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Alternative Low Cost Construction Materials & Techniques

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ABSTRACT: Affordability is measured in terms of disposable income, In the context of housing, affordability means the financial capacity of an individual to buy or rent a house. In 2008, the High Level Task Force on Affordable Housing for All, setup by the Government of India, defined affordability as a measure of household gross annual income and the size of a housing unit. In this project we work on Rat Trap Bond and Filler Slab Concept for alternative low cost construction material. The need of alternative building technologies and materials has arisen in the past few years. Fortunately, there are many such options available at our disposal which when used in suitable combinations can save huge amounts of money and hence can result in affordable construction costs. Filler slab technology is a simple and a very innovative technology for a slab construction. The reason why, concrete and steel are used together to construct RCC slab, is in their individual properties as separate building materials and their individual limitation. Concrete is good in taking compression and steel is good in tension. Thus RCC slab is a product which resists both compressions as well as tensile. One such building technique is the use of 'RAT TRAP BOND' masonry. Contrary to other technologies, this amazing building technology is not new to us. RTB was first introduced in India in 1970, by renowned Architect Sir Laurie Baker. Since then, it has been used in many Government buildings and small village panchayats. In this modern age, we have overlooked this extremely useful technology which, while providing the same strength to the walls also saves us time and labor and also material cost to the extent of about 23% when compared with a standard 230mm brick masonry wall. In this project we have outlined the importance of RTB technology along with the construction details and also provided some comparative calculations to highlight the savings that can be achieved against the conventional solid brickwork

KEYWORDS: Building Material; Low-Cost Housing;Sustainability, Rat Trap Bond, Filler Slab.

I. INTRODUCTION

1.1. Introduction of the project work

Over the last five, or so decades, developing countries in particular have experienced phenomenal growth of urban areas partly due to policies that have tended to favor urbanization as an engine of rapid development. However, this trend has had worsening urban housing conditions and in particular, the sprawl of informal settlements and slums is the single-most manifestation of the urbanization phenomenon that has brought about human misery, poverty, insecurity and failures of

National policies, administration and economies (UN Habitat: 2008).Green building has taken off in recent year with many builders and new home owners looking for new and different methods of construction that can potentially offset energy cost. Construction of low cost housing by using the low cost building materials increases the access to buildings by low income group peoples. Low cost housing can be achieved by use of efficient planning and project management, low cost materials, economical construction technologies and use of alternate construction methods available. The profit gained from use of such methods can decrease the cost of construction and make the low cost housing accessible to all. The use of low cost alternate building materials also prevents the rise of construction cost due to use of scarce building materials which eventually increase the cost of the project. Some alternative building material can be made out

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of natural materials, while others can help to lower energy costs of the occupant once built. Regardless of what the goal of the builder is, alternative building material and their use is on the rise.

1.2 Eco friendly and Alternative Building Material

In addition to the conventionally used materials there are various alternative technologies and materials developed by various research organizations, innovators and manufacturers in India that are beneficial in the housing construction. As part of this Information collected has been provided in the subsequent sections. Low cost Housing materials can be broadly classified into natural materials and manmade materials according to the source of the building materials

1.3 Natural Materials

1.3.1Random-straw or Coconut Fiber Stabilized Soil

Straw-soil mix is an ancient construction material and has been used in many countries for years. Application of modern geotechnical techniques to this material can further improve both strength and durability. Results with silty clay using the standard AASHTO Compaction procedure applied with the tensile test show that for 1% by weight of straw, the tensile strength increase three times than that soil with no straw and also the soil-straw mix gives high ductility behavior. The percent of straw increase to the tensile strength increase reaches an optimum condition approximately around 1.6% by weight and further increases of straw will decrease tensile strength. From wet-dry test results, the coconut fiber gives better durability. If a sulphur coating is applied to the compacted straw-soil mix, better water resistance is gained. Straw-soil mix can also simulate the soil-root system.

1.3.2 Bamboo

After China, India is the second largest in bamboo production. Coupled with China, it holds 50% of the world's total share of bamboo production. Of the total 136 species of bamboo occurring in India, 58 species spread out over 10 genera are endemic to the north eastern part of India alone (Sharma, 1987) The forest area, over which bamboos occur in India, on a conservative estimate, is about 9.57 million hectares, which constitutes about 12.8% of the total area under forests (Bahadur and Verma, 1980).). Its widespread availability and rapid growth in areas of China, Japan and India has made this grass an interesting structural material due to its affordability, easy assembly and relatively long durability. A bamboo hut was constructed in 1955 which was treated with 4 percent CCa and since it has no deterioration. But bamboo culms offer some disadvantage like Bamboo has a circular profile which makes it inherently difficult to connect other members. Also Bamboo has no support in the middle as it is hollow there, hence it cannot be subjected to high compressive forces perpendicular to the culms face. Some ongoing bamboo products are:

1) Corrugated Bamboo Roofing Sheet: A successfulroofing material with a development of traditional material comes from Bamboo Board. It is eco-friendly, light- weight, strong and durable and has minimal fire hazard when compared to thatch and other roofing materials. These sheets can be used for roofing, walling, door and window shutters and other components in building construction.

1.3.4 Earth

Earth is the oldest building material known to mankind. But its widespread use is hindered due to the limitations like water penetration, erosion of walls at level by splashing of water from ground surfaces, attack by termites and pests, high maintenance requirements etc. These limitations can be overcome by using compressed earths block and non-erodible mud plaster.

1) Compressed Earth Block

The compressed earth block is the developed form of moulded earth block, more commonly known as the adobe block. This technology offers an economic, environment friendly masonry. Stabilized earth blocks are manufactured by compacting raw material earth mixed with a stabilizer such as cement or lime using manual soil press.

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2) Nonerodable Mud Plaster

Central Building Research Institute, India has devel-oped an economical but effective process to protect mud walls by applying non-erodible mud plaster. Non-erodible mud is prepared by mixing bitumen cutback (Bitumen & Kerosene oil mixture) with a specified mud plaste. Nonerodible mud plastered walls are resistant to water erosion. Centre for Science for Villages, Wardha India has developed a technique of providing potter made tile lining to mud-walls protecting them from rain and moisture.

1.3.5 Straw

Straw is basically an agricultural by-product which comprises only of the plant stalks (mostly cereals) after removal of grain and chaff. Rice straw has the highest silica content making it the toughest amongst all other cereal straws. Straw is considered as an environmental problem as its burning causes breathing problems. Straw and Straw bale have a huge scope in India as it is one of the largest producers of straw bale. 46% of total land (32, 87,590 sq·km) of India is agricultural land and out of a total population of 1, 17, 09, 38,000 people 58.4% are solely dependent upon agriculture as a means of livelihood. So straw has high potential as an alternate building material. It is also fire resistant as it does not support combustion, is thermally insulated, has sound and moisture insulation and is not toxic.

