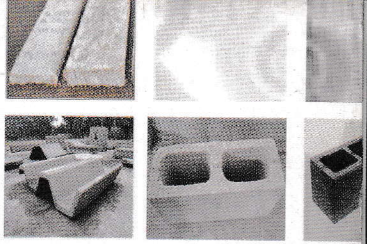
Special Report 2018



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HOUSING AND BUILDING RESEARCH INSTITUTE

MINISTRY OF HOUSING AND PUBLIC WORKS

Special Report 2018

March 2018

HOUSING AND BUILDING RESEARCH INSTITUTE

MINISTRY OF HOUSING AND PUBLIC WORKS

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Special Report 2018

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HOUSING AND BUILDING RESEARCH INSTITUTE
MINISTRY OF HOUSING AND PUBLIC WORKS

PREFACE

"Housing and Building Research Institute" was established to mitigate the post-Independence housing needs of the mass population of Bangladesh. From the birth of the Institute, it has not succeeded in accomplishing its long time urged prosperity. In recent years, the Institute has achieved unprecedented success in the organization through application-based research program. The present accomplishments by the Institute have been pursued on the basis of the instructions of the Honorable Prime Minister given to HBRI in the year 2014 and SDG based 7th Five-year plan.

This special report comprises the Institute's achievement as well as the progress of the research and development ventures. Study reveals that one percent of agricultural land is being wasted every year, mainly due to unplanned rural housing and burnt brick kilns. If this trend of reduction in agricultural land continues, in the near future, food security will be in danger. Moreover, due to brick kiln, environmental pollution is being generated. The researchers of the organization have devoted themselves to the development of the substitutes of burnt clay bricks from the year 2013. As a result, development of Cement Stabilized Earth Block, Interlocking, Thermal, Hollow Block and Ferrocement technology, which are agro-friendly, environment-friendly, disaster resilient, sustainable and cost-effective, have been propagated to discourage the use of burnt clay brick. In addition to the extensive use of alternative construction materials and technology, various activities of the countrywide promotion and expansion have been adopted. Participation in the countrywide development fair, organizing the first earthquake exhibition, different workshops, publications, print and electronic media promotion are some other activities. It is worth mentioning that this particular report has been mentioned in the past five years. HBRI has already completed some demonstration program using alternative products in its own premises. Besides research and development activities, the institution is also contributing to the development of human resources. Till this date, over 10 thousand professionals have been trained. Currently the training for "Development of Five Hundred Thousand Skilled Laborers" is going on.

Instructed by the Government to train 5 lac construction workers, HBRI has already started ToT program to train the the trainers along side the preparation of relevant DPP.

I like to extend wholehearted felicitation to all concerned for preparing the report to appear in public. We cordially welcome any informed opinion about our works from our valued readers and thus assure that any of such feedbacks will be highly appreciated and evaluated with gratitude.

Mohammad Abu Sadeque PEng.
Director
Housing and Building Research Institute

HOUSING AND BUILDING RESEARCH INSTITUTE
MINISTRY OF HOUSING AND PUBLIC WORKS

EDITORIAL

This is a matter of great pleasure that we are publishing special report on the progress of the Institute's research and development programs. This special report is an all-inclusive and vibrant document of HBRI which evaluates the works, and discusses the organization's interpretation of the upcoming prospects. The report conveys the Institute's message and a crystal clear idea about the organization in a comprehensive manner.

Housing is one of the basic human needs. The increased growth of population is reaching the highest urge of proper housing and accommodation system. This phenomenon is helping to boost the need of construction materials. Burnt clay brick is being considered as the most common and widely used building component. However, the immense number of brickfields are emitting huge amount of greenhouse gases. As a consequence, every year we are losing a large extent of agricultural land.Therefore, there is an urgent need of moving toward alternative building materials.

Housing and Building Research Institute is working for the development in the construction system of the country by improving and inventing eco-friendly and sustainable alternative building materials. Honorable Prime Minister has instructed HBRI to focus on the dissemination and vast implementation of the research products throughout the country. The work progress regarding the implementation of the instructions given by Honorable Prime Minister to HBRI has been included in this special report. With this view in mind, our institution is publishing a special report which includes all the research and development programs as well as the information concerning alternative building materials and innovative technologies. The aim of the publication is to encourage the mass people to use more environmental and agricultural friendly, sustainable and cost effective building materials in construction. HBRI is always prepared to deliver technical support to the concerned individuals.

