ALTERNATE AND LOW COST CONSTRUCTION MATERIALS AND TECHNIQUES

Submitted in partial fulfilment of the requirements

for the degree of

MASTER OF ENGINEERING

in

CIVIL ENGINEERING

(With specialization in Construction Engineering and Management)

by

Shaikh Mohd Aqeeb

(Registration Number: Anjuman-33)

Under the guidance of

Dr. R. B. Magar

Department of Civil Engineering

School of Engineering and Technology

Anjuman-I-Islam's Kalsekar Technical Campus

New Panvel, Navi Mumbai-410206

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A Dissertation Report on

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CERTIFICATE

This is to certify that the project entitled **"Alternate and Low Cost Construction Materials and Techniques"** is a bonafide work of **Shaikh Mohd. Aqeeb (15CEM14)** submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Master of Engineering" in "Civil Engineering (With Specialization in Construction Engineering and Management)"

Dr. R. B. Magar	**Dr. Abdul Razak Honnutagi**
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APPROVAL SHEET

This dissertation report entitled "Alternate and Low Cost Construction Materials and Techniques" by Shaikh Mohd. Aqeeb is approved for the degree of "Civil Engineering with Specialization in Construction Engineering and Management"

Examiners

1. ....

2. ....

Supervisors:

1. ....

2. ....

Date:

Place: Panvel

DECLARATION

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

Shaikh Mohd. Aqeeb
(15CEM14)

Date:

ABSTRACT

This study addresses the issue of ever-escalating costs of housing projects by designing affordable, economic residential projects by using low-cost housing materials and adopting new designing techniques and using software likes ETABS and AUTOCAD. In this study, various building methodologies and alternative low-cost building materials are explored and compared with conventional methodologies and materials from the safety, economic, durability, aesthetic and functional point of view. Prefabricated components like precast RC planks, precast hollow concrete panels, precast concrete/ferro-cement panels and alternative building materials like fly –ash sand lime bricks, solid concrete and stone blocks, cellular concrete, laterite blocks, dry-hydrated lime, rice-husk ash pozzolona and hollow concrete blocks are employed. In this study to appraise alternative building materials and technologies for wall and roof construction. This study encompasses the use of sound construction techniques by employing ETABS and AUTOCAD as tools for planning and designing solutions for low cost housing. The Project highlights the benefits of low cost and sustainable building materials over conventional and steel buildings, its scope and application to residential buildings and technology envisaged for the same. The main findings of the study are that consider Rs.225/Sq. ft can be saved by using the techniques discussed above. This proves that using low cost housing technologies is a cost effective construction approach for the industry.

Keywords— Low Cost Housing; Precast RC Planks; Precast Concrete; Fly-Ash Sand Lime Bricks; Cellular Concrete; Rice Husk Ash.

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ABBREVIATION NOTATION AND NOMENCLATURE

NBO	National Building Organization
FICCI	Federation of Indian Chambers of Commerce and Industry
CSIR	Council of Scientific & Industrial Research
NBRI	National Building Research Institute
SERC	Structural Engineering Research Centre
BMTPC	Building Material & Technology Promotion Council
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
MHADA	Maharashtra Housing and Area Development Authority
CBRI	Central Building Research Institute
CA	Cost Analysis
CUM	Cubic Meter
SQF	Square feet
KG	Kilogram

Chapter 1

Introduction

1.1 General

Housing is one of the basic human needs along with food, clothing and education. Mankind has been evolving different kind shelter changing civilizations and time. Human ingenuity has led to construction of structures as tall as 110 storeys in recent times. High rise buildings dot the skyline of the large cities all over the world. Notwithstanding the rapid stride in the field of building technology, providing shelter to the teeming millions at affordable cost remains a distant reality in most of the developing countries across the globe. A World Bank study conducted in 2015 showed that 55% of the households in Mexico City, 35% in Bangkok, 68% in Nairobi, 47% in Bogota, 64% in Ahmedabad, and 63% in Madras were unable to afford the cheapest dwellings available in the open markets of those cities. Position in these cities has since further deteriorated (Lal, 2003).

Like any other developing country, India too is presently passing through a phase of acute housing shortage. As per National Buildings Organization (NBO) estimates, in 2015, there was a shortage of 31 million dwelling units in the country out of which shortage of 10.4 million units existed in the urban sector and the remaining 20.6 million units in the rural sector. The backlog of housing is expected to mount up to 41 million by the turn of century. The picture is abysmally dismal at the lower end of the economic ladder. According to an UN estimate, over 33 per cent of the population in developing countries is houseless. A recent study undertaken by the UNCHS reveals that over 100 million people live in a state of absolute homelessness, while in excess of one billion people are forced by circumstances to reside in desperately inadequate housing conditions which threaten their health, security, safety and

Dignity. The Economic Survey of India for 2015-2016 indicates that in 2005, There were about 0.6 million absolutely homeless households in the country and the number has further grown in the intervening period. As per one estimate in 2016, there three million absolutely homeless households in the country (Bredenoord, 2016).

It is significant that against the annual population growth rate of 2% in the country, the number of residential buildings has increased at an annual rate of only 1.5 percent. One Australia or Nepal, equivalent to a population of 17 million people is being added to the Indian population annually. With the uncontrolled population explosion and rapid pace of urbanization, the problem of providing shelter to the poor is bound accentuate in coming years. According to the Federation of Indian Chambers of Commerce and Industry (FICCI), keeping in view the existing housing crisis in the country, the present addition of 2.5 million units a year is hopelessly inadequate Singh and Kumar (2016).

To complete the project with minimum/optimum cost is always a challenge to the management of any building construction project in India, where the building need is very high. The need for housing consist not only the demand for up gradation and renovation of existing housing stock but also the need for construction of new dwelling units. Therefore, to find a shelter for each one at a low-cost is the greatest challenge of all times. However, the demand for a roof over one's head had been increasing continuously and there has been a persistent gap between the demand for and supply of housing stock in India. This causes an acute shortage of dwelling units in the country (Hutcheson, 2011).

The problem is becoming grave mainly because the house construction has not kept pace with the growing demand. The major factor leading to the housing shortage is the slow increase in housing construction in relation to the population growth. The pace of housing construction has been extremely slow because of the speculative increase in land price and rising cost of construction. Hence, the achievement of housing is decreasing whereas the need for housing go on increasing year after year thus bringing about an imbalance between both the demand for and supply of housing. Resultantly, for millions of people in India, the desire of owning a house remain only a long cherished dream unfulfilled so far it is impossible to handle the problem of minimizing the project cost from a normal cost (Dobson and Sourani,2012).

To overcome such difficulties, Managements are looking for new alternative construction materials and techniques approaches and one such approach is the use of low cost construction. In this approach the phases of the project are accomplished concurrently instead in series. The complexities that arise in managing projects are tackled through proper restructuring of project organization; upgrade management commitment, Proper materials selection and planning of activities, safeguard project quality, managing project risk equitably. and managing the cost reduction techniques employed in housing construction (Baker,1986). The Council for Works and Housing (CWHR) is an R & D organization under the aegis of the ministry of science and technology. The main function of this council is to promote scientific research on problems related to different types of civil engineering structures such as buildings, roads, bridges, dams, harbours, treatment plants etc. The CWHR has endeavoured in R & D work for the development of durable, economical and innovative materials for the construction industry with focus on the utilization of local/ indigenous techniques and materials for import substitution of construction inputs. Construction dating back to the very existence of man, forms the basis of all developments. It is a vehicle for the growth of culture and civilization. Every rational beings longs to have a shelter to protect their families. Therefore, Shelter occupies the most important position among the construction activities. People want not only mere physical shelter but also a home as part of the total way of life. It is a place where people in general fulfil1 the basic domestic and personal functions of family life, physical and mental health, working efficiency, emotional security and social status (Jasvi and Bera ,2015).

Therefore, to find a shelter for each one at a low-cost is the greatest challenge of all time. However, the demand for a roof over one's head had been increasing continuously and there has been a persistent gap between the demand for and supply of housing stock in India. This causes an acute shortage of dwelling units in the country. The problem is becoming grave mainly because the house construction has not kept pace with the growing demand. The major factor leading to the housing shortage is the slow increase in housing construction in relation to the population growth. The pace of housing construction has been extremely slow because of the speculative increase in land price and rising cost of construction. Hence, the achievement of housing is decreasing whereas the need for housing go on increasing year after year thus bringing about an imbalance between both the demand for and supply of housing. Resultantly, for millions of people in India, the desire of owning a house remain only a long cherished dream unfulfilled so far (Lal,2003).

As far as Maharashtra state is concerned the gap between both the aggregate demand for and aggregate supply of housing is highly relevant. This causes a high level of housing inadequacy in the state. Due to the escalating rise in price of building materials the housing has become totally in accessible to many. Now, the price of building materials alone contributes to 60-70 percent of the cost of construction. The predominant use of conventional construction materials like steel, cement, burnt clay bricks and timber clearly shows an increasing trend in the construction costs over the years. The cost of construction is increasing

By 13-15 percent each year even when the inflation is less than double digit. Therefore, the most important subject with immediate interest is the reduction in building costs. The Cost Effective Environment Friendly (CEEF) technology is making sustained efforts to implement advance programming and architectural planning, rational and structural designs, organization, execution and management of works and using new materials and construction devices (Taur and Devi,2009).

Low cost housing materials

Low cost housing materials can be broadly classified into natural and manmade materials according to the source of the building materials are blast furnace slag, fly ash bricks, Rice husk-ash, phosphogypsum, lime-sludge, bagasse, Ferro cement, tire-veneer, plastic wood, synthetic fiber, recycled agg, fly ash, bamboo, wheat straw (Chowdhury and Roy ,2013).

Low cost housing techniques

Some of the roofing/flooring components are precast RC planks, prefabricated brick panels, precast RC channel roofing, Precast hollow slabs, Precast concrete panels, L panel roofing, Thinner walls or single brick thick wall, Precast hyperbolic shell for roofing, Fly ash sand lime bricks, Solid concrete and stone block, Concrete door with wooden shutter, Concrete window with glazed shutters (Taur and Devi,2009).

Adoption of innovative cost-effective construction techniques

In the research labs „show-how‟ in the field, and experimental housing scheme was initiated under the aegis of the NBO by the government of India in 1962.Under the scheme, innovative construction techniques and improved building materials, which were evolved as product of basic and applied research were tried out under field conditions in prototype experimental buildings for their technical and economic evaluation successful techniques were subsequently propagated for wider adoption. Under this scheme, construction department sponsored projects for putting up of 40 to 50 houses incorporating new technologies, design concepts and materials etc. (Tapkir et al.2016).

Adoption of precast elements in partial prefabrication

Brief details of some of the popular precast building components, namely, precast RC roofing/flooring elements, precast thin RC lintels, precast RC door and window frames, which have been successfully tried out under the NBO experimental projects and their subsequent large-scale utilization in several housing projects undertaken by various construction departments/agencies in India (Ganiron and Almaewae,2014).

Precast roofing systems

Roofing accounts for up to 25% of cost of construction of a house. By using precast roofing components, 20 to 30% economy could be achieved in the cost of roof construction. Some of the popular precast roofing/flooring techniques promoted by the NBO, which have manifold advantages of saving in cost, consumption of cement and steel and increased pace of construction, are described below. All these systems make use of components which are fabricated on the ground, ready in all respect for erection in building. In-situ concreting, work is minimized in these systems so that the speed of construction is not affected. The necessity for putting up cantering and shuttering as in the case of cast-in-situ reinforced concrete (RC slab completely) is eliminated under these roofing systems. The provision of cantering and shuttering is a time-consuming process and elimination of the same leads to considerable saving in erection time (Zami and lee, 2009).