The following are the profiles of some construction alternatives constructed with straws and straw bales.

Life Extended Thatch Roofing: It is one of the lo-cally available and environment friendly alternative for corrugated sheets. By treating it with copper sulphate solution, its life can be extended by reducing the effect of biodegradability. Additional layer of treatment on the roof surface using phosphorylated spray or CNSL oil imparts water proofing, fire resistance, termite proofing and weathering resistance (Developed by CBRI/RRL-TVM).

Improved Thatch Roofing: In order to decrease thefire hazard of thatch roof and making it water repellent a treatment had been designed by the Central Building Re- search Institute. It essentials the thatch layers are plastered with specified mud plasters making it durable and fire resistant.

1.3.6 Fiber Cement Composites

From centuries, mankind has used the various natural fibres for a wide spectrum of applications ranging from consumption to housing. In recent days many researchers have explored the possibilities of using the natural fibre obtained from different plants, which includes bagasse, cereal straw, corn stalk, cotton stalk, kenaf, rice husk/rice straw etc as an alternative building material. Due to the light weight, high strength to weight ratio, corrosion resistance and other advantages, natural fiber based composites are becoming important alternatives for building materials for use in civil engineering fields. A few of the important composites are summarized as under:

1.2 Problem statement

In existing approach affordability is measured in terms of disposable income, In the context of housing, affordability means the financial capacity of an individual to buy or rent a house. In 2008, the High Level Task Force on Affordable Housing for All, setup by the Government of India, defined affordability as a measure of household gross annual income and the size of a housing unit. Itrecommended that for economically weaker section and low income groups, the suggested affordability is cost not exceeding four times of the household gross annual income and EMI/ rent not exceeding 30% of the household's gross monthly income for a unit with carpet area not exceeding 300 and 600 sq.ft. For middle income category of houses, the cost was recommended as five times the household gross annual income and EMI/ rent not exceeding 40%, for a prescribed carpet area not exceeding 1200 sq.ft. India is currently facing a shortage of about 17.6 million houses.

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1.3 Objective

1. To study different types of construction materials and techniques to reduce cost of constructions mostly Rat Trap Bond and Filler Slab.
2. Alternative & low cost construction material & techniques used for sustainableDevelopment using Rat Trap Bond and Filler Slab.
3. To identify total cost required to completing a project using conventional andCost effective Technology.
4. To compare cost & Time reduction by adopting different material & techniquesfor projects.

1.4 Scope of the Project

The scope of the project is low cost house designed and constructed as any other house with regard of foundation, structure and strength using Rat Trap Bond and Filler Slab. The reduction in cost is achieved through effective utilization of locally available building materials and techniques that are durable, economical, accepted by users and not requiring costly maintenance.

II. LITERATURE REVIEW

2.1 Gap Analysis

2.1.1 NANO HOUSE-

After its revolution on wheels, the Tatasare aiming at a Nano house, which will cost between Rs 3.9 lakh and Rs 6.7 lakh. Tata Housing, a subsidiary of Tata Sons, has launched its low-cost housing initiative called the SHUBH GRIHA project. The first SHUBH GRIHA Township will be launched at Boisar in Mumbai. Tata Housing has tied up with SBI and HDFC to help potential buyers with finance options.

2.1.2 CIDCO-

City and Industrial Development Corporation of Maharashtra Limited (CIDCO) is all set to launch a new housing scheme under its lottery 2014 in Kharaghar Sector 36 in navi Mumbai on July 22. After the successful selling of hiendhomes in Kharaghar, CIDCO will offer affordable houses for LIG and EWS category. CIDCO will offer 3292 affordable homes under the lottery July 2014 in Kharaghar in sector 36. The economically weaker section of the society with an annual income of below Rs. 16,000 per month will be the beneficiaries for 80% of under construction flats. The rest 20% of the flats will belong to the people who fall under the LIG category and the income group of 16,000 to 40,000 per month. The new homes will be ready for possession by March 2016. The carpet area of EWS flats is 307 square foot while LIG flats will have a carpet area of 370 square foot.

2.1.3 MEGHALAYA AFFORDABLE HOUSING

SCHEME- The state government of Meghalaya is planning for a new affordable housing scheme for the people of the state. The scheme is named as Meghalaya Affordable Housing Scheme for which the government has created all the guidelines
and sent the scheme to the Planning Department for necessaryapprovals. Besides this, several other criteria for constructing a house under the scheme. According to the source, government is planning to construct 10,000 houses across the state. Under the scheme 25% of total cost of houses to the beneficiaries from EWS (economical weaker section) and for remaining 75%, loan will be provided to the beneficiary.

2.1.4 MIGSUN AMULYA AFFORDABLE HOUSINGMigsun

Amulya PMAY is located at the prime location of Raj Nagar Extension Ghaziabad and offering 1BHK and 2BHK flats for allotment. The size of affordable houses under PM

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AwasYojana is in the range of 55.80 Sq. Mt. to 75.92 Sq. Mt. And the cost of these residential flats is also affordable startsfrom Rs. Rs. 9.9 lakh.

2.1.5 GLS ARAWALI HOMES-

An affordable housing project of GLS Infratech Private Limited located at the prime location of Sector-4 Gurgaon. The project is approved under affordable housing policy 2013 of Haryana government. GLS Arawali Homes Affordable Housing Project is spread over the area of 10 acres offering 2BHK flats in high-rise apartments. The area of flat is around 750 square feet. Total two type of 2BHK flats having a carpet area of 567 square feet and 576 square feet available for allotment. Low cost housing technique: It is found that cost-effective and alternative construction technologies, which apart from reducing construction cost by the reduction of quantity of building materials through improved and innovative techniques, can play a great role in providing better housing methods and protecting the environment. The detail procedures of each step used for the project are as follow:

2.2 LITERATURE REVIEW

Anwar Khitab et al. The aim of this research paper is to address the futuristic construction materials. Relevant data of the developments made during the recent past are also presented. It is believed that nanotechnology is going to play an important role in the development of futuristic building materials. The innovations could be two-fold; one is the modification of classical materials and the other should cover the invention of novel materials. The primary goal of all such materials should be environment friendliness. Secondarily, they should be durable and cost effective. Thirdly, they should address the space shortage. Innovations are needed as man is also planning to colonize moon and other planets. Fourthly, they should have adequate strength to cater the natural and manmade calamities. In short, they should serve the coming generations in the best possible way, which is the sole purpose of an engineering discipline.

Jerry Magutu et al . This paper is based on a literature review and an evaluation of practices that have been I place with respect to low cost building materials and technologies so as to lower costs and hence make the buildings, especially housing for the majority urban poor who have meager resources and hence cannot afford conventionally built houses. The paper utilized both secondary data from the literature, and an empirical study of pilot projects that have been constructed in different regions of Kenya by utilizing traditional architectural research techniques akin to observational techniques in the social sciences, augmented by open-ended interviews and discussions with the different actors in the advocacy and use of low cost materials and technologies in building. This study found out that topmost of the constraints that hinder wider application and universalism for the alternative materials and technologies is largely due to both lack of standards and specifications, and also information by the general populace about them. Otherwise I general, the alternative materials and their technologies are quite economical, durable, sanitary and safe in construction as attested to my findings from the case studies for this paper

.