I cordially convey my heart warming thanks to our Director, Mohammad Abu Sadeque PEng., for his instructions towards the publication of this report. I affectionately convey my appreciation towards the research fellows of our Institute; Ishtiak Mahmud, Hasan Shahriyer, Hasibul Hasan Shawon and Rubaiyet Haliza for their continuous effort in completing the entire publication process.

Md. Akhter Hossain Sarker
Senior Research Officer
Housing and Building Research Institute

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INTRODUCTION

Housing and Building Research Institute is an autonomous organization under the Ministry of Housing and Public Works with a constitutional framework of 18 members of Governing Council headed by the Hon'ble Minister in charge of the Ministry. It runs by the allocation of Government grants from the revenue fund.

Since its beginning, all the Divisions of the Institute rendered useful contributions in research program in the field of housing problem. Besides that, extension services in the form of consultancy, laboratory testing and planning pertaining to building activity in both public and private sectors were done successfully.

The Institute is the only National Research institute, which is entrusted to conduct research in housing problem, innovations in construction materials, technology and planning. A well-equipped team has also organized to perform the sub-soil investigation and testing of building materials for quality control in construction.

Objectives of the Institute

- To promote technical and scientific studies and research on various problems of building construction and building materials industries and of human settlement as a whole;
- To study the availability, development and utilization of indigenous building materials;
- To promote new and better uses of commonly used building materials;
- To encourage adoption of quality control measures in building construction;
- To initiate actions for the improvement of the technology, method of planning and designing of building construction and maintenance work in the housing sector;
- To develop inexpensive and new materials and technology for building construction through pilot projects;
- To initiate research program and case-studies in the field of housing and building research in co-operation with the National council for Science and Technology and other research institute and universities;
- To evaluate its research activities and to initiate actions for adoption of research results;
- To introduce fellowship and scholarship for the purpose of encouraging research and technical and scientific studies in the field of housing and building constructions;
- To train research personnel and technicians for the purpose of carrying out its research activities;
- To provide consultation and advisory services in the field of housing and building research;
- To disseminate latest knowledge on the problems of housing and building construction;
- To publish regularly research reports, research bulletins, technical reports and other reports on the work done by it; and
- To do such other acts or things as may be necessary or convenient to be done in connection with, or incidental or conductive to, the performance of the aforesaid functions.

Institutional Set up

The institution is no running under the general direction and superintendence of the affairs and business of the Institute are vested into the Governing Council. The Director is the ex-officio member-Secretary of the council and the Chief Executive Officer of the Institute. Over the years the Institute has been able to build up necessary laboratory facilities for test/research works and recruit a good number of qualified engineers/architects/scientist with experience and training in home and abroad. Constant efforts of imparting higher education and training both in local and foreign lands to research personnel are being made and this is the keystone of R&D policies. The Institute has a total of 153 personnel including 33 qualified research personnel. All activities including R&D program are now being executed through the following Divisions and Sections:

Divisions

1) Building Materials Division
2) Structural Engineering and Construction Division
3) Soil Mechanics and Foundation Engineering Division
4) Housing Division

Sections

1) Administrative and Account Section
2) Information and Documentation Section
3) Bureau of Extension Testing and Consultancy (BETC)
4) Training Cell

Building Materials Division

This division is engaged with research and development of producing new or better construction materials from locally available indigenous raw materials, industrial and agricultural wastes with emphasis to augment the supply and use as substitute for commonly used materials. For example, this division is now engaged in development of alternative to burnt clay bricks. Many other research program has also been taken to develop environment friendly and cost-effective building materials such as development of ferrocement sandwich wall panel, development of thermal bricks/blocks, development of Compressed Stabilized Earth Block and Interlocking Blocks etc .

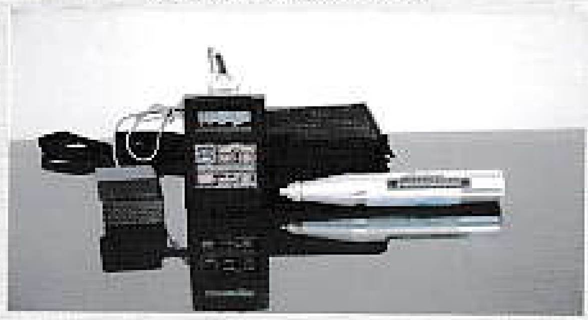
Beside this some dissemination program has been taken for some alternative building materials like 3D panel and Cellular Light-weight Concrete (CLC) developed in Bangladesh. These alternative materials have been used in three projects in HBRI Camus from which one for display center, one for Training center and another one for Multi storied Rural Housing Model.