1.2 Scope of the work

In view of the aforementioned problem as specified from the literature review following scope is outlined for the present investigation.

1) Scope of the study is the consumption of building materials changes both quantitatively and qualitatively in the various stages of housing construction. Accordingly, the cost of construction also changes between the conventional and cost - effective technologies.
2) Overall this study will be very useful for the previous, ongoing, and upcoming future construction projects of high scale area to minimize the cost, time and waste and also the enhancement of structure.

1.3 Aims and objectives of the work

The aim of this experimental work is to apply conventional and cost effective technology of construction. House is one of the biggest need and low cost housing gives the houses to people at reasonable rate. Pursuant to this, following objectives are proposed in the present investigation.

- To study different types of construction materials and technique used, to reduce the cost of construction.
- Alternate and low cost construction materials and techniques used for sustainable development.
- To identify total cost required for completing a project using conventional and cost effective technology.
- To compare cost and time reduction by adopting different materials and techniques for large scale project.

1.4 Organization of dissertation

This dissertation report comprises of following chapters. The brief contents have been discussed as below:

Chapter 1 Contains the background to the study, Relevance of the study, Scope of the work, Aim and Objective of the work, Organization of the dissertation & Limitations of the study.

Chapter 2 Contains overall review of literature on alternate and low cost construction materials and techniques for low cost housing.

Chapter 3 Deals with the low cost housing methodology includes that planning, analysis and designing and modelling of a residential building.

Chapter 4 Explains about the various low cost construction materials and techniques.

Chapter 5 Deals with the results and discussions on the relative cost variations between conventional and cost-effective technologies.

Chapter 6 Provides conclusions, future scope, and summary.

1.5 Limitation of the work

This work has been confronted with the limitation of non-availability of some required data and information. However, maximum attempt has been made to enable the work a fruitful pursuit, keeping errors the minimum.

Chapter 2

Literature Review

2.1 General

Home has been the centre and instrument for mankind's moral and material progress since the advent of civilization. Since home life affects the very foundation of an individual's life, the house becomes an integral part of the first step in house construction is collecting money to own a house. These days one need not have ready cash to start house construction. There are many financing institutions which give a helping hand in fulfilling one's dream of owning a house. Thus is a topic on which many studies have not been done in our country. The available literature is reviewed under the following heads. Importance of housing, problems, shortages, cost effectiveness, environment awareness and various sources of housing finance, urbanization approach, Marxian views, effects of decentralization, and the developmental efforts for the future housing sector (Taur and Devi, 2009).

2.2 Overview of Literature Review

Zami and Lee (2009) have reported that the economic benefits of contemporary earth construction in low cost urban housing state, it is observed that stabilized earth is an alternative building material on each continent and in each age. This article reviews and argues the economic benefits of using earth as a building material and describes the associated construction techniques for urban housing provision in developing countries.

Taur and Devi (2009) explained the low cost housing, it is observed that, this paper goals to argument out the various aspects of prefabricated construction methodologies for low cost housing by highlighting the different prefabrication techniques, and the economic advantages accomplished by its adoption. In a building the foundation, walls, entries and windows, floorings and roofs are the most important components, which can be analysed individually based on the needs thus, improving the speed of construction and dropping the construction cost. The major current methods of construction systems considered here are namely, structural block walls, mortar fewer block walls, prefabricated roofing components like precast RC planks, precast hollow concrete panels, precast concrete/Ferro cement panels are considered.

Tam (2011) explained the cost effective of using low cost housing technologies in construction. It is found that about 26.11% and 22.68% of the building cost can be saved by consuming low cost housing technologies in assessment with the traditional construction methods.

Hutcheson (2011) studied the project management of low cost housing in developing countries, it is observed that the study of this paper include designs, cost control systems, communications, contract law and planning. An appreciation of the evidence compounded from the problems portrayed throughout the paper leads to decisions of the need for simplifications of designs, the impact of inadequate local support and hence the need for detailed and complete advanced planning. In addition, the conclusions stress the need for the careful collection of self-supportive teams of multi-disciplined professionals and sub professionals.

Lin (2011) explained human resource allocation for remote construction projects; it is observed that when allocating human resources for the management team of distant Projects sites, these firms have the strategies between assigning regular staff and hiring local temporary employees. This paper first proposes a decision making model for human resource allocation in remote construction cost. The case study results show that regular project administrators, who are able to reduce managerial flaws and cut down project losses are favoured over local ones.

Dobson and Sourani (2012) explained sustainable construction, it is observed that the objective in this paper were to found if there is a belief within the commerce that sustainability means increased cost and to investigate whether using sustainable construction methods save money by reducing a building carbon output and running costs. Following the literature survey, a questionnaire survey has been carried out to canvas opinions within industry. This paper will benefit customers and designers as they can see how integrating sustainability into new buildings will enable big savings on utility and maintenance costs once the building is operational.

Pachecotorgal and Jalai (2012) explained earth construction and building materials, it is observed that in this paper earth construction has a major expression in less developed countries, on the other hand the mimetic temptations near more poisoning construction techniques based on reinforced concrete and bricks that fired up are likely to favour a change near a clear unsustainable design. In order to disclosure and highlight the importance of earth construction this article reviews some environmental benefits such as non-renewable resource consumption, waster generation, energy consumption, carbon dioxide emissions and indoor air quality.

Bakhtyar (2013) presented a review on low cost housing process in Malaysia, it is observed that, the results confirmed that making balance between low income obligations and developer’s profit-making is the key element for building more LCH in the country.

Caponetto and Francisc (2013) explained ecological materials and technologies in low cost building systems, it is observed that the high recyclability of natural materials that can be used in low cost building associated with construction techniques capable of exploiting the principles of bioclimatic architecture for liveliness needs allow us to create building environmentally conscious and responsible. At the same time the project of a special block was developed to meet the needs of sustainability and ease of construction.

Chowdhury and Roy (2013) explained prospects of low cost housing in India, it is observed that in this paper alternative construction materials mainly natural material such as bamboo, straw, usage of bagasse-cement boards and panels, bagasse –PVC boards, Coir-CNSL board, Jute coir composites, coconut and wooden chips roofing materials, manmade materials like fly ash, aerosol panels, ferro cement, rice husk were studied and the potential of these materials to be used as alternate building materials is brought out.

Nilanjan and Souuvanic (2013) explained cost effective building construction technologies, it is observed that this paper studied the acceptability and adaptability potential of different cost effective building constructions through field survey, literature study and technical calculations and tried to find out the most appropriate one among those.

Raspall and Arora (2014) explained the building from end-of-life an alternative approach for low-cost urban housing, it is observed that our research investigates the possibilities of beating into the life cycle of construction materials as a basis of unexploited construction components for low-cost housing. In the informal city, a market of salvaged materials is already in place. Though, in the urbanized world, reuse practices in construction are characteristically dismissed. This research contributes with strategies to secure very low-cost housing units consuming reused construction components, focused on the functional, aesthetic and economic aspects.

Ganiron and Almaewae (2014) explained prefabricated technology in a modular home, it is observed that one of interesting perceptions in the study is that prefabricated components has a significance change in the terms of a construction cost as relate to the old-fashioned methods due to the materials and fast band short time duration of construction.

Ugochukwu (2015) explained the local building materials, it is observed that the paper recognizes the problem of inadequate housing as a critical challenge to sustainable urban growth and cities development. Extensive use of recycled materials help conserve restores and preserves the ecosystem. Green buildings wastes management ensures resources and energy efficiency. The closeness of materials saves cost and decreases pollution by fuel through transportation.

Jasvi and Bera (2015) studied on sustainable use of low cost building materials in the rural, it is observed that, the main challenge is to use the materials in structural constituent for low cost housing and their adaptation to influences like – technical, social, ecological, physical – through different products. It encounters the idea about the need of housing in country side India and explains different uses of materials and the techniques of building construction for LIG people, urban poor's in different aspects of building. It covers the use of local materials in the building to reduce cost and it makes affordable houses for low income people.

Bredenoord (2016) explained sustainable housing and building materials for low-income households, it is observed that sustainable goals for low-cost housing and applications are achievable. Measures concerning the physical development of neighbourhoods, such as urban density and connectivity are equally as important as measures concerning community development. The final comprise support for community built organizations, small housing cooperatives (or similar forms of cooperation) and individual households – or small groups – that build and increase their houses incrementally. Adequate design and social organization and support are preconditions for achieving sustainability in incremental housing.

Singh and Kumar (2016) explained low cost housing, need for today's world, it is observed that construction cost in India is increasing at around 50 per cent over the average inflation levels. It has enumerated increase of up to 15 per cent all year, mainly due to cost of basic building materials such as steel, cement, bricks, timber and other inputs as well as cost of labour. As a result, the cost of building by means of conventional construction materials and construction is becoming beyond the affordable limits particularly for low-income groups of population as well as a big cross section of middle - income groups. So, there is essential to adopt cost-effective construction methods either by up-gradation of traditional technologies using local resources or applying current construction materials and methods with well-organized inputs leading to economic solutions. By using low cost housing technologies, we can reduce approx. 25% of the total cost of housing.

Tapkir et al. (2016) explained the study and analysis of low cost housing based on construction techniques, it is observed that, there are three factors that affecting the cost of project time, materials used and techniques. In this paper different methods were discussed for cost control and reduction.

2.3 Summary

The above discussion of various aspects of housing in general and housing finance in particular has been a modest attempt to develop a structure for the present study. The chief contention of this conceptual frame work is that housing scenario in a developing country with its complicated structure cannot be explained with a single theory. A synthetic approach which takes into consideration the impacts of urbanization, decentralization, Marxian views on housing, cost analysis and indigenization of house designs, alone can do justice to the housing sector which is being investigated.

Chapter 3

Methodology

3.1 General

This study will be very useful for the previous, ongoing, and upcoming future construction projects of high scale area to minimize the cost, time and waste and also the enhancement of structure. This work is organized into following five stages which is shown in Figure 3.1 in the form of flow chart.

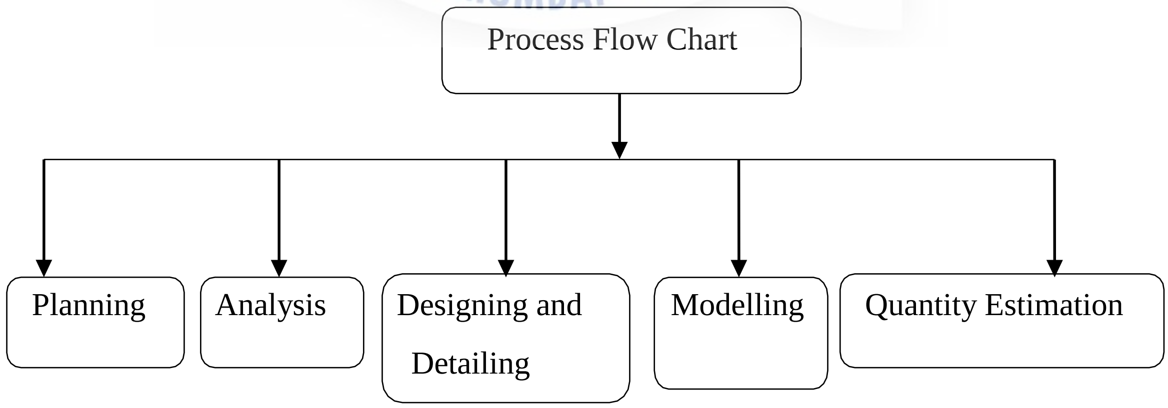

Figure 3.1 Methodology adopted in the present work

This Figure shows the flow chart of methodology based on the planning, analysis, designing and detailing, modelling and quantity estimation will be done by using software auto cad, Etabs and Autodesk Revit.