Ar.Vidya et al. Since economical factors have influenced the construction industry dramatically in recent years and in many parts of the world steel is scarce and expensive, many researchers are searching for low-cost materials as a substitute or alternative for the present situation. Recently, various materials have shown promise for future use as a major construction material. The purpose of this paper is to highlight alternative low-cost building materials for possible use in low-cost housing having advantages on areas such as India where concrete or steel housing is expensive.

ShrutiMutkekaretal. Housing is major problem faced by developing countries like India. The most basic building material for construction of permanent houses is the burnt clay brick, Cement and steel. A significant quantity of raw material and fuel is utilized in making these conventional building materials and even the manufacturing processes of these materials create environmental problems. This paper presents study on sustainable and low-cost alternative building material – Flyash, having advantages on areas where conventional building material for housing is expensive and hazardous to environment.

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S M SITUMBEKO et al. The provision of housing that is fully serviced and affordable remains a major challenge for most developing countries. A lot of settlements still comprise of poor housing structures that are prone to damage during inclement weather, with poor or no utilities, few community facilities and poor roads. Several third world governments have attempted to address the issue through housing policies or programmes such as provision of serviced sites and extendible units. Other measures include housing schemes such as subsidized home loans, distribution of (free-) house plans, and through promoting private sector involvement.
These attempts have not addressed the issue in full; indications are that the main problem is that all systems that have been tried are aimed at providing conventional housing units using inadequate resources – skills, equipment, materials and finance. The reality though is that most developing countries do not have adequate capital resources to construct conventional dwellings.
Clearly there is need to look for alternatives; this paper examines and suggests alternatives building techniques and designs that while still providing acceptable housing, do so at reduced costs.

Mohammad Sharif Zami et al. Earth has been used as a construction material in every continent and in every age, largely due to its versatility and widespread availability. It is one of the oldest building materials. The use of earth on site as a building material saves manufacturing cost, time, energy, environmental pollution and transportation cost. As a result of Operation Murambatsvina (Cleanup campaign carried out in 2005) in Zimbabwe, the percentage of squatters has increased. A solution has to be found out to provide sustainable low cost housing for these squatter's that is 'eco'-friendly and will preserve the environment for future generations whilst catering for the needs of the present inhabitants. This paper discusses an alternative building material; earth can also be used in the construction of low cost sustainable houses in Zimbabwe which is significantly cheaper than using conventional bricks.

K.Jaiganesh et al. Low Cost Housing is a different concept which deals with effective costing and following of techniques which help in reducing the cost construction through the use of faraway available materials beside with and technology improved skills without losing the power, performance and life of the structure. There is huge misconception that low cost housing is suitable for only subnormal works and they are built by using cheap building materials of low quality. The fact is that Low cost housing is done by proper management of resources. Economy is also achieved by postponing finishing works or implementing them in phases. Cost of reduction is achieved by selection of more efficient material or by an improved design. Construction of low cost housing by using the low cost construction materials increases the access to buildings by low income group peoples. Advantages of low cost building materials are pollution prevention, Reducing Energy Consumption and use of Natural materials, Use of Local material, Energy Efficiency, Use of non-toxic building materials, Longitivity, durability and maintenance of building material, Recyclability and reusability of building material and Biodegrability. The reviews on various low cost building designs and management are presented in this paper

Vivek Kumar et al.this paper reviews the Alternate construction materials and techniques for building design in the field of civil engineering. It comprises the important analysis and results from the experimental and literature of many authors. Housing is a great problem in today's world. The most basic building material for construction of houses is the conventional burnt clay brick. A significant quantity of fuel is utilized in making these bricks. Also, continuous removal of upper surface of soil mass, in producing conventional bricks, creates environmental problems. A feasibility study has been done on the comparison of fly ash brick and conventional clay brick. Fly ash is an industrial waste which is just a burden for the industry we can take it free of cost from the industries and can utilize it for the manufacturing of fly ash brick. Fly ash brick have sufficient strength and comparatively low cost than conventional clay bricks. Conventional clay bricks can be replaced with fly ash bricks, which can reduce the overall cost of a house.

Bakhoum E. S.et al. In the construction industry, selection of sustainable structural materials during the design phase leads to move towards more sustainable construction. Therefore, there is a need to select more green building materials to be used in construction. Based on the promising vision of future needs for sustainable development this paper presents a comparative study between conventional and eco-friendly building materials using sustainability measures.

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A prototype of two storeys was constructed using eco- friendly building materials (integrated bricks, rice straw bales, M2 system, plain concrete, and Rockwool sandwich panels). A sustainable decision support system (SDSS) was used to compare between the structural building materials of the two structural systems. The results showed that the eco-friendly system had better sustainability rank (67%) than the conventional system (56%). In addition, the results of SDSS showed that the Eco-friendly system was better than the conventional system during the three phases of total life cycle assessment (manufacturing, construction and demolition) by 11%, 0.5% and 9%, respectively.

Harsh Mittal et al. Low cost housing is a new concept which describes affordability of housing in terms of disposal income and gives the technique to reduce the cost of construction. Low cost housing is beneficial for EWS and LIG.

Bredenoord J et al. The access to affordable housing in the Global South is very limited for millions. Many households have chosen for incremental self-construction; herewith sustainability does not have the highest priority. The main question is whether affordable housing for the urban poor and the need for sustainable housing and urban development can be combined. Transference of knowledge to (self) builders is a key issue, as is the role of assistance in self-help housing. It is argued in this paper that sustainable goals for low-cost housing and applications are achievable. Measures concerning the physical development of neighborhoods, such as urban density and connectivity are equally as important as measures concerning community development. The latter include support for community based organizations, small housing cooperatives (or similar forms of cooperation) and individual households – or small groups – that build and improve their houses incrementally. Adequate planning and social organization andcooperation are preconditions for achieving sustainability in incremental housing.

III. RESEARCH METHODOLOGY

Methodology 1 – Rat trap bond

Rat trap bond- Rat trap bond is a brick masonry method of wall construction, in which bricks are placed in vertical position instead of conventional horizontal position and thus creating a cavity (hollow space) within the wall. Architect Laurie Baker introduced it in Kerala in the 1970s and used it extensively for its lower construction cost, reduced material requirement and better thermal efficiency than conventional masonry wall, without compromising strength of the wall.