Evaluation of properties and performance of different building materials and conducting the standard test for quality control of the materials are also included in the scope of activities. There are two laboratories under this division namely a) Physical Testing and Research Laboratory (PTRL) and b) Chemical Testing and Research Laboratory (CTRL). The tests and consultancy services rendered by this Division are

- Determination of physical and mechanical properties of building materials.
- Chemical analysis of building materials
- Suitability test of soil for the production of bricks
- Chemical analysis of water, soil, paints etc.
- Performance test of paints and distemper.

Consultancy service for the manufacture of building materials/elements and on various building problems like efflorescence and corrosion

Chemical Testing Laboratory



Micro Cover Meter

Universal Testing Machine

Structural Engineering and Construction Division

This division is entrusted with research and development of economic/durable structures so as to economize the use of building materials and enhance speed of construction and reduce the cost of that. Considering the socio-economic, environmental and climatic condition of Bangladesh, this division is engaged in finding out the less costly and more durable building component using the indigenous building materials with a view to improve the living condition of the people of urban, rural and disaster prone areas. Simultaneously to ensure the quality of construction works this division has been playing the role with introducing prefabrication construction technique besides cast-in-situ system. Moreover, this division is engaged in dissemination of research findings through Extension and Dissemination wing attached with it. The test and Consultancy services rendered by this division are

- Perform load tests.
- Structural design and building construction guidance.
- Consultancy service for the construction low cost buildings

Soil Mechanics and Foundation Engineering Division

This division is engaged with evaluation of properties of soils in the fields as well as in the laboratory and economic foundation design for structures. The tests and consultancy services rendered by this division are,

A view of Soil Mechanics and Foundation Engineering Laboratory

- Physical properties of soil
- Unconfined compression test
- Compaction test
- Consolidation test
- Tri-axial shear test
- Standard penetration test (SPT)
- Collection of undisturbed sample by boring (up to 150 ft.)
- Consultancy services for the sub-soil investigation

Drilling Rig Machine

Housing Division

To study the best possible use of land, space (both covered and open), housing environment and planning, functional design of building, rationalization of Architectural concept are the key words of this division appropriate methods for design and construction techniques and materials for the rural and urban housing of the country is also another major field of research. The consultancy services rendered by this division are:-

- Architechtural design for all types of buildings
- Layout plan for small community/complex with proper use of land and space
- Consultancy service for the construction of low cost houses

Information and Documentation Section

This section is entrusted to support the various research works of this institute through providing right information at right time. There is Library within Information and Documentation Section which is functioning as the knowledge bank and plays a vital role to achieve the aims and objects of the institute. It contains a wide collection of books, research papers, periodicals, microfilms, microfiches, technical reports, notes etc. The Information and Documentation Section always provides with necessary information regarding, building construction architecture, construction, management, Ferro cement technology, housing science, environmental engineering and planning etc. to the professional staff, researchers, engineers, architects, technical personnel, personnel, scientists, teachers and students of this institute and different organization.

It responds to quarries received time to time from the public, students, researchers and scholars who write to or visit this section. This section also subscribes to International Journal for Housing Science and Applications, Open House International, TBA Architectural International Journal, ACI journal etc. It has received remarkable reprints, reports, booklets, bulletins etc. from different research organizations from home and abroad. The present position of Library stock is: books 5246 numbers as well as journals and others publications 11732 numbers. These publications are most useful and unique and play in important role in ensuring effectiveness of the concerned researches.

Administration Section

The Administration Section assists the Director and other senior officials of the Institute in running the day-to-day administrative business of the office and is responsible for implementing the administrative decisions of the government as well as that of the authority. The section also assists in implementing the decisions and the directives of the Governing Council of the Institute for submission of all types of official files and papers. The administration section manages and preserves all official records.

Accounts Section

The Account Section is responsible for maintaining the financial accounts of the Institute, operating the bank accounts, Contributory Provident Fund (CPF) as well as other accounts of the Institute as required from time to time. Through consultation with the Director, this section prepares the annual budget to the Institute and co-operates with the external auditors during audit and pursues the queries and other financial matters.