3.2 Planning

Planning of a residential building has been done as per building bye-laws and IS code requirement, keeping in mind the accommodation requirement for 20 families, for this purpose, AutoCAD software is used. Building consists of G+3 residential storeys.

3.3 Analysis

After completion of planning the project will move ahead by analysing and designing process with the help of Etabs software. Etabs offers a single user interface to perform analysis, design, detailing, and reporting. This software will analyse and design an educational complex with much ease. Etabs gives analysis and design for beams and columns only. There is a step-by-step procedure followed by us for analysing and designing the structure. The steps are explained in detail in proper sequence below:

- Saving AutoCAD file as .DXF file.
- Opening .DXF file in Etabs and provide unit in meters.
- Define material like M30, M35 etc. Grades of concretes & Fe 415, Fe500, etc. Steel as per IS code provided in options.
- Define section properties: Placement of beams and columns: Beams and columns are placed as indicated in Centre line plan. After placement of beams and columns, the view typical floors are as follows:
- Loads define: Different type of load such as live, dead, masonry, seismic loads, etc.
- Assign of loads: loads are assign on beams, columns and slabs.
- Load cases: Different types of load cases are defined.
- Load combinations: Different combination of loads are embedded in Etabs as per IS code.
- Defining functions: Functions for seismic load for X & Y direction are defined under response spectrum.
- Assigning diaphragm: Rigid diaphragm is provided.

- Joints are restrained at plinth level.
- Checking the model for assigned beams, columns and slabs.
- After checking the model, analysis is run and the model is found to be safe.

After analysing the structure, we did the design check of frame section and obtained the required area of steel for each structural member. Also we get to know that none of the beam or column is over-stressed.

3.4 Designing and detailing of slab and footing

After analysing the structure, detailing of the structural members is done. Under this head, we can provide the number of main bars, number of distribution bars and spacing between the stirrups (tie bars) as per the area of steel obtained from the analysis of structure. Different structural members on different floors may or may not have same design and detailing schedule.

3.5 Modelling

This project demonstrates how to create and manage more complex projects and draw model using Autodesk Revit software as the base layer. The group focuses on the modelling of civil and building engineering structures both linear and non-linear. In modelling the quantity of material will be estimated and the 3-dimensional view will be displayed. Revit is a single software application that supports a BIM (Building Information Modelling) work flow from concept to construction. Use Revit to model designs with precision, optimize performance and collaborate more effectively.

3.6 Quantity estimation

Estimation of the quantities of materials is generated using Autodesk Revit software. Estimation is generated automatically in this software. We have estimated the quantity of steel and concrete in structural beams, columns and footing for the whole structure. This is done by selecting “view” option. Then go in “scheduling” on the “Task bar”. Then we sort the table columns by family type, count, volume and estimated rebar volume.

Chapter 4

Low Cost Construction Materials and Techniques

4.1 General

The main thrust of building research has been to improve upon the conventional practices and develop new prefabricated and cast-in-situ construction methods, mechanical aids, modern management techniques to achieve appreciable reduction in cost and time of construction and to effect maximum possible saving in the consumption of costly and scarce materials like cement and steel as well as improving quality in construction. Techniques for construction of walls and roofs were developed with a view to make an optimum use of local materials such as soil, bricks, lime and timber (BMPTC, 2015). The Central and State construction departments, housing boards, development authorities and other construction agencies either on charitable or voluntary basis have come forward for promoting the innovative techniques in their large scale housing programmes. Some important innovative techniques are used by these agencies for the construction of walls, roofs and building services (e.g.: drainage) which consume over 50 % of building cost (Zami and lee,2009).

On the other hand, organizations like National Building Organization (NBO) New Delhi, Building Materials and Technology Promotion Council (BMPTC) New Delhi, Housing and Urban Development Corporation (HUDCO), New Delhi and Housing Development Finance Corporation (HDFC), The National Network of Nirmithikendras under the aegis of HUDCO and COSTFORD centres throughout the state have been playing useful role in the promotion of innovative construction techniques evolved by the aforesaid research institutions in the country. NBO had experimented with 60 innovative cost reducing techniques in as many experimental projects (BMPTC, 2015). Amongst 60 types of construction techniques only two dozen techniques found wider application in large scale housing programmes. Emphasis was laid on partial prefabrication instead of total prefabrication in the construction of NB0 experimental buildings. Such a system leads to saving in cost and speed in construction. (BMPTC, 2015). Out of these precast components successfully employed in the experimental buildings precast roofing units viz, reinforced concrete (RC) channel units, precast RC solid plants and joists, precast- RCC lintels, stone block masonry are noteworthy. Other popular technologies emerging out of successful field trial of the innovative techniques include the concept of construction of 4-5 storeyed buildings having single-brick (23 cm) load bearing walls, in all the storeys, double storeyed construction with 19 cm load bearing masonry walls use of 11 cm (half brick) thick load bearing masonry construction having Z-shape in cross section for the urban poor and single slack system of plumbing (BMPTC, 2015).

Several alternative building materials like secondary species of timber, dry-hydrated lime, flyash and plastics had been successfully tried out under several NB0 experimental projects. Fly ash, an industrial waste from thermal plants, has been experimented in a big way under several such NBO projects sponsored by the Naïvely Lignite Corporation (NLC) Military Engineering service (MES), Haryana Housing Board and Tamilnadu Housing Board etc. It was tried out as partial replacement of cement in plaster and mortar and in the production of bricks and blocks. The results of such experimentation have been quite encouraging (BMPTC, 2015).

The Building Materials Technology Promotion Council (BMTPC) under the ministry of urban affairs and employment has undertaken identification of potential technologies which could help in larger utilization of industrial wastes like fly ash, phosphogypsum and. blast furnace slag in construction industry. The council has prepared technical profiles in respect of clay-fly ash burnt bricks, fly-ash-sand-lime bricks, cellular concrete components, alumina red mud bricks and phosphogypsum based building components for their larger exploitation in building activities (BMPTC,2015).

Thus, there is enormous potential in terms of technical capabilities available in the country which could be Judiciously exploited for providing affordable housing to the masses. Thus, before embarking upon a particular technology it is important to work out the "cost effectiveness". In case of thin precast flooring/roofing units, due attention should be given to the proper detailing of Joints and for ensuring diaphragm action of such roof floor (BMPTC, 2015). Therefore, while undertaking any mass housing programmes, due consideration is required to be given to the holistic approach to the various issues related to it such as financial resources, land availability, provision of necessary infrastructural services, selection of suitable cost effective construction techniques and materials etc. (BMPTC,2015).

4.2 Some cost reduction materials and techniques.

For cutting down the construction cost various cost reducing devices have been introduced by Maharashtra Housing and Development Authority (MHADA) at National level and Slum Rehabilitation Authority (SRA) Centres in the state for their large scale housing construction. Some of them are the following.

4.2.1 Thinner walls or single brick thick walls

Using thinner walls in construction and single brick thick walls, enhance the structural safety of buildings (Lal, 2003).

4.2.2 Load bearing brick work

It is now possible to construct 4-5 storey buildings in load bearing brick-work. By the adoption of this technique 5 - 15 percent saving in cost is achieved depending upon the structural requirements, type and strength of bricks etc. Over 1, 60, 000 houses have so

Far been constructed with this technique by the major construction agencies like central PWD (CPWD). Delhi Development Authority (DDA), Military Engineering Service (MES), Tamil Nadu Housing Board, Tamil Nadu Slum Clearance Board, PWD West Bengal and Uttar Pradesh etc. (Lal, 2003). It is recommended by CBRI that due to the adoption of thinner section of wall and newer type of bonding, the load carrying capacity of walls subjected to axil and eccentric loads should be reduced by 15 percent. By the adoption of 19 cm thick walls 17 percent saving in construction of bricks and mortar is achieved. As both the faces of the walls are even, only 10 mm thick plaster is required. An additional advantage by the use of this technique is the increase in floor area for the same plinth area. Using this technique several LIG and EWS houses were completed at Ludhiana under NB0 experimental housing scheme. Some houses were constructed in Maharashtra also.

(Lal, 2003).

4.2.3 Brick-on-edge cavity wall

The Central Building Research institute (CBRI) Rookie has developed a technique of construction of brick-on-edge 20 cm thick cavity wall which consists of two masonry leaves each of 7.5 cm thickness with a continuous air gap of 5 cm between them. The leaves are tied together either by corrosion proof metal ties or brick or concrete blocks. Two storeys residential buildings could be constructed with such cavity of bricks having crushing strength not less than 100 N/mm2 and mortar not leaner than 1: 3 in cement or 1: 1: 6 in cement and lime.

The adoption of brick cavity walls result in a saving of up to 30 percent in bricks and mortars, 15 percent in overall cost as compared to 23 cm thick brick walls and the inner leaves remains dry. This technique was used for the construction of middle school buildings in shanti agar, Rookie and by University of Rookie for lecturer's residences. It was also used under NBO experimental housing scheme for assistant professor quarters at thapar institute of technology, Patiala and Several double storey quarters in Gandhi Nagar Township, Gujarat, and a large number of both institutional and residential buildings in Tamil Nadu and Kerala (Laurie, 1986).

4.2.4 Precast stone masonry block

Stone masonry wall is 15-20 percent cheaper in cost as compared to random rubble masonry where bricks are costly. . A large number of houses have been constructed with stone masonry blocks in different parts of the country by different construction organizations. majority of the houses are constructing by using precast stone masonry block. In Andhra Pradesh and west Bengal prefab factories have come up which supply these blocks (Lal,2003).

4.2.5 Modular brick masonry walls

To introduce and achieve the benefits of modular planning in building construction it is necessary to produce bricks in a module of 10 cm. The nominal size of modular brick is 20 cm X 10 cm and so it has some advantages over the conventional bricks viz, it gives more floor area. Results in up to 10% saving in the quantity of bricks and 24% in the consumption of mortar. Consumes less clay and coal (Lal, 2003).

4.2.6 Hollow Clay Blocks for Shell Type Houses

Hollow clay blocks are arranged in a category profile and supported over a foundation of random rubble or brick masonry. The shell serves both as wall and roof for the house. There is considerable saving in cement and no steel is used. About 15% saving in cost could be achieved. A large number of houses have been constructed with hollow clay blocks in the states of Kerala and Tamil Nadu (Laurie,1986).

4.2.7 Sundried brick walls with waterproof treatment

The use of mud walls is still a predominant feature in villages. Such walls require continuous attention and repair every year as the rain erode them. CBRl Rookie has developed a non-erodible mud plaster which makes the walls water repellent. When the mud plaster is partially dry a leaping of cow dung and soil (1: l) is applied. When it is dry, the surface can be white or colour washed if desired (Lal,2003).

4.2.8 Precast hyperbolic shell for roofing

By adoption of hyperbolic shell roofing system. Beams and columns could be avoided and long spans such as stores, halls, etc. could be covered in an economical way. The use of such type of shells require less maintenance and are aesthetically pleasing (Lal,2003).