Figure1. Rat trap bond mechanism

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Advantages of using rat trap bond

1. Requires approximately 25% less bricks and 40% less mortar than traditional masonry
2. Reduced material requirement results in considerable cost saving
3. Strength of wall is not compromised, it remains same as traditional masonry wall.
4. Cavity induced in wall provides better thermal insulation, resulting in cooler interiors during summer and warmer interiors during winter.
5. All vertical and horizontal reinforced bands, lintels (for standard size openings), electrical conduits are hidden inside wall, resulting in better aesthetic appearance without plastering (exposed brickwork).

The rat trap bond is a masonry technique, where the bricks are used in a way which creates a cavity within the wall, while maintaining the same wall thickness as for a conventional brick masonry wall. While in a conventional English bond or Flemish bond, bricks are laid flat, in a Rat trap bond, they are placed on edge forming the inner and outer face of the wall, with cross bricks bridging the two faces. The main advantage of Rat-trap bond is reduction in the number of bricks and mortar required as compared to English/ Flemish bond because of the cavity formed in the wall. The cavity also makes the wall more thermally efficient. This also reduces the embodied energy of brick masonry by saving number of bricks and the cement-sand mortar. It is suitable for use, wherever one-brick thick wall is required. Since its original dissemination in Kerala in the 1970sby architect Laurie Baker, rat trap bond has been extensively used in every category of building from large institutional complexes, community buildings. Government offices/village panchayats, individual homes both for high income and middle income and also in government supported EWS housing programs. The following figure shows the basic layout difference in the traditional English/ Flemish Bond Masonry methods Vs Rat Trap Bond Masonry.

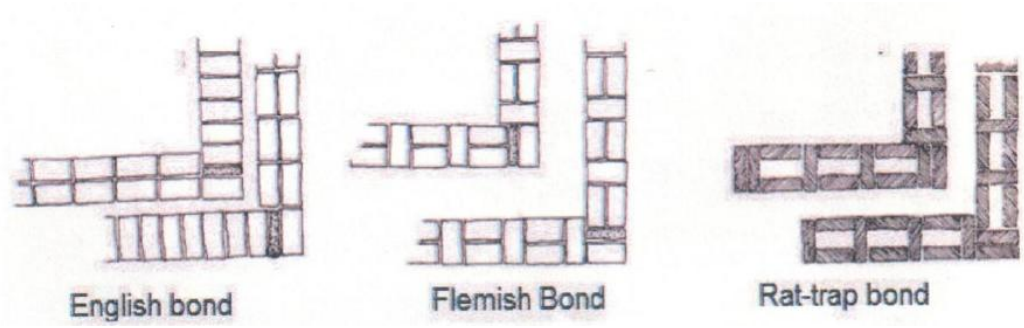

Figure2.Various Bonds in Brick Masonry

3.1 Construction Details The following Flowchart explains the general schematic of the wall construction process using Rat Trap Bond Masonry:

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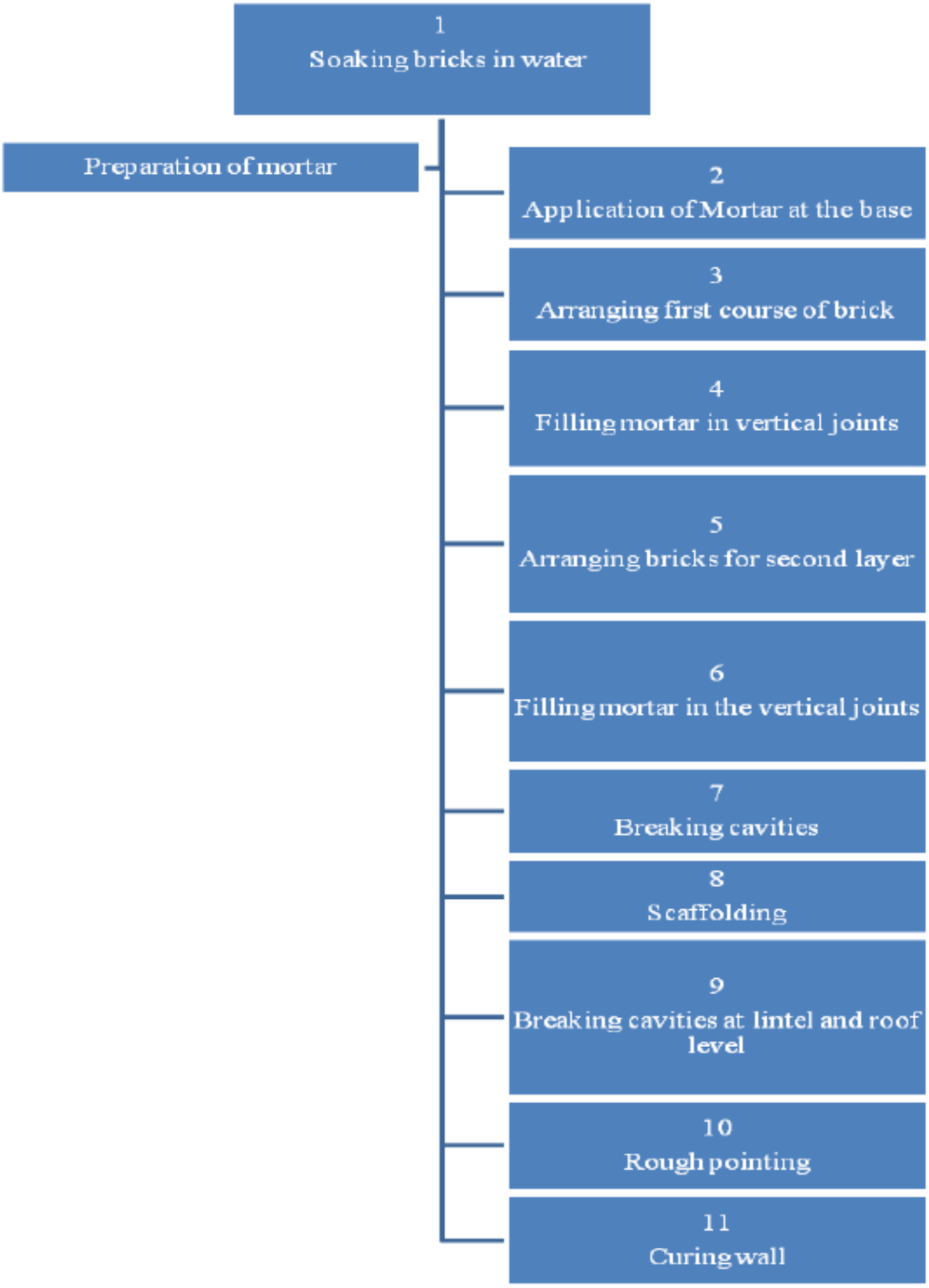

Figure3. How chart fin- Rat Trap Bond Masonary Construction Process

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Benefits & Issues

1. By adopting this method of masonry, you can save on approx. 20-35% less bricks and 30-50% less mortar; also this reduces the cost of a 9 inch wall by 20-30 % and productivity of work enhances.

