sanitary are embedded before concreting which avoids breaking and making of structures. Whenever there is a challenge of construction in least possible time with best quality.

The technology will contribute in solving to a great extent in addressing the vision of housing for all and slum free cities as initiated by the Union & State Governments.

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