4.2.9 Rice husk ash and lime

For utilization of agro-wastes a house was constructed for the first time, using rice husk ash and lime as partial replacement of cement in construction. Rice Husk Ash and Lime has been used as cement in the fabrication of hollow, load bearing blocks and for mortar in plaster. The roof is prefabricated and consists of battens tiles; here too port land cement has been replaced by Rice Husk Ash to the extent of 30%. The foundation and base course are made up with soil stabilized with cement. The cost of construction was reduced by 37%as compared to cost of construction by conventional methods (Lal,2003).

4.2.10 Ground granulated blast furnace slag (GGBS)

For utilization of industrial waste material, a room was constructed, using ground granulated blast furnace slag, (a waste product of Pakistan Steel Mills,) as partial replacement of cement in construction. Load bearing walls are made of lime-slag-soil stabilized blocks. The lime-slag mixture consists of 30% lime and 70% slag. The blocks contain 10% of this mixture and 90% of soil by weight. The roof is prefabricated and consists of battens and tiles.30% Portland Cement has been saved in the tiles by replacing with it with slag. The mosaic floor constitutes the mixture of slag, lime, cement and marble chips. The cost of construction was reduced by 25% to 30% as compared to cost of construction by conventional method. (Lal, 2003).

4.2.11 Soil cement stabilized blocks masonry walls and pre-fabricated roof

For utilization of industrial wastes, a five room school was constructed using soil-cement stabilized blocks for masonry walls and pre-fabricated roof using slag as partial replacement of cement in construction. The foundation and base course of the floor is made of soil cement stabilized material. The load bearing walls have been constructed using soil cement stabilized blocks. The roof is constructed with precast batten tiles wherein 30% Portland cement has been replaced with finely ground granular slag. Air cooled slag was used in all the roofing elements as coarse aggregate. The cost of construction was reduced by 43% as compared to cost of construction by conventional methods. (Ganiron and Almaewae, 2014).

4.2.12 Construction of low cost housing unit

A demonstration and experimental low cost housing unit was constructed by utilization of alternative low cost construction materials and techniques including wastes. The overall saving of this house is 24% as compared to cost of construction by conventional methods. Masonry walls have been constructed using irregular stone pieces, cast in low grade concrete to obtain shape of regular block masonry. Saving in the cost of shuttering has been achieved by using pre-cast U-shaped channel blocks as lintels. The hollow spaces are filled with concrete with reinforcement bars. Arches have been constructed by using old truck tyres to save shuttering and labour cost. Cost of doors, windows, and their frames has been reduced by casting them with Ferro cement. Reinforced burnt clay pot slab tiles, reinforced burnt clay brick slab tile, Precast RCC battens and Ferro cement barrel shell planks. (Laurie,1986).

4.2.13 Wheat straw concrete block masonary walls

A model room is constructed by using wheat straw concrete block masonry for load bearing walls with lightweight R.C.C. tile batten-roofing system. This type of construction is economical and thermally comfortable for rural houses. The construction is simple, low cost and can be constructed on self-help basis. Mould release agents have been developed to provide the very best concrete stamp release and still allow optimum colour retention in decorative concrete. It can be used in conjunction with concrete stamping store colour hardener to insure the best combination on the market today. Concrete stamping store release agents give a beautiful antique finish to the surface of stamped concrete. When used alone, it highlights the natural grey concrete with the defining lines of the concrete stamp. When used together, the colour hardener and release agent create a very pleasing contrast. (Laurie, 1986).

4.3 Summary

The proper handling of man-power and materials requirement is very necessary to reduce the construction cost. An estimate of man power and materials is generally required prior to the start of actual construction for seeking technical and other administrative sanction, calculating the requirement of various materials and labour, planning and budgeting purposes, calling and Justification of tenders etc.

Chapter 5

Results and Discussions

5.1 General

At present both conventional and cost effective technologies are available in the field of house-building. Among these technological options the most one to be selected. But the selection of technology should be done only after having a comparative cost evaluation between the two. Then only we can ascertain the economy in construction and of the optimum use of materials.

5.2 Planning

Planning of a residential building has been done as per building bye-laws and IS code requirement, keeping in mind the accommodation requirement for 20 families, for this purpose, AutoCAD software is used. Building consist of Ground + 3 Residential storeys. Each floor consists of 5 flats. Each flat is assigned to individual family. Every flat is equipped with attached w.c and bath, and a modern furnished kitchen and bedroom. Typical floor plan as shown in Figure-5.1.

Figure 5.1 Typical floor plan

This Figure shows the typical floor plan, ground floor consist of 5 flat. Each flat is assigned to individual family. Every flat is equipped with attached w.c and bath, and a modern furnished kitchen and bedroom. There are 1 flat with 1RK and rest all flat are 1BHK. First floor, second floor and Third Floor Plan, First Floor, Second Floor and Third Floor each floor consist of 5 flat. Each flat is assigned to individual family. Every flat is equipped with attached w.c and bath, and a modern furnished kitchen and bedroom. There are all flat are 1bhk.

5.3 Etabs

After the detailed analysis of structure, the following results is obtained which shows the area of steel required in respective structural members (beams, columns, shear walls). Along with the steel area, the bending moment details, shear force details and deflections in each beam is also obtained in a systematic manner. All these details are obtained in an auto-generated ".docx" file which is generated automatically by Etabs software while we work on the structure. Necessary snapshots are provided below. The reinforcement details of typical beam sections are shown in Figure 5.2.

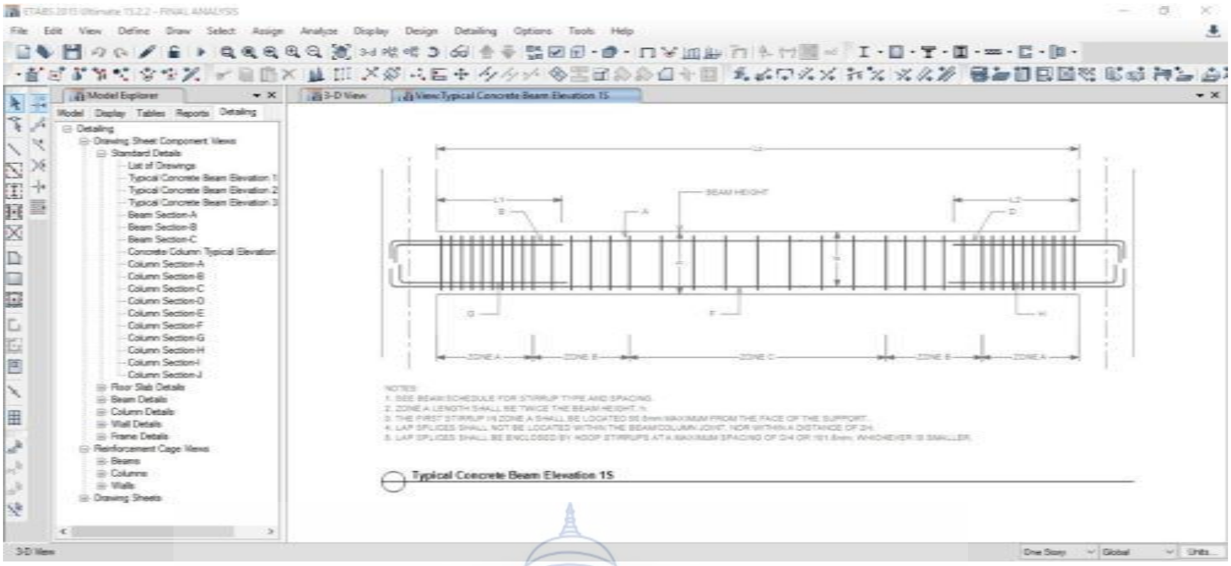

Figure 5.2 Reinforcement details of typical beam

This Figure shows the reinforcement details of Typical Beam (Elevation view) for slab. Along with the steel area, the bending moment details, shear force details and deflections in each beam is also obtained in a systematic manner

After the detailed analysis of structure, the results are obtained which shows the area of steel required in respective structural member's columns. Along with the steel area, the bending moment details, shear force details and deflections in each beam is also obtained in a systematic manner. All these details are obtained in an auto-generated ".docx" file which is generated automatically by Etabs software while we work on the structure. Necessary snapshots are provided below. The reinforcement details of typical column sections are shown in Figure 5.3.

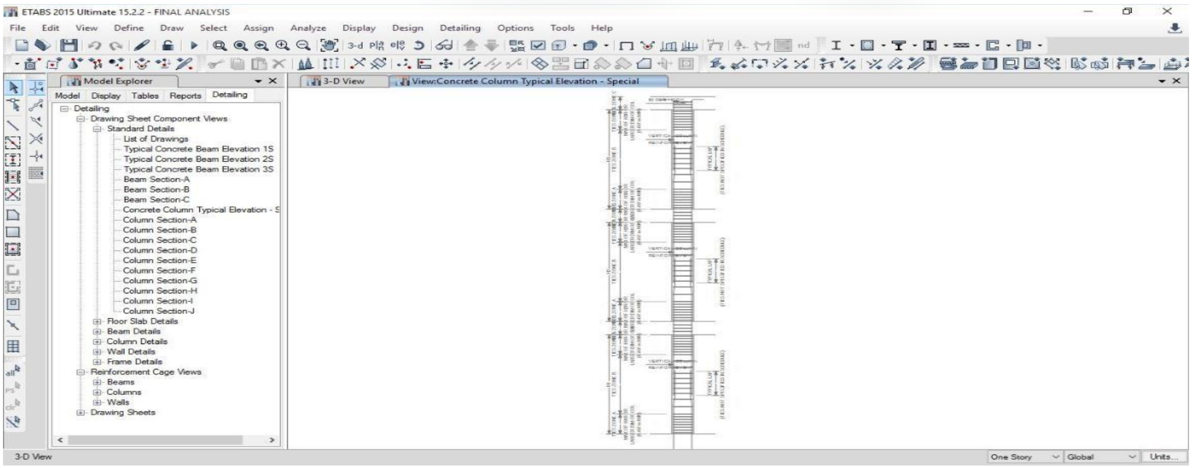

Figure 5.3 Reinforcement details of typical column

This Figure shows the reinforcement details for Columns (Elevation view). Along with the steel area, the bending moment details, shear force details and deflections in each column is also obtained in a systematic manner. (Appendix I-shows that the designs of slabs are done in Microsoft excel spreadsheets total quantity of steel and total quantity of concrete.) The design of slabs and footing are done in Microsoft Excel Spreadsheets. Also calculation of slabs is done on excel sheet for cross checking. The schedules for slab are shown in Table 5.1

.