2. For 1 m3 of Rat trap bond, 470 bricks are required compared to conventional brick wall where a total of 550 bricks are required.

Rat trap bond wall is a cavity wall construction with added advantage of thermal comfort. The interiors remain cooler in summer and warmer in winters.

4. Rat-trap bond when kept exposed, create aesthetically pleasing wall surface and cost of plastering and painting also may be avoided.

5. Rat trap bond can be used for load bearing as well as thick partition walls.

6. All works such as pillars, sill bands, window and tie beams can be concealed.

7. The walls have approx. 20% less dead weight and hence the foundations and other supporting structural members can suitably be designed, this gives an added advantage of cost saving for foundation.

8. Virgin materials such as bricks, cement and steel can be considerably saved upon by adopting this technology. It will also help reduce the Embodied Energy of virgin materials and save the production of Green House Gases into the atmosphere.

9. In case for more structural safety, reinforcement bars can be inserted through the cavity till tile foundation.
There are some issues though which have to be dealt with or kept in mind before commencement of construction work during the planning stage. These are mentioned below:

1. Service's installations should be planned during the masonry construction if not exposed.

2. It is most suited where good quality bricks with straight and sharp edges are available -better avoided when good quality and uniform size bricks are not available

3. If the mason is not skilled enough, cement mortar can get wasted by falling into the wall cavity.

4. Needs pre-planning in case of concealed electrical conduiting because chasing brickwork, like in conventional practice, is not possible. However, this can be taken care of by identifying location of wiring and plumbing in the design and planning stage, so that solid courses of brickwork may be provided in masonry where the conduits will run.

Performance Validation

a. Rat trap bond can be very easily adapted for earthquake/seismic strengthening i.e. provision of horizontal tie bands and vertical reinforcement in the brickwork cavity.

b. The rat trap bond technique has been validated by the Department of Civil Engineering, Anna University Chennai. The results conclude that "the rat-trap bond wall can be safely used for low cost housing having 2 storey with short span not exceeding 4.2 m and with storey height not exceeding 3 m, using bricks of minimum compressive strength 50 kg/cm2 with cement mortar 1:3.

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c. Rat trap bonded brick masonry has been widely used in all parts of the country. Its excellent weathering over the past 30 years is the best performance guarantee. Importantly, an unplastered brie' wall in rat trap bond masonry requires very little recurring maintenance cost since there is no external plaster/painting.

Methodology- 2: Filler slab

Filler slab- Filler slab technology is a simple and a very innovative technology for a slab construction. The reason why, concrete and steel are used together to construct RCC slab, is in their individual properties as separate building materials and their individual limitation. Concrete is good in taking compression and steel is good in tension. Thus RCC slab is a product which resists both compression as well as tensile. which indicates the neutral axis and also tension concrete in the bottom fibers of the slab which is in tension but the top fibers will be in compression. Knowing this much is the key to understand the filler slab technology. Tension in a slab is on the bottom fiber and compression on the top fiber. That means if we want to optimize the structure we can remove concrete from the tension zone where it is not much needed. That's the key behind filler slab construction.Filler slab technology is a simple and a very innovative technology for a slab construction.The reason why, concrete and steel are used together to construct RCC slab, is in their individual properties as separate building materials and their individual limitation. Concrete is good in taking compression and steel is good in tension. Thus RCC slab is a product which resists both compression as well as tensile.

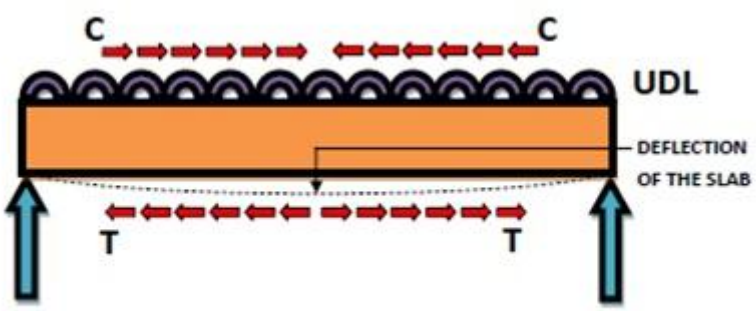

Figure4. Simply supported slab cross section

Knowing this much if we want to move further to understand the "Filler slab" technology, we will have to further study the cross section of a typical simply supported RCC Slab. Under its own load and applied load, the slab will try to bend as shown in the Figure 1.

Figure5. Showing unwanted tension concrete

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If we refer Figure 2, which indicates the neutral axis and also tension concrete in the bottom fibers of the slab which is in tension but the top fibers will be in compression. Knowing this much is the key to understand the filler slab technology. Tension in a slab is on the bottom fiber and compression on the top fiber. That means if we want to optimize the structure we can remove concrete from the tension zone where it is not much needed. That's the key behind filler slab construction.This is a very cost effective roofing technology. Knowing the way slab is constructed on site (w.r.t. Gujarat, India), it is not easy to remove, the concrete from the tension zone, hence we try and replace (partially); that part of concrete using light weight and low cost filler material. This method of construction is called filler slab.Filler slab technology is being used across India, but substantial amount of work on the successful promotion and transfer of this technology was done by Ar. Laurie Baker in South India. It is one place where filler slab has crossed the boundary of research and controlled implementation to being one of the regular options of construction by both government and private sector and also architects and designers have been promoting this technology.These filler materials are so placed as not to compromise the structural strength, stability and durability, resulting in replacing unwanted and non-functional tension concrete, from below and thus resulting in economy of high energy material consumption and respective cost savings and decreased dead load of the slab.An internal cavity can be provided between the filler material which adds an extra advantage; other than cost savings and energy savings; improved thermal comfort for the interiors. Also an added advantage of lower dead weight transferred to the supporting elements and finally onto the foundation to further adds up cost saving in design of these elements.These filler materials are so placed as not to compromise the structural strength, stability and durability, resulting in replacing unwanted and non-functional tension concrete, from below and thus resulting in economy of high energy material's, consumption and considerable cost saving and decreased dead load of the slab.

Advantages of filler slab technology-

1) By adopting RCC filler slab construction compared to a RCC solid (conventional) slab in case where Pune tiles are used as a filler material, you can save on approximately 19% of the total concrete and including the cost of filler material, you can save around 5-10% of your concrete cost.
2) Another advantage is, if the filler material is just a waste i.e. for ex temporary Pune tiles that are removed from the roof to construct a pukka roof, you can save upon nearly 15% on your roof concrete construction cost.
3) Filler slab technology can also be applied to mass housing projects and township projects to gain high cost saving and also saving in high energy consumingmaterials.
4) Another advantage can be of a better thermal comfort if a cavity is kept between the filler material or the filler material itself has a cavity. For example tow Pune tiles/Clay tiles can be kept one over the other to form an air cavity thus keeping the interiors of your house remain cooler in summer and warmer in winters.
5) Filler slabs can be kept exposed (with proper workmanship) to create aesthetically pleasing ceiling with a view of filler material from below and thus the cost of plastering and/or painting also can be avoided.
6) RCC being made of cement, steel, sand and aggregates, is a very high energy intensive material. So reduction in concrete quantity compared to conventional slab construction, adds this technology to the list of sustainable and environment friendly technologies and corporation green building features.