Bureau of Extension Testing and Consultancy (BETC): In order to promote and popularize the various building materials and techniques achieved through research and to channelize these innovations gradually in the construction methodology of the country, the Wing is responsible to make,

- Close liaison with building industries/local bodies/private builders for inclusion of these techniques/materials in their construction
- Demonstration of new techniques/materials in construction and their feedback. Dissemination of information publicity through radio, television, newspaper & publication of booklets, folders, manuals etc.

Training Cell

As one of the way of dissemination of the research output, the Institute offers training courses as scheduled in its annual program. The courses/seminar/workshops are organized by the Training Cell of the institute for different level of participants.

Currently the Institute offers the following training programs:

a) Professionals Training Program for Graduate Engineers and Architects

b) Training program for different NGOs to introduce Alternative Building developed by the Institute

c) Industrial attachment program for different Technical Universities and/or Institutes

d) Training program for professional on Disaster Resilient Housing

e) Practical learning using laboratories of the Institute for students of public and private universities

f) Training for House Builders named "Nijer Bari Nijei Kori"

Instruction from Honorable Prime Minister to HBRI

The honourable Prime Minister visited the Ministry of Housing and Public Works. During her visit, she introduced a set of thirty (30) rulings. Among the rulings introduced by the honourable Prime Minister, #24, #25 & #26 are related to Housing and Building research Institute (HBRI). The rulings are as follow:

- Effort must be taken to widely publicize the Building materials invented by Housing and Building Research Institute under the Ministry. Appropriate planning should be undertaken to apply and utilize the research findings effectively.
- Using of ferrocement at shelter projects and projects of rural housing should be started.
- The feasibility of making blocks with sands obtainable through river dredging has to be explored and experimented. Initiative should be taken to make eco-friendly bricks by using the acquired mud at the same time. Coordinated steps should be taken jointly by the Ministry of Inland Water Transportation and the Ministry of Water Resources to achieve the objective.

Steps taken in implementing the instruction:

- Various campaigns have been undertaken to widely publicize the invented building materials by the Institute.
- Outlining a plan for utilizing the fruits of research works effectively is underway.
- Technical assistance has been provided to build 20 huts under "Asrayan – 2" project.
- The following alternative building materials have been invented by making use of dredging soil:

Compressed Stabilized Earth Block (CSEB)

The Compressed Stabilized Earth Block (CSEB) is made by compressing a mixture of 10% cement with dredging soil.

Advantages:

1. By sparing agricultural land, it reduces the risk in food security.
2. Cost effective.
3. Stopping use of forest resources.
4. Reducing the emission of carbon.
5. Making use of dredging soil thereby keeping the rivers and canals flowing.
6. Being eco-friendly.
7. Creating employment in remote areas of the country.

Compressed Stabilized Earth Block (with jute fiber)

CSEB is manufactured by compressing a proportionally mixed amount of dredging soil, cement and sand in a machine. Despite having several advantages, this kind of block gets damaged or broken at the edges during transportation or for other reasons, thus losing its utility to construct wall without plaster. In order to overcome this shortcoming, some jute fiber is used in the mixture. As a result, the sharp corners of the blocks are prevented from unwanted decay; moreover, this kind of CSEB is resistant to destructive test as they hold on together, these blocks seem to be useful in constructing earthquake resilient buildings.

Advantages

1. Strengthening the brick by using jute fiber.
2. Transform the brick into more portable.

Interlocking Block

This block is useable to lay the foundation of a weight bearing wall without the help of any mortar. A wall constructed with interlocking block may be designed as a frame structure if metal rods are inserted in wholes at proportionate distances and mortar casting is applied on them so that they create beams at consecutive distances.

Advantages

1. Savings in construction material.
2. Construction without making use of mortar.
3. Saves time in the construction process.
4. Low cost construction.

Concrete Hollow Block

Concrete Hollow Block may be used for the construction of both weight bearable and non-weight bearable walls. As these large concrete blocks require less than usual number of attachments, the use of mortar will be significantly less. Hollow Block works good as a buffer zone and is resistant to noise, heat and humidity as well. This block is built with a mixture of 20% cement and 80% sand.