Table 5.1 Schedule for Slab

Sr. No	Mark	Count	Thickness (mm)	Grade of concrete	Grade of steel	Total Load (KN/m)	Area of steel (X)	Area of steel (Y)	Diameter of bar (mm)	Spacing (X)	Spacing (Y)	Total quantity of steel (Kg)	Total quantity of concrete (Cum)
1	S1	32	200	25	415	9	240	240	10	300	320	114.62	172.8
2	S2	36	200	25	415	9	287.7	240	10	270	320	134.77	213.12
3	S3	40	200	25	415	9	545.6	243.29	10	140	320	281.97	349.6
4	S4	30	200	25	415	9	240	240	10	300	320	118.25	175.36
5	S5	32	200	25	415	9	240	240	10	300	320	37.07	50.1
6	S6	10	200	25	415	9	240	240	10	300	320	43.64	19.8
7	S7	8	200	25	415	9	823.18	375.18	10	100	210	612.74	101.84
8	S8	12	200	25	415	9	373.49	331.84	10	210	230	182.31	75.24
9	S9	12	200	25	415	9	609.49	240	10	120	320	386.68	134.28
Total quantity												**1912.05**	**1292.14**

This table shows that the design of slabs is done in Microsoft excel spreadsheets total quantity of steel and total quantity of concrete. This is the final table concluding the of slab total quantity of construction materials required in execution of all the units in the whole structure. The table shows that the marking, thickness, grade of concrete, grade of steel, area of steel, diameter of bar, spacing, steel and concrete of slab area. (Appendix II-shows that the design calculation for isolated footing of shear wall are done in Microsoft excel spreadsheets total quantity of steel and total quantity of concrete.) After the detailed analysis of structure, the results are obtained which shows the area of steel required in respective structural member's shear wall. Along with the steel area, the bending moment details, shear force details and deflections in each shear wall is also obtained in a systematic manner. Figure 5.4. shows that the reinforcement details footing for shear wall with 2000KN.

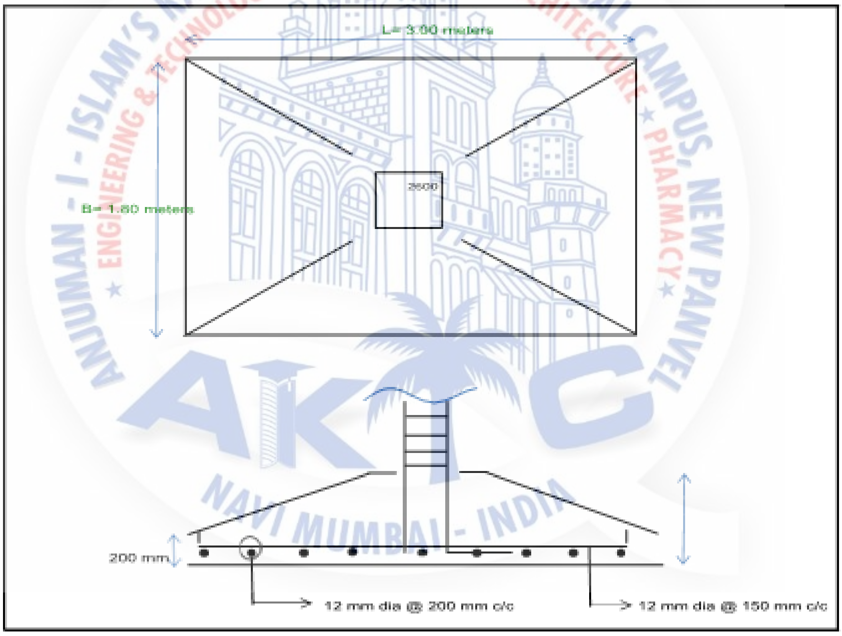

Figure 5.4 Footing for shear wall with 2000 KN load

This Figure shows that the reinforcement details footing for shear wall with 2000 KN load. Along with the steel area, the bending moment details, shear force details and deflections in each footing is also obtained in a systematic manner. Length= 3.0 meter, width= 1.80 meter, Depth= 500 mm, T12@200 mm c/c, T12@150 mm c/c.

After the detailed analysis of structure, the result is obtained which shows the area of steel required in respective structural member's shear wall. Along with the steel area, the bending moment details, shear force details and deflections in each shear wall is also obtained in a systematic manner. Figure 5.5 shows that the reinforcement details footing for shear wall with 3000KN.

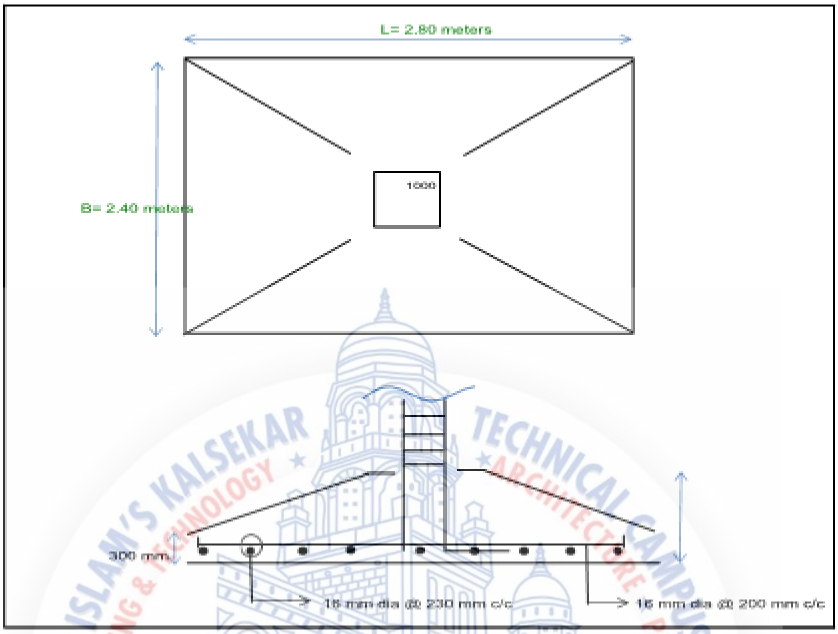

Figure 5.5 Footing for column with 3000 KN load

This Figure shows that the reinforcement details for footing for shear wall with 3000 KN load. Along with the steel area, the bending moment details, shear force details and deflections in each footing is also obtained in a systematic manner. Length= 2.80 meter, width= 2.40 meter, Depth= 750 mm, T16@200 mm c/c, T16@200 mm c/c.

After the detailed analysis of structure, the result is obtained which shows the area of steel required in respective structural member's shear wall. Along with the steel area, the bending moment details, shear force details and deflections in each shear wall is also obtained in a systematic manner. Figure 5.6 shows that the reinforcement details footing for shear wall with 4000KN.

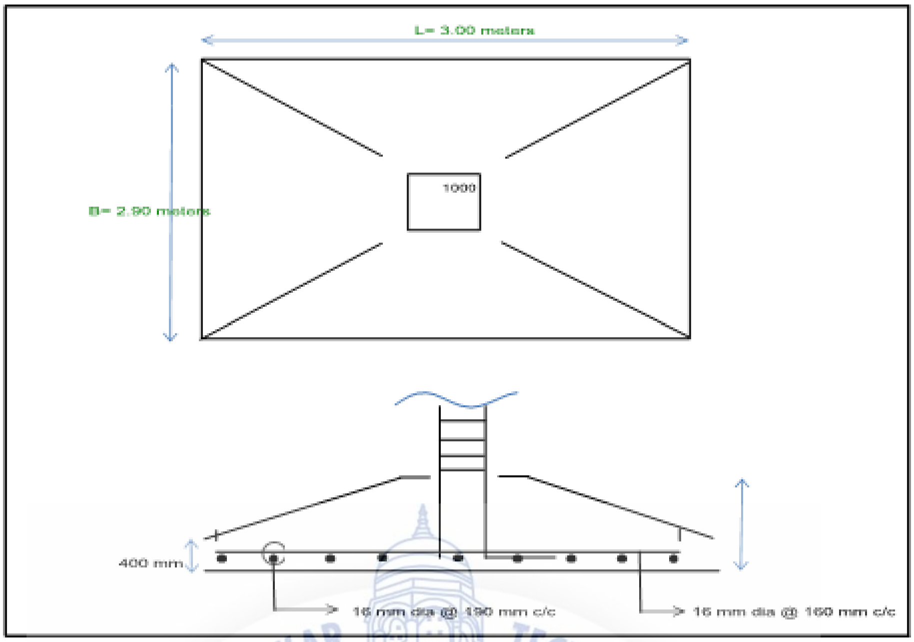

Figure 5.6 Footing for column with 4000 KN load

This Figure shows that the reinforcement details for footing for shear wall with 4000 KN load. Along with the steel area, the bending moment details, shear force details and deflections in each footing is also obtained in a systematic manner. L= 3.0 meter, B= 2.90 meter, D= 900 mm, T16@200 mm c/c, T16@150 mm c/c.

After the detailed analysis of structure, the results are obtained which shows the area of steel required in respective structural member's shear wall. Along with the steel area, the bending moment details, shear force details and deflections in each shear wall is also obtained in a systematic manner. Figure 5.7 shows that the reinforcement details footing for shear wall with 5000KN.

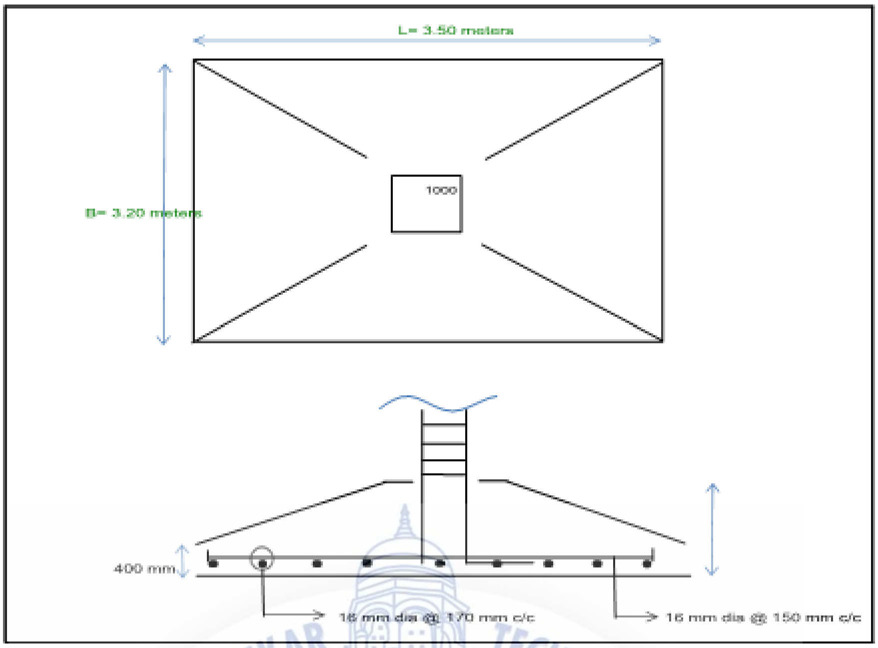

Figure 5.7 Footing for column with 5000 KN load

Above Figure 5.7 shows that, the reinforcement details for footing for shear wall with 5000 KN load. Along with the steel area, the bending moment details, shear force details and deflections in each footing is also obtained in a systematic manner. Length= 3.5 meter, width= 3.2 meter, Depth= 1 meter, T16@175 mm c/c, T16@150 mm c/c.

5.4 Autodesk Revit (3d view)

This project demonstrates how to create and manage more complex projects and draw model using Autodesk Revit software as the base layer. The group focuses on the modelling of civil and building engineering structures, both linear and non-linear. In modelling the quantity of material will be estimated and the 3-Dimensional view will be displayed. Revit is a single software application that supports a BIM (Building Information Modelling) work flow from concept to construction. Use Revit to model designs with precision, optimize performance and collaborate more effectively. Figure 5.8 shows that the 3D view of given building.