Materials Selection as Per Need and Design

Light weight, inert and inexpensive materials such as low grade Mangalore tiles, Burnt Clay Bricks, Hollow Concrete blocks, Stabilized Mud blocks/ Hollow Mud blocks, Clay pots, Coconut shells etc. can be used as filler materials. These materials are laid in the grids of steel reinforcement rods and concreting/concrete topping is done over them.

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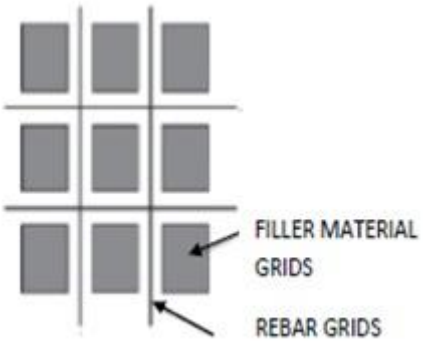

Figure6. Filler material arrangement

The following points to be kept in mind for filler material selection:

- Filler material should be inert in nature. It should not react with concrete or steel in RCC slab constructed.
- Filler materials water absorption should be checked for as it will soak the hydration water from concrete.
- Filler material should be light in weight, so that overall weight of the slab reduces and also the dead load onto the foundations is reduced.
- Filler material should be low cost so that it cost is much lesser then the cost of the concrete it replaces. This is very important to achieve economy.
- Filler material should be of a size and cross-section, which can be accommodated within the spacing of the reinforcement and also thickness wise could be accommodated within the cross section of the slab.
- Moreover the Filler slab also provides insulation (compared to a conventional RCC slab) from the hot climate outside the building, providing thermal comfort to the user.
- Filler material texture should match with the desired ceiling finish requirements so as not to provide an ugly ceiling pattern.

IV. EXPERIMENTAL ANALYSIS / CASE STUDY

1. RAT-TRAP BOND

Design and Construction

Rat-trap bond masonry can be used to construct a small double storeyed residential building in load bearing construction, using the specific construction details which are followed in this technique. The principal requirement for rat-trap brickwork is the availability of good quality bricks.

The Guiding Principle The following can be taken as guiding principle for strength of bricks for Rat-trap brickwork: The data presented here is for Short Span not exceeding 4.2 meters, and Roof/ Floor Loads as per IS 875.

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Table 1: The Strength Requirement Guide

Sr. No.	Type of Building Construction	Recommended Compressive Strength of Bricks	
Best Practice		Minimum Allowable	
1	1 Load bearing, double storied	More than 50 kg/cm2	40 kg/ cm2
2	Load bearing, single storied	More than 40 kg/ cm2	35 kg/ cm2
3	Infill masonry in frame structure, no restriction on number of storey	Minimum 35 kg/ crn2	--

Modular Design To ensure maximum advantage of the technique, it is preferable that the masonry is designed in a modular pattern at the design stage itself, after the prevailing brick size available for use has been ascertained. For best rat-trap brickwork, there should be no half bricks/ quarter bricks used in brickwork, unlike their common use in conventional brickwork. This will disturb the staggering of joints in rat-trap brickwork and affect the integrity of brickwork.

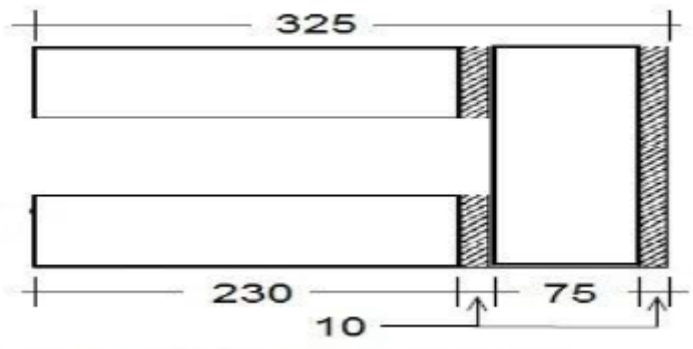

Figure7. Module of Rat trap Bond Masonry

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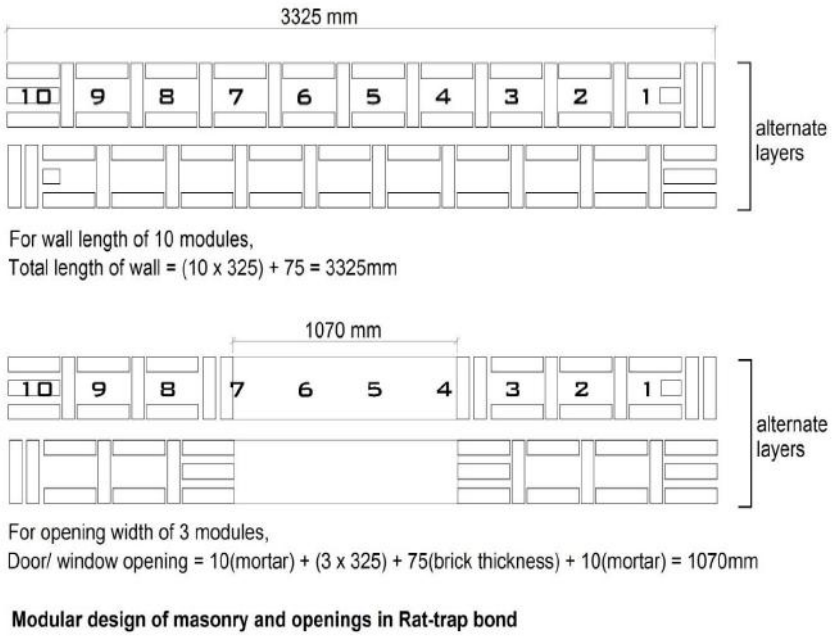

Figure8. Modular Design of Rat trap Bond Masonry

2. FILLER SLAB

Size of the filler material will be very crucial. It is must to decide the filler material before the slab is designed. The dimension of filler material will help decide the spacing of reinforcement and accordingly the depth of the slab and other structural details will be worked out.Also, filler material should be properly soaked in water so that it does not absorb any water from the concrete. While installing the filler material, one will have to decide the concreting sequence of the slab i.e. from where the concrete will be started and how will it progress to cover the whole slab.Filler materials like Manglore tiles/Clay tiles can be installed in two layers (2 nos. one over the other) entrapping an air cavity between the two tiles. A sketch showing cross section of a filler slab with manglore tile is shown below. This will improve the thermal properties of the slab.