Advantages

1. Reducing wastage of agricultural land and forest resources.
2. No fuel is needed.
3. Does not negatively affect the environment.
4. Can be produced throughout the year.
5. Higher absorption capability.
6. More effective in controlling heat and fire.
7. Better balance between the structure and its durability.

Ferro cement Sandwich panel

Ferro cement sandwich panel is built by applying Ferro cement technology (wire mesh and mortar) on both sides of a polystyrene sheet. This panel can be applied on the walls and roofs of buildings. The greatest advantage of sandwich Panels is that with these panels it is possible to construct a pre-fabricated house in a very short period of time.

Advantages

1. More proportionate.
2. Resilient to noise and heat.
3. Weight bearing capabilily.
4. Facilitates quick construction of pre-fabricated houses.

Role of HBRI in 7th five year plan of Bangladesh

- Housing and Building Research Institute will focus on bringing innovation including alternatives to traditional bricks with a target of achieving zero use of agricultural top soil for brick production, and standardization of construction materials through research.
- Special emphasis will be given for extension services to disseminate newly developed technologies and building materials which will be agriculture and environment friendly, disaster resilient and affordable.
- It will also continue updating the Bangladesh National Building Code (BNBC) on a pilot basis, steps will be taken for construction of 75 low cost multistoried residential buildings at different villages during the 7th five years Plan period.

Cement Stabilized Earth Block (CSEB) Using Dredged Soil

ABSTRACT

This paper represents an experimental study on Cement Stabilized Earth Block made of dredged soil and stabilized by Ordinary Portland Cement (OPC). The dredged soil was collected from various point of Bangladesh namely, Kapotakkho river, Brahmmaputra river and Housing and Building Research Institute (HBRI) Campus.

The complete project was divided into two broad phase. In first phase, the optimum percentage of stabilizer (cement) was found out. After testing these blocks by water jet, submersion, modulus of rupture, and compression, the 10% cement mix with dredged soil proved to be viable options for economical and durable blocks.

In second phase, CSEB was made with adding sand (Brahmmaputra soil) and Jute fiber as reinforcement. Stabilizer (cement) was kept constant for each type of block as 10%. Different type of curing like air curing, sun curing and polythene wrapping curing were incorporated and tested for three days, seven days, fourteen days, and twenty eight days. The observations on different composition and curing condition and change in strength with maturity age sowed that each composition has its own superiority to others on particular area. For example, CSEB made of HBRI soil and cured at natural air can bear more compressive load where Kapotakkho-Brahmmaputra soil cured at sun is less susceptible to moisture absorption.

1. INTRODUCTION

1.1. Background

The use of earth, as building material dates back thousands of years. Dried earth construction is common in some region of world where the specific climate and economic condition dictate and where the earth construction is aesthetically accepted to all. Raw earth has been used for the construction of buildings since the most ancient times, and the traditional housing that exists in many parts of our planet bears witness to this fact. Abandoned and forgotten with the advent of industrial building materials, particularly concrete and steel, it is today the subject of renewed interest in developing countries as well as in industrialized countries. Often criticized for its sensitivity to water and its lack of durability, this building material has in its present form many advantages for the construction of durable, comfortable and low-cost housing. The present form is termed as Stabilized Compressed Earth Block (SCEB). If logic and modern methods are applied to its use, it can be all of the following:

- Efficient and durable;
- Available locally and cheaply;
- Economical in energy and in foreign currency for developing countries;
- An encouragement for the development of building trade skills;
- Job creating;
- Capital gains generating;
- A dynamic for the building sector;
- Ideal for small and medium scale industries.

Earthen building construction materials production techniques varies from very primary to modern sophisticated mechanized and industrial process. The idea of compacting earth to improve the quality and performance of molded earth blocks is, however, far from new and it was with wooden tamps that the first compressed earth blocks were produced. The turning point in the use of presses and in the way in which compressed earth blocks were used for building and architectural purposes came only with effect from 1952, following the invention of the famous little CINVA-RAM press. This was to be used throughout the world.