Figure 5.8 3D view of proposed building

Above Figure 5.8 shows that the step by step procedure for modelling in Autodesk Revit is mentioned below. Importing the AutoCAD plans for ground, 1st, 2nd and 3th floor. Defining levels: levels are defined from plinth level to 3th floor. Editing walls beams and columns: dimensions for different walls beams and columns are duplicated as per schedule obtained from Etabs analysis. Modelling of ground floor: beams, columns and walls which are required on ground floor as per the AutoCAD drawing is placed. Modelling of 1st floor: This floor is being modelled as per the comfort of the family. Floors 2nd & 3rd are replica of 1st Floor. The Flats on this floor are modelled to be residing with their families. There are 5 flats on each floor with all 1bhk flats. Each living room is equipped with 2 sofas and a centre table. Kitchen is provided in each room with latest amenities. After obtaining the detailed design reports and necessary AutoCAD plans, we have also done the rebar Modelling on Revit which shows the reinforcement details in particular structural members as per the design. The screenshots of reinforced structural members obtained after rebar Modelling. Revit is a single software application that supports a BIM (Building Information Modelling) work flow from concept to construction. Use Revit to model designs with precision, optimize performance and collaborate more effectively. Figure 5.9 shows that the 3D view of reinforcement details in column and footing.

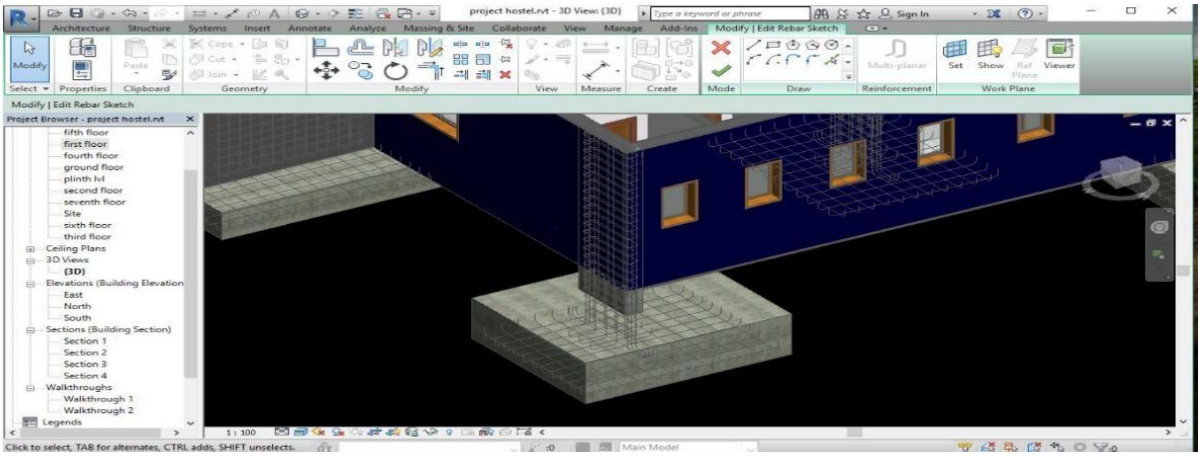

Figure 5.9 Reinforcement details in column and footing

This Figure shows that the after obtaining the detailed design reports and necessary AutoCAD plans, the 3D modelling of the structure is carried out in Autodesk Revit. We have also done the rebar modelling on Revit which shows the reinforcement details in particular structural members as per the design. The screenshots of reinforced structural members obtained after rebar modelling.

After obtaining the detailed design reports and necessary AutoCAD plans, we have also done the rebar modelling on Revit which shows the reinforcement details in particular structural members as per the design. The screenshots of reinforced structural members obtained after rebar modelling. Revit is a single software application that supports a BIM (Building Information Modelling) work flow from concept to construction. Use Revit to model designs with precision, optimize performance and collaborate more effectively. Figure 5.10 shows that 3D view of reinforcement details in beams.

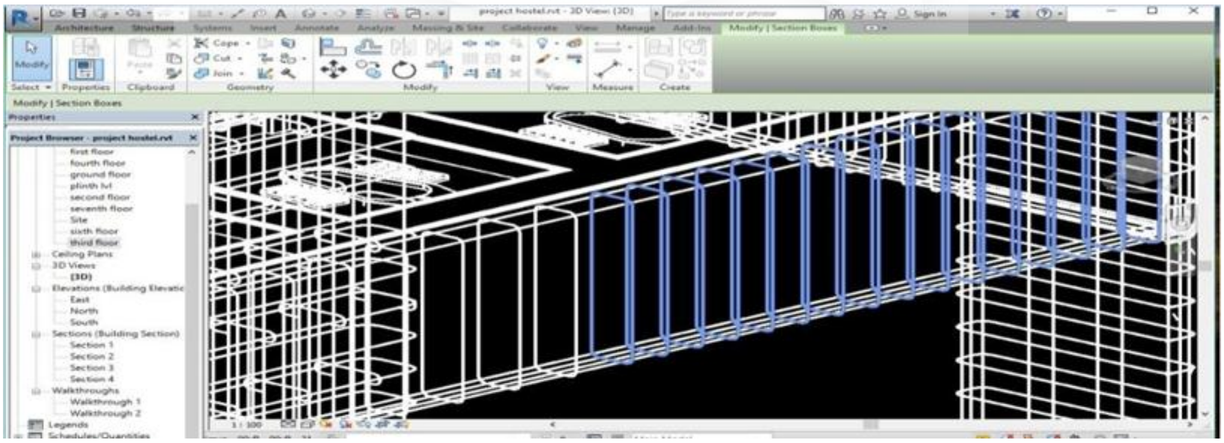

Figure 5.10 Reinforcement details in Beams

This Figure shows that the rebar modelling on Revit which shows the reinforcement details in particular structural members as per the design. The screenshots of reinforced structural members obtained after rebar modelling.

5.5 Quantity estimation:

After completing the modelling part, we have done the quantity estimation from Autodesk Revit software. Quantity of concrete and steel is obtained successfully for all structural members. Following are the snaps showing the total quantity of steel and concrete for individual structural members. Table 5.2 shows that the total quantity of concrete and steel.

Table 5.2 Quantity estimation for total concrete and steel

Quantity Estimation	**Beam**	**Column**	**Footing**	**Wall**	**Slab**	**Total Quantities**
Concrete(cum)	188.50	174.5	106.95	30	1600	2099.95
Steel (kg)	6615.43	5348.199	766.53	-	13333.82	26063.979

This Table shows that the final table concluding the total quantity of construction materials required in execution of all the units in the whole structure. After overviewing the above three software, discussion can be done that AutoCAD is one of the most efficient and user-friendly software for planning purpose. Etabs give the user wide possibilities for designing almost any kind of structure in any region and under various conditions. Autodesk Revit is the most comfortable and user friendly software for 3D modelling as it is very easy to understand the commands as well as to execute them. It also provides a wide range of libraries for massing as well as for interior designing purpose.

5.6 Difference in Conventional and Cost effective techniques

The details cost comparison are as follows of an 8000 sq. feet plinth area, residential building both work results point out the same fact that there is much economy in laying out the cost effective technology Table 5.3.

Table 5.3 Cost comparison of an 8000 Sq. feet plinth area, Residential Building

Sr. No	Materials	Quantity		Rates in Rupees	Total Expenditure	
		Conventional	Cost Effective		Conventional	Cost Effective
1.	Rubble	110 brass	110 brass	1500 per brass	1,65,000.	1,65,000.
2.	Sand	258 brass	200 brass	6900 per brass	1,780,200.	1,38,000.
3.	Cement	3000 bags	2500 bags	400 per bag	12,00,000.	10,00,000.
4.	Metal 15mm	150 brass	120 brass	1200 per brass	1,80,000.	1,44,000.
5.	Metal 20mm	70 brass	-	800 per brass	56,000.	-
6.	Bricks	2,00000 Nos	174000Nos	5500 per 1000	11,00,000.	9,57,000.
7.	Wooden door	-	-	-	1,13,000.	-
8.	Wooden window	-	-	-	1,07,300.	.-
9.	Concrete door	-	130 m^2	3000 per m^2	-	3,90,000.
10.	Concrete window	-	130 m^2	2700 per m^2	-	3,51,000
11.	Steel	28.546 ton	22.001 ton	42000 per ton	11,98,932.	9,24,000.
12.	Red oxide	300 kg	250 kg	200 per kg	60,000.	60,000.
13.	White cement	1800 kg	1800 kg	40 per kg	72,000.	72,000.
14.	Tiles	12 tons	-	2200 per ton	-	26,400.
15.	Lime	250 kg	-	20 per kg	-	5,000.
16.	Paint	500 liters	500 liters	200 per liter	1,00,000.	1,00,000.
17.	Labour charge	-	-	-	2,27,568.	2,27,568.
18.	Electrification	-	-	-	1,60,000	1,60,000
19.	Water supply	-	-	-	1,80,000.	1,80,000.
20.	Miscellaneous	-	-	-	1,00,000.	1,00,000.
	Total				**68,00,000.**	**49,99,968.**

This Table shows the total cost of any residential project by using conventional technology is Rs.68, 00,000 while by using new specification is Rs.49, 99,968. Thus, the total saving by cost-effective specification over conventional specification is Rs.18,00,032 (Rs.68,00,000-Rs.49,99,968). Again, the average sq. feet cost by conventional specification is Rs.850/Sq. feet while that of cost effective specification is Rs. 625/Sq.feet. Therefore, the average sq. feet saving by cost-effective technology when compared to the conventional technology is Rs 225/Sq.feet.

Therefore, the main aspect of cost effectiveness is architectural planning and structural designing. This includes grouping of functional space, judiciously in a combat manner to reduce the service cost. Selection of structural system, load-bearing walls or framed structure is another aspect of planning.

The materials rate conventional and cost effective technology with regard to the present study a survey has been made to find out the relative cost variations between conventional and cost effective technologies with respect to an 8000 sq. feet plinth area residential building are shown in Figure 5.11.

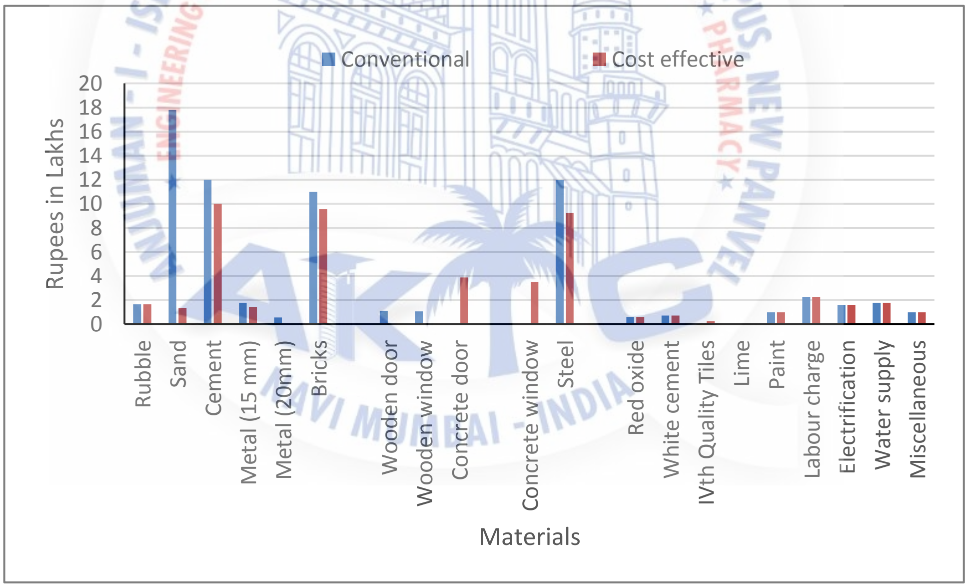

Figure 5.11 Cost variations between conventional and cost effective techniques

This Figure shows the materials rates conventional and cost effective technology with regard to the present study a survey has been made to find out the relative cost variations between conventional and cost effective technologies with respect to an 8000 sq. feet plinth area residential building. This Figure shows the total cost of any residential project by using software the average sq. feet cost by conventional specification is Rs.850/Sq. feet while that of cost effective specification is Rs. 625/Sq.feet. Therefore, the average sq. feet saving by cost-effective technology when compared to the conventional technology is Rs. 225/Sq.feet.