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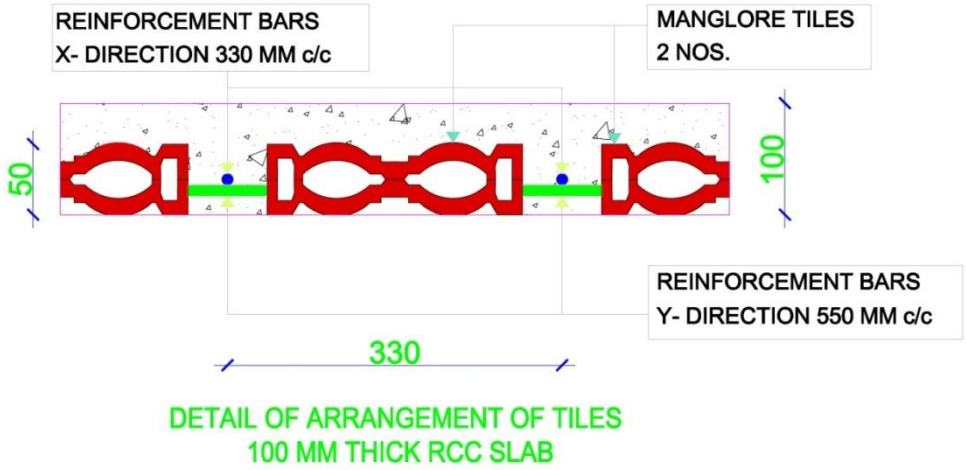

Figure9.Filler slab section - Manglore tile filler material.

Advantages of Filler Slab Technology:

By adopting RCC filler slab construction compared to a RCC solid (conventional) slab in case where manglore tiles are used as a filler material, you can save on approximately 19% of the total concrete and including the cost of filler material, you can save around 5-10% of your concrete cost.

- Another advantage is, if the filler material is just a waste i.e. for ex temporary manglore tiles that are removed from the roof to construct a pukka roof, you can save upon nearly 15% on your roof concrete construction cost.
- Building a 25 sq. m slab can save you approx. Rs. 5000 from your concrete cost.
- Filler slab technology can also be applied to mass housing projects and township projects to gain high cost saving and also saving in high energy consuming materials.
- Another advantage can be of a better thermal comfort if a cavity is kept between the filler material or the filler material itself has a cavity. For example tow manglore tiles/Clay tiles can be kept one over the other to form an air cavity thus keeping the interiors of your house remain cooler in summer and warmer in winters.
- Filler slabs can be kept exposed (with proper workmanship) to create aesthetically pleasing ceiling with a view of filler material from below and thus the cost of plastering and/or painting also can be avoided.
- RCC being made of cement, steel, sand and aggregates, is a very high energy intensive material. So reduction in concrete quantity compared to conventional slab construction, adds this technology to the list of sustainable and environment friendly technologies and corporating green building features.

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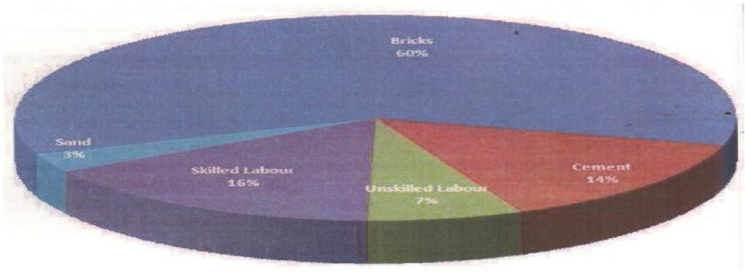
V. RESULT AND DISCUSSION

1. Rat Trap Bond

Cost Analysis, Advantages and Comparison

Following is a general cost breakup of a brick masonry built in Rat Trap Bond.



Figur10. Cost Breakup

As we can see the major component of the cost involved in the construction is the cost of bricks i.e. about 60 %, followed with Skilled Labour (16%) and then Cement (14%). Hence, the saving in the required quantity of bricks attained in this masonry technique goes a long way in achieving cost-effective housing solution to the public.

Labour, Material & Cost Savings:
For having a general idea of the savings that can be obtained on a normal basis by switching from conventional brickwork to Rat Trap Bond Masonary technique is given below. Following assumptions are made for the given calculations:
1. Number of Storey : 2
2. Plinth Area : 100 Sq.m
3. Total Brickwork : 70 Cu.m
4. Class of Bricks used : Class I
5. Sand Grading : Moderately Coarse/ Not too fine
6. Mortar Ration : 1:4
7. Basic Rates of materials : Cement = Rs. 275/ Bag Sand = Rs. 1770/ Cu.m Bricks = Rs. 4000/ 1000 No.

Table 2: Savings in Materials

Sr. No.	Description	Unit	Savings
In units		In Percentage	
1	Cement	Bags	78	57
2	Bricks	No	5599	19
3	Sand	Cu.m	13	61

Table 3: Savings in Cost

Sr. No.	Description	Unit	Savings
In units		In Rs.	
1	Cement	Bags	78	21450
2	Bricks	No	5599	22396
3	Sand	Cu.m	13	23010

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Embodied Energy is the sum of all the energy required to produce any goods or services, considered as if that energy was incorporated or 'embodied' in the product itself. The concept can be useful in determining the effectiveness of energy-producing or energy-saving devices, or the "real" replacement cost of a building, and, because energy-inputs usually entail greenhouse gas emissions, in deciding whether a product contributes to or mitigates global warming. One fundamental question is: does the device produce more energy or save more energy than it took to make it? Embodied energy is an accounting method which aims to find the sum total of the energy necessary for an entire product life-cycle. Determining what constitutes this life-cycle includes assessing the relevance and extent of energy into raw material extraction, transport, manufacture, assembly, installation, disassembly, deconstruction and/or decomposition as well as human and secondary resources. Different methodologies produce different understandings of the scale and scope of application and the type of energy embodied.

Comparison and Advantages of Rat Trap Bond

Advantages:-
1) By adopting this method of masonry, you can save on- approx. 20-35% less bricks and 30-50% less mortar; also this reduces the cost of a 9 inch wall by 20-30% and productivity of work enhances.
2) For 1 m3 of rat trap bond, 470 bricks are required compare to conventional brick wall where a total of 550 bricks are required.
3) Rat trap bond when kept exposed, create aesthetically pleasing wall surface and cost of plastering and painting also may be avoided.
4) Rat trap bond can be used for load bearing as well as thick partition walls. 5) Rat trap bond wall is a cavity wall construction with added advantage of thermal comfort. The interior remain cooler in summer and warmer in winters.