1.2. Advantages and Disadvantages of CSEB

The main advantages of using CSEB as walling materials in residential buildings are summarized below

- Soil is available in large quantities in most regions.
- Cheap and affordable - in most parts of the world, soil is easily accessible to low-income groups. In some locations, it is the only material available.
- Ease of use - usually no very specialized equipment is required.
- Suitable as a construction material for most parts of the building.
- Fire resistant - non-combustible with excellent fire resistance properties.
- Beneficial climatic performance in most regions due to its high thermal capacity, low thermal conductivity and porosity, thus it can moderate extreme outdoor temperatures and maintain a satisfactory internal temperature balance.
- Low energy input in processing and handling soil - only about 1% of the energy required manufacturing and processing the same volume of cement concrete. This aspect was investigated by the Desert Architecture Unit which has discovered that the energy needed to manufacture and process one cubic meter of soil is about 36 MJ (10 kwh), while that required for the manufacture of the same volume of concrete is about 3000 MJ (833 kwh). Similar findings were also reported by Habitat (UNCHS), Technical Note No. 12 comparing adobe with fired clay bricks.
- Environmental appropriateness - the use of this almost unlimited resource in its natural state involves no pollution and negligible energy consumption, thus further benefiting the environment by saving biomass fuel.

The main disadvantages of using CSEB as walling materials in residential buildings are summarized below

- Reduced durability - if not regularly maintained and properly protected, particularly in areas affected by medium to high rainfall.
- Low tensile strength – poor resistance to bending moments, to be used only in compression e.g. bearing walls, domes and vaults.
- Low resistance to abrasion and impact - if not sufficiently reinforced or protected.
- Low acceptability amongst most social groups - considered by many to be a second class and generally inferior building material.
- On account of these problems - earth as a building material lacks institutional acceptability in most countries as a result, building codes and performance standards have not been fully developed.

2. TEST PROGRAM

The complete project was divided into two broad phase. In the first phase, the optimum percentage of stabilizer (cement) was found out. The test procedure and observed result was discussed in previous report on CSEB. Testing blocks with different percentage, it was observed that 10% cement by weight is viable in Bangladesh in all respect. In the second phase, CSEB was made with adding sand (Brahmmaputra soil) and Jute fiber as reinforcement. Stabilizer (cement) was kept constant for each type of block as 10%. Different type of curing like air curing, sun curing and polythene wrapping curing were incorporated and tested for three days, seven days, fourteen days, and twenty eight days. The observations on different composition and curing condition and change in strength with maturity age are the matter of discussion of this report.

2.1. Preparation of Test Specimen:

2.1.1. The Requirements for Preparation

The basic materials required for the production of compressed stabilized earth building blocks are soil, stabilizer, and water. The stabilizer, whether lime or cement or some other material, is usually available in powder or liquid form, ready for use. The soil may be wet or dry when it is first obtained, and will probably not be homogeneous. In order to have uniform soil, it is often necessary to crush it so that it can pass through a 5 to 6mm mesh sieve.

Different soil types may also need to be used together so as to obtain good quality products. For instance, heavy clay may be improved by addition of a sandy soil. It is not only important to measure the optimum proportion of ingredients, but also to mix them thoroughly. Mixing brings the stabilizer and soil into direct contact, thus improving the physical interactions as well as the chemical reaction and cementing action. It also reduces the risk of uneven production of low quality blocks. Various types and sizes of mixing equipment are available in the market.

2.1.1.1. Weathering

Mostly, the dredged soil is wet and contains high amount of moisture. Breaking into powder and pulverizing the wet soil requires complex machineries. To avoid complex machineries, collected dredged soil was kept under a shade for 15 to 25 days. In this period the soil was weathered and dried to ease the breaking operation.

2.1.1.2. Grinding followed by screening

The material is pressed between two surfaces - a rather inefficient and tedious process in which bigger stones are broken up, however, only simple machinery is required. The broken up lumps of soil are then passed through a screen.

2.1.1.3. Pulverization of soil

The material is hit with great force so it disintegrates. The machinery required is complex but we used manual labor with wooden mallet.

2.1.1.4. Sieving

Soil contains various sizes of grain, from very fine dust up to pieces that are still too large for use in block production. The oversized material should be removed by sieving, either using a built-in sieve, as with the pendulum crusher, or as a separate operation.

The simplest sieving device is a screen made from a wire mesh, nailed to a supporting wooden frame and inclined at approximately 45° to the ground. The material is thrown against the screen, fine material passes through and the coarse, oversized material runs down the front. Alternatively, the screen can be suspended horizontally from a tree or over a pit. The latter method is only suitable in the case where most material can pass through easily otherwise too much coarse material is collected, and the screen becomes blocked and needs frequent emptying.