5.7 Summary

Both work results point out the same fact that there is much economy in laying out the cost effective technology and so it can be definitely opted as a remedy to overcome the severe housing inadequacy in the country. Thus, a housing project designed to satisfy residential need and improve living conditions in a depressed area will probably increase the number of individuals housed among the target populations. The major reason for the change in the construction costs between conventional and cost-effective specification is due to the change in the methods of construction and types of building materials used. The Analysis showing the change in the types of materials employed by each technology is a must.

Chapter 6

Summary and Conclusions

6.1 General

The main aspect of cost effectiveness is architectural planning and structural designing. This includes grouping of functional space, judiciously, in a combats manner to reduce the service cost. Selection of structural system, load-bearing walls or framed structure is another aspect of planning.

6.2 Summary

After experimental investigation finally, the factors such as income status of the households, size of family and availability/non-availability of grant from the government for housing have been taken as the determining factors of the demand for low-cost housing technology by the households. Based on these, the work found that all these factors are having a close association with the demand for alternate and low-cost construction materials and techniques. Thus, it is clear that among such factors no single factor can be isolated as the dominant factor in determining the demand for low-cost house.

6.3 Conclusions

- From the above procedure and result obtained it can be concluding that, present both the conventional and cost effective technologies are available in the field of housing construction.
- Among these, the cost-effective technology has the advantage of economy in construction, saving of time and energy and of the optimum use of materials. Since the building materials are locally available the huge transportation costs incurred for transporting the materials and the delay in construction can be avoided. Thus, cost-effective technology, no doubt, can be opted as a permanent remedy to overcome the severe housing inadequacy in the country.
- Accordingly, the survey results reveal that if we use conventional specification for housing we have to spend around Rs. 850 per square feet plinth area whereas by using cost effective technology the per square feet cost is Rs. 625. Thus, when compared to conventional specification, the average square feet saving by cost effective specification is Rs.225.

6.4 Scope of future work

The Industrial and agricultural waste like fly-ash, phosphogypsum, blast furnace slag, red mud, rice husk and coir waste, etc. hold great promise as building materials. Several governmental efforts have been undertaken in recent years the country to popularize use of such materials. Some of the measures initiated in this regard are listed as below.

- Study and find to providing fiscal incentive to the entrepreneurs willing to undertake manufacturer of building products based on industrial wastes like fly-ash and phosphogypsum, the government of India has been announcing fiscal incentives in the past three union budgets. Excise duty has been exempted on materials and components using these industrial wastes as a raw material.
- In order to meet the growing demand of housing in the country, there is exigency to adopt appropriate technology which could affect economy in consumption of scare building materials like cement and steel as well as speed in construction. In urban centres especially in metropolitan centres, where there exists huge backlog of housing, there is urgency to build large number of houses at affordable cost to meet the requirement of housing.

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APPENDIX I

- Design of slab S1: Design of slab is carried out using and the result are shown.

(Design details of slab S1)

DESIGN OF SLAB AS PER IS-456 2000 — **s1**

Job No :- **Date :-** 4/30/2017

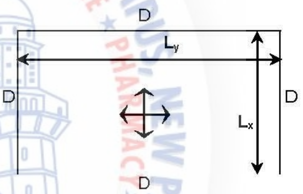
Project :- **Slab ID :** s1

Thickness of slab, D =	250	mm.
Grade of concrete f_{ck} =	25	N/mm^2.
Grade of Steel f_y =	415	N/mm^2.
Clear cover =	20	mm.
sunk in slab =	0	mm.
diameter of short bar =	10	mm.
diameter of long bar =	10	mm.

self load	625	kg/m^2
live	300	kg/m^2
floor finish	100	kg/m^2
sunk load	0	kg/m^2
cobba	0	kg/m^2
TOTAL	1025	kg/m^2

Span & End Conditions for :

short bar	L_x =	3	m.	10
long bar	L_y =	9	m.	10



(L_y/L_x) = 3.00

Aspect ratio α_y = 0.01

α_x = 0.99

SHORT BAR: *(To be provided along the shorter direction).*

Mux =	1.37	t-m.	
K =	0.27		*Section is singly reinforce.*
Pt =	0.12	%.	*Provide min reinf. of 0.12%. (cl.26.5.2.1), IS-456: 2000).*
Ast =	300	mm^2.	
Deflection d =	0.33	mm.	*Safe in deflection.*
spacing require, s =	262	mm c\c.	*< 3d, hence ok. (cl.26.3.3.b(1), IS-456: 2000).*

provide 10 mm diameter bar @ 262 c\c.

LONG BAR: *(To be provided along the longer direction).*

Muy =	0.15	t-m.	
K =	0.03		*Section is singly reinforce.*
Pt =	0.12	%.	*Provide min reinf. of 0.12%. (cl.26.5.2.1, IS-456: 2000).*
Ast =	300	mm^2.	
Deflection d =	0.37	mm.	*Safe in deflection.*
spacing require, s =	262	mm c\c.	*< 5d, Hence ok. (cl.26.3.3.b(2), IS-456: 2000)*

provide 10 mm diameter bar @ 262 c\c.

Summary			**Quantity**	*(approx.)*
	mm.	@		
Thickness.	250		6.75	cum.
short bar.	10	262	66.55	kg.
long bar.	10	262	72.10	kg.
sunk.	0		20.54	kg/cum.

VALID FOR	*(tick appropriate block).*
Tender.	
Approval.	
Execution.	

- Design of slab S2: Design of slab is carried out using and the result are shown.

(Design details of slab S2)

DESIGN OF SLAB AS PER IS-456 2000 — s2

Job No :- **Date :-** 4/30/2017

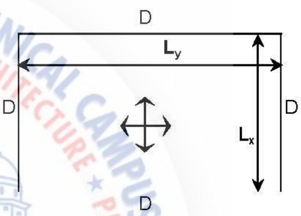
Project :- **Slab ID :** s2

Thickness of slab, D =	200	mm.
Grade of concrete f_{ck} =	25	N/mm^2.
Grade of Steel f_y =	415	N/mm^2.
Clear cover =	20	mm.
sunk in slab =	0	mm.
diameter of short bar =	10	mm.
diameter of long bar =	10	mm.

self load	500	kg/m^2
live	300	kg/m^2
floor finish	100	kg/m^2
sunk load	0	kg/m^2
cobba	0	kg/m^2
TOTAL	900	kg/m^2

Span & End Conditions for :

short bar	L_x =	3.7	m.	10
long bar	L_y =	8	m.	10



(L_y/L_x) = 2.16

Aspect ratio α_y = 0.04

α_x = 0.96

SHORT BAR: *(To be provided along the shorter direction).*

Mux =	1.77 t-m.	
K =	0.58	*Section is singly reinforce.*
Pt =	0.16 %.	*> 0.12%, Hence ok. (cl.26.5.2.1, IS-456: 2000).*
Ast =	287.7 mm^2.	
Deflection d =	1.26 mm.	*Safe in deflection.*
spacing require, s =	273 mm c\c.	*< 3d, hence ok. (cl.26.3.3.b(1), IS-456: 2000).*

provide 10 mm diameter bar @ 273 c\c.

LONG BAR: *(To be provided along the longer direction).*

Muy =	0.38 t-m.	
K =	0.14	*Section is singly reinforce.*
Pt =	0.12 %.	*Provide min reinf. of 0.12%. (cl.26.5.2.1, IS-456: 2000).*
Ast =	240 mm^2.	
Deflection d =	1.41 mm.	*Safe in deflection.*
spacing require, s =	328 mm c\c.	*< 5d, Hence ok. (cl.26.3.3.b(2), IS-456: 2000)*

provide 10 mm diameter bar @ 328 c\c.

Summary			**Quantity** *(approx.)*	
	mm.	@		
Thickness.	200		5.92	cum.
short bar.	10	273	70.68	kg.
long bar.	10	328	64.09	kg.
sunk.	0		22.76	kg/cum.

VALID FOR *(tick appropriate block).*	
Tender.	
Approval.	
Execution.	

- Design of slab S3: Design of slab is carried out using and the results are shown.

(Design details of slab S3)

DESIGN OF SLAB AS PER IS-456 2000 — s3

Job No :- | **Date :-** 4/30/2017

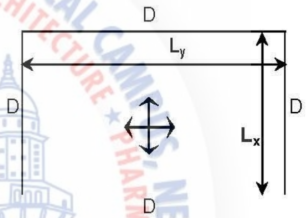
Project :- | **Slab ID** s3

Thickness of slab, D =	200	mm.
Grade of concrete f_{ck} =	25	N/mm^2.
Grade of Steel f_y =	415	N/mm^2.
Clear cover =	20	mm.
sunk in slab =	0	mm.
diameter of short bar =	10	mm.
diameter of long bar =	10	mm.

self load	500	kg/m^2
live	300	kg/m^2
floor finish	100	kg/m^2
sunk load	0	kg/m^2
cobba	0	kg/m^2
TOTAL	**900**	kg/m^2

Span & End Conditions for :

short bar	L_x =	5.36	m.	10
long bar	L_y =	8.15	m.	10



(L_y/L_x) = 1.52

Aspect ratio α_y = 0.16

α_x = 0.84

SHORT BAR: *(To be provided along the shorter direction).*

Mux = 3.27 t-m.

K = 1.07 *Section is singly reinforce.*

Pt = 0.31 %. *> 0.12%, Hence ok. (cl.26.5.2.1, IS-456: 2000).*

Ast = 545.6 mm^2.

Deflection d = 4.89 mm. *Safe in deflection.*

spacing require, s = 144 mm c\c. *< 3d, hence ok. (cl.26.3.3.b(1), IS-456: 2000).*

provide 10 mm diameter bar @ 144 c\c.

LONG BAR: *(To be provided along the longer direction).*

Muy = 1.41 t-m.

K = 0.52 *Section is singly reinforce.*

Pt = 0.15 %. *> 0.12%, Hence ok. (cl.26.5.2.1, IS-456: 2000).*

Ast = 243.29 mm^2.

Deflection d = 5.47 mm. *Safe in deflection.*

spacing require, s = 323 mm c\c. *< 5d, Hence ok. (cl.26.3.3.b(2), IS-456: 2000)*

provide 10 mm diameter bar @ 323 c\c.

Summary	mm.	@	**Quantity** *(approx.)*	
Thickness.	200		8.74	cum.
short bar.	10	144	191.57	kg.
long bar.	10	323	90.40	kg.
sunk.	0		32.27	kg/cum.

VALID FOR *(tick appropriate block).*	
Tender.	
Approval.	
Execution.	

APPENDIX II

- The following is the design calculation for isolated footing of shear wall.

For 2000 KN load: footing size design as shown.. Design calculation for isolated footing of shear wall.