Cost Saving
Material saving per m3: Rat trap bond VS. Convention) brickwork • 1.11 bags(57% saving) = Rs 288/m3 saving in cement cost. • 80 nos. of bricks(20% saving) = Rs 576 saving in brick cost. • 40.18 m3 less sand (61% saving) = Rs 13/m3 saving.

2. **COST SAVINGS FILLER SLAB**

Material saving assuming a 100 mm thick slab 2.54×3.86 m, and calculating the material and cost savings as per market material rates of Ahmedabad, Gujarat, August, 2011 and comparing the savings **for 1 m^3** : RCC Filler slab vs. Conventional Solid RCC Slab.

- 1.61 bags (19% saving) = Rs 418/ m^3 saving in cement cost.
- 0.09 m^3 less sand (19% saving) = Rs 21/ m^3 saving in sand cost.
- 0.18 m^3 less aggregates (19% saving) = Rs 127/ m^3 saving in aggregates cost.
- 10 kg less steel/m^3 of slab casted = Rs 500/m^3 saving in reinforcement cost.

The table below shows the consumoption of materials and cost savings for **1 m^3** quantity of the slab:

Table 4: Cost saving/cu.m of concrete slab

Material description	Conventional slab	Filler slab	Savings/cu.m	% saving /cu.m	Savings (Rs.)
Cement (kg)	422.67	342.35	80.31	19%	418
Sand (cu.m)	0.48	0.39	0.09	19%	21
Aggregates (cu.m)	0.96	0.78	0.18	19%	127
Steel (kg)	28.20	17.48	10.72	38%	536
TOTAL =					1102

The figures in the table seem less as the slab taken for calculation is a small size slab. Elaborating this savings, assuming a normal MIG house area of 100 sq.m ground area and of two stories. Assuming the slab area comes to be 160 sq.m. for this house, the total savings in concrete cost can be Rs. 30,000. Also if the filler material is not a virgin material for the slab construction, you can save about Rs. 90,000 from your concrete cost.

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EMBODIED ENERGY SAVINGS

The table below shows the embodied energy calculations for a 200 sq.m house slab. Slab dimensions to be same as above in

Cost Savings.

The table below shows the embodied energy calculations for a 200 sq.m house slab.

EMBODIED ENERGY CALCULATIONS FOR A 200 SQ.M HOUSE SLAB									
No	Material	Embodied energy (MJ)	Unit	Energy Source	Conventional building		Filler slab technology		Manglore Tiles reused
					Quantity consumed	Total embodied energy (MJ)	Quantity consumed	Total embodied energy (MJ)	Total embodied energy (MJ)
1	Concrete (m^3)								
	Cement (kg)	5.85	1 kg	Coal+Deisel+Elec	8453.34	49452.07	6847.07	40055.35	40055.35
	Coarse aggregates (m^3)	108	1 m^3	Coal+Deisel+Elec	19.15	2068.42	15.51	1675.38	1675.38
	Fine aggregates (m^3)	87.5	1 m^3	Diesel	10	837.90	7.76	678.68	678.68
2	Reinforcing Steel (kg)	42	1 kg	Coal+Deisel+Elec	564.02	23688.66	349.58	14682.29	14682.29
3	Manglore Tiles	5	1 tile	Firewood/coal	0.00	0.00	1468.73	7343.64	0.00
TOTAL EMBODIED ENERGY (MJ) =						76047.04		64435.35	57091.71
DIFFERENCE (MJ) =								11611.70	18955.34
% SAVINGS									15

Note: Firewood is a renewable resource. However, demand for this fuel can outpace its ability to regenerate on local and regional level.

Now 1 Kwh = 3.6 MJ . Therefore a saving of 3220 Kwh of ELECTRICITY equivalent is achieved.

This is equivalent to 0.28 metric tonnes of OIL saving.

This is equivalent to 3.22 tonnes of CO2 gas released to the atmosphere .

This is equivalent to saving of 4800 hours of AC electricity consumption or 200 days.

This is equivalent to saving of 77400 hours of a Colour TV electricity consumption or a period of 9 years.

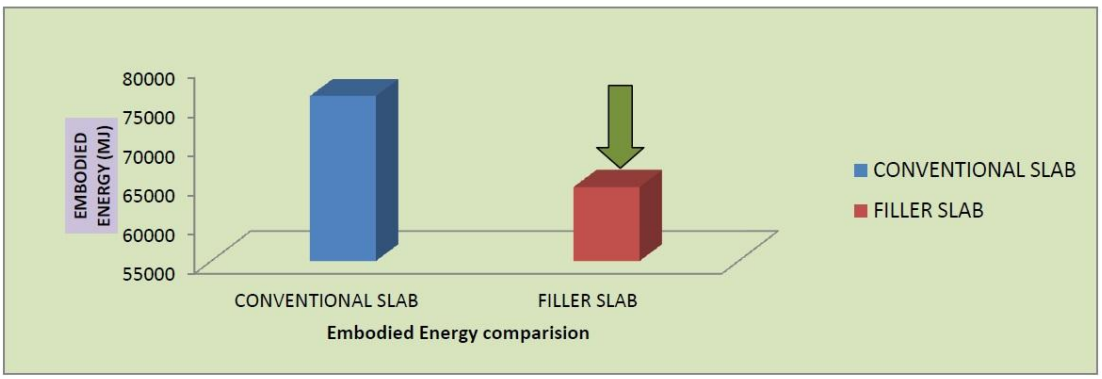

Figure12.Cost Comparison: Conventional RCC solid slab v.s. RCC Filler Slab

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VI. CONCLUSION

Housing is the basic need and right of all human beings. During our ages, due to tremendous rise in property market rates, the dream of common middle class and lower income group people remains a dream, as the reality of non-affordability is bitterly painful. **In this project we work on Rat Trap Bond and Filler Slab Concept for alternative low cost construction material**. Many efforts at governmental levels have failed to alleviate the problems of the common people's housing shortage which continues to grow at an alarming rate. Filler slab technology is a simple and a very innovative technology for a slab construction. The reason why, concrete and steel are used together to construct RCC slab, is in their individual properties as separate building materials and their individual limitation. Concrete is good in taking compression and steel is good in tension. Thus RCC slab is a product which resists both compression as well as tensile. The shortage we see today is not about housing itself, it's actually about `Affordable Housing' Fortunately enough, the solution to affordable housing shortage (especially urban) is within our reach. We cannot control the hikes in the land rates, but Endeavour to minimize the costs of construction by switching to some simple, cost-effective building materials and technologies. One such solution is the use of Rat-Trap Bond Masonry Technique. It's simple, and easy to construct and effects into an overall savings of about 23 % in the costs in comparison to conventional brick work, while also reducing its impact on the environment by achieving a huge saving in the embodied energy consumption. We think that this is the need of the hour that our governments take up this issue on war-foot level and promote and subsidize as much as possible the use of such green, environment-friendly and cost-effective technologies. This will help today's common man to bring the house of his dreams a reality.

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