(Design calculation for isolated footing of shear wall)

Isolated Footing

1	**Footing Size Design**		
	Load	Pu	2000 KN
	Design Load	P	1467 KN
	Moment in x dir	Mux	0 KN-m
	Moment in y dir	Muy	10 KN-m
	Column size	cx	2600 mm
		cy	300 mm
	SBC	q	350 KN/sqm
	Footing Size required	A req	4.19 sqmm
	Footing Size Provided	L	3.00 meters
		B	1.80 meters
	Area Provided	A prvd	5.40 meters
		Zx	1.62
		Zx	2.70
	Net upward pressure	Nup	274 KNm2

Footing Size OK

2 **Slab Design**

	lx	0.200
	ly	0.750
Bending Moment in x dir	Mx	8 KN-m
Bending Moment in y dir	My	116 KN-m
Concrete	fck	20 MPa
Steel	fy	415 MPa
Minimum Depth Required	dmin	205
Depth Provided	D	500 mm
Clear Cover	c	50 mm
Effective Cover	d'	56 mm
Effective Depth	d'	444 mm

Area of Steel	Spacing c/c in mm		
	12#	16#	20#
533 sqmm	212 c/c	377 c/c	590 c/c
748 sqmm	151 c/c	269 c/c	420 c/c

Minimum Ast required across x direcion

Ast across x direction	12 mm dia @ 200 mm c/c	565 sqmm
Ast across y direction	12 mm dia @ 150 mm c/c	754 sqmm

width	1000 mm		
Mulim/bd^2	Mulim		
2.76	544 KN-m		
xumax/d	xumax	Rumax	Section Check
0.48	213	0.138	7.1
SRB			
a	0.7529		
b	-3.6105		
c	0.0417		
-p	0.0116		
Ast	51		
Min steel %	0.205		
Ast	51		
Min Steel	533		
Max Steel	17760		
Ast	533		
Pt provided	0.1200		
β	19.352		
ks trial	0.61538462		
ks	0.61538462		

width	1000 mm		
Mulim/bd^2	Mulim		
2.76	544 KN-m		
xumax/d	xumax	Rumax	Section Check
0.48	213	0.138	7.1
SRB			
a	0.7529		
b	-3.6105		
c	0.5865		
-p	0.1684		
Ast	748		
Min steel %	0.205		
Ast	748		
Min Steel	533		
Max Steel	17760		
Ast	748		
Pt provided	0.1684		
β	13.793		
ks trial	0.61538462		
ks	0.61538462		

3 **One Way Shear along x direction**

Vu1	-181 KN
ζv	-0.226 MPa
ζc	0.260 MPa
Vc1	208 KN

One Way Shear Check OK

4 **One Way Shear along y direction**

Vu1	377 KN
ζv	0.283 MPa
ζc	0.303 MPa
Vc1	403 KN

One Way Shear Check OK

5 **Two Way Shear**

Vu2	1289 KN
ζv	0.383 MPa
ks*ζc	0.688 MPa
Vc1	2314 KN

Two Way Shear Check OK

- There are 3 types of columns dealing with different loadings i.e. 3000kn, 4000kn and 5000kn (approximately). So we have designed 3 different columns individually. The calculations are shown below.

For 3000 KN load: footing size design as shown

(Design calculation for isolated footing of shear wall)

Isolated Footing

1 **Footing Size Design**

Load	Pu	3000 KN
Design Load	P	2200 KN
Moment in x dir	Mux	30 KN-m
Moment in y dir	Muy	30 KN-m
Column size	cx	1000 mm
	cy	300 mm
SBC	q	350 KN/sqm
Footing Size required	A req	6.29 sqmm
Footing Size Provided	L	2.80 meters
	B	2.40 meters
Area Provided	A prvd	6.72 meters
	Zx	2.69
	Zx	3.14
Net upward pressure	Nup	341 KNm2

Footing Size OK

2 **Slab Design**

	lx	0.900
	ly	1.050
Bending Moment in x dir	Mx	207 KN-m
Bending Moment in y dir	My	282 KN-m
Concrete	fck	30 MPa
Steel	fy	500 MPa
Minimum Depth Required	dmin	266
Depth Provided	D	**750 mm**
Clear Cover	c	50 mm
Effective Cover	d'	58 mm
Effective Depth	d'	692 mm

Area of Steel	Spacing c/c in mm		
	12#	16#	20#
830 sqmm	136 c/c	242 c/c	378 c/c
960 sqmm	118 c/c	210 c/c	327 c/c

Minimum Ast required across x direcion

Ast across x direction	**16 mm dia @ 230 mm c/c**	**874 sqmm**
Ast across y direction	**16 mm dia @ 200 mm c/c**	**1005 sqmm**

width	1000 mm		
Mulim/bd^2	Mulim		
3.99	1911 KN-m		
xumax/d	xumax	Rumax	Section Check
0.46	316	0.133	8.3
SRB			
a	0.7286		
b	-4.3500		
c	0.4329		
-p	0.1012		
Ast	700		
Min steel %	0.170		
Ast	700		
Min Steel	830		
Max Steel	27680		
Ast	830		
Pt provided	0.1200		
β	29.028		
ks trial	0.8		
ks	0.8		

width	1000 mm		
Mulim/bd^2	Mulim		
3.99	1911 KN-m		
xumax/d	xumax	Rumax	Section Check
0.46	316	0.133	8.3
SRB			
a	0.7286		
b	-4.3500		
c	0.5892		
-p	0.1387		
Ast	960		
Min steel %	0.170		
Ast	960		
Min Steel	830		
Max Steel	27680		
Ast	960		
Pt provided	0.1387		
β	25.121		
ks trial	0.8		
ks	0.8		

3 **One Way Shear along x direction**

Vu1	255 KN
ζv	0.154 MPa
ζc	0.265 MPa
Vc1	440 KN

One Way Shear Check OK

4 **One Way Shear along y direction**

Vu1	513 KN
ζv	0.265 MPa
ζc	0.283 MPa
Vc1	549 KN

One Way Shear Check OK

5 **Two Way Shear**

Vu2	2580 KN
ζv	0.695 MPa
ks*ζc	1.095 MPa
Vc1	4069 KN

Two Way Shear Check OK

2 **Slab Design**

	lx	1.000
	ly	1.300
Bending Moment in x dir	Mx	260 KN-m
Bending Moment in y dir	My	439 KN-m
Concrete	fck	30 MPa
Steel	fy	500 MPa
Minimum Depth Required	dmin	332
Depth Provided	D	900 mm
Clear Cover	c	50 mm
Effective Cover	d'	58 mm
Effective Depth	d'	842 mm

Area of Steel	Spacing c/c in mm		
	12#	16#	20#
1010 sqmm	112 c/c	199 c/c	311 c/c
1229 sqmm	92 c/c	164 c/c	256 c/c

Minimum Ast required across x direcion

Ast across x direction	16 mm dia @ 190 mm c/c	1058 sqmm
Ast across y direction	16 mm dia @ 160 mm c/c	1257 sqmm

width	1000 mm		
Mulim/bd²	Mulim		
3.99	2829 KN-m		
xumax/d	xumax	Rumax	Section Check
0.46	384	0.133	8.3
SRB			
a	0.7286		
b	-4.3500		
c	0.3666		
-p	0.0855		
Ast	720		
Min steel %	0.170		
Ast	720		
Min Steel	1010		
Max Steel	33680		
Ast	1010		
Pt provided	0.1200		
β	29.028		
ks trial	0.8		
ks	0.8		

width	1000 mm		
Mulim/bd²	Mulim		
3.99	2829 KN-m		
xumax/d	xumax	Rumax	Section Check
0.46	384	0.133	8.3
SRB			
a	0.7286		
b	-4.3500		
c	0.6195		
-p	0.1460		
Ast	1229		
Min steel %	0.170		
Ast	1229		
Min Steel	1010		
Max Steel	33680		
Ast	1229		
Pt provided	0.1460		
β	23.860		
ks trial	0.8		
ks	0.8		

3 **One Way Shear along x direction**

Vu1	238 KN
ζv	0.098 MPa
ζc	0.265 MPa
Vc1	647 KN

One Way Shear Check OK

4 **One Way Shear along y direction**

Vu1	714 KN
ζv	0.283 MPa
ζc	0.290 MPa
Vc1	732 KN

One Way Shear Check OK

5 **Two Way Shear**

Vu2	3429 KN
ζv	0.682 MPa
ks*ζc	1.095 MPa
Vc1	5505 KN

Two Way Shear Check OK

For 5000 KN load: footing size design as shown

(Design calculation for isolated footing of shear wall)

Isolated Footing

1 Footing Size Design

Load	Pu	5000 KN
Design Load	P	3667 KN
Moment in x dir	Mux	30 KN-m
Moment in y dir	Muy	30 KN-m
Column size	cx	1000 mm
	cy	300 mm
SBC	q	350 KN/sqm
Footing Size required	A req	10.48 sqmm
Footing Size Provided	L	3.50 meters
	B	3.20 meters
Area Provided	Aprvd	11.20 meters
	Zx	5.97
	Zx	6.53
Net upward pressure	Nup	334 KNm2

Footing Size OK

2 **Slab Design**

	lx	1.250
	ly	1.450
Bending Moment in x dir	Mx	391 KN-m
Bending Moment in y dir	My	526 KN-m
Concrete	fck	30 MPa
Steel	fy	500 MPa
Minimum Depth Required	dmin	364
Depth Provided	D	1000 mm
Clear Cover	c	50 mm
Effective Cover	d'	58 mm
Effective Depth	d'	942 mm

Area of Steel	Spacing c/c in mm		
	12#	16#	20#
1130 sqmm	100 c/c	178 c/c	278 c/c
1315 sqmm	86 c/c	153 c/c	239 c/c

Minimum Ast required across x direcion

Ast across x direction	16 mm dia @ 170 mm c/c	1183 sqmm
Ast across y direction	16 mm dia @ 150 mm c/c	1340 sqmm

width	1000 mm	
Mulim/bd^2	Mulim	
3.99	3541 KN-m	

xumax/d	xumax	Rumax	Section Check
0.46	430	0.133	8.3

SRB	
a	0.7286
b	-4.3500
c	0.4408
-p	0.1031
Ast	971

Min steel %	0.170
Ast	971
Min Steel	1130
Max Steel	37680
Ast	1130
Pt provided	0.1200
β	29.028
ks trial	0.8
ks	0.8

width	1000 mm	
Mulim/bd^2	Mulim	
3.99	3541 KN-m	

xumax/d	xumax	Rumax	Section Check
0.46	430	0.133	8.3

SRB	
a	0.7286
b	-4.3500
c	0.5932
-p	0.1396
Ast	1315

Min steel %	0.170
Ast	1315
Min Steel	1130
Max Steel	37680
Ast	1315
Pt provided	0.1396
β	24.948
ks trial	0.8
ks	0.8

3 **One Way Shear along x direction**

Vu1	493 KN
ζv	0.164 MPa
ζc	0.265 MPa
Vc1	799 KN

One Way Shear Check OK

4 **One Way Shear along y direction**

Vu1	890 KN
ζv	0.270 MPa
ζc	0.284 MPa
Vc1	937 KN

One Way Shear Check OK

5 **Two Way Shear**

Vu2	4400 KN
ζv	0.734 MPa
ks*ζc	1.095 MPa
Vc1	6571 KN

Two Way Shear Check OK

LIST OF PUBLICATIONS

1. "Sustainable Low Cost Housing for Alternate Construction Materials & Techniques", *International Conference on Emanations in Modern Technology and Engineering (ICEMTE-2017)*, ISSN (Online): 2321 - 8169, Volume-5, Issue -3, pp. 18-21, 2017. (Paper Presented & Published)

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