2.1.1.5. Proportioning

Before starting production, tests should be performed to establish the right proportion of soil, stabilizer and water for the production of good quality blocks. The proportions of these materials and water should then be used throughout the production process. To ensure uniformity in the compressed stabilized earth blocks produced, the weight or volume of each material used in the block making process should be measured at the same physical state for subsequent batches of blocks. The volume of soil or stabilizer should ideally be measured in dry or slightly damp conditions.

Being confirmed from previous phase of the research, we used 10% cement as stabilizer and potable water to form a consistent mix.

2.1.1.6. Mixing

In order to produce good quality blocks, it is very important that mixing be as thorough as possible. Dry materials should be mixed first until they are a uniform color, then water is added and mixing continued until a homogeneous mix is obtained. Mixing can be performed by hand on a hard surface, with spades, hoes, or shovels.

It is much better to add a little water at a time, sprinkled over the top of the mix from a watering can with a rose spray on the nozzle. The wet mix should be turned over many times with a spade or other suitable tool. A little more water may then be added, and the whole mixture turned over again. This process should be repeated until all the water has been mixed in.

A concrete mixer, even if available, will not be useful for mixing the wet soil, since the latter will tend to stick on the sides of the rotating drum. If machinery is to be used for mixing, it should have paddles or blades that move separately from the container. However, field experience shows that hand-mixing methods are often more satisfactory, more efficient and cheaper than mechanical mixing, and are less likely to produce small balls of soil that are troublesome at the block molding stage.

2.1.2. Block Production

Many aspects should be taken into consideration before launching an operation to produce compressed stabilized earth building blocks:

- Amount and type of stabilizer required,
- Soil properties and its suitability for stabilization,
- Building standards and hence quality of blocks required,
- Load bearing requirements of construction i.e. single storey or more.

Generally, there is a wide variation of acceptable standards that vary according to local weather conditions. Blocks with wet compressive strengths in the range or 2.8MN/m2 or more should be adequate for one and two-story buildings. Blocks of this type would probably not require external surface protection against adverse weather conditions. For one-storey buildings,

Dredged Soil

Breaking of dredged soil into pieces

Screening of broken soil

Screened Sample

Weiging of Cement and Soil

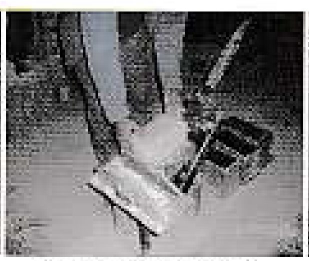
Mixing of Soil Cement with Water

Mechanical Mold

Mixed Soil Filling in Mold

Mechanical Compaction after hand Compaction

Demolding by Reverse pressing



Removing the brick from Mold

Curing in open air and Shed

Water Spray Curing

blocks with a compressive strength in the order of 2.0 MN/m2 will probably be strong enough, but where rainfall is high, an external treatment is necessary. Since the wet strength of a compressed stabilized earth block wall may be less than two-thirds of its dry strength. It should be remembered that all compressive strength tests should be carried out on samples which have been soaked in water for a minimum of 24 hours after the necessary curing period.

The final wet compressive strength of a compressed earth block depends not only on soil type, but also on the type and amount of stabilizer, the molding pressure, and the curing conditions.

The soil preparation and pressing operation can be best described by the pictures below.

2.2. Curing

To achieve maximum strength, compressed stabilized earth blocks need a period of damp curing, where they are kept moist. This is a common requirement for all cementitious materials. What is important is that the moisture of the soil mix is retained within the body of the block for a few days. If the block is left exposed to hot dry weather conditions, the surface material will lose its moisture and the clay particles will tend to shrink. This will cause surface cracks on the block faces.

In practice, various methods are used to ensure proper curing. Such methods include the use of plastic bags, grass, leaves, etc. to prevent moisture from escaping. After two or three days, depending on the local temperatures, cement stabilized blocks complete their primary cure. They can then be removed from their protective cover and stacked in a pile, as shown in Figure. As the stack of blocks is built up, the top layer should always be wetted and covered, and the lower layer should be allowed to air-dry to achieve maximum strength. Alternatively, freshly molded blocks can be laid out in a single layer, on a non-absorbent surface, and covered with a sheet to prevent loss of moisture.

The required duration of curing varies from soil to soil and, more significantly, which type of stabilizer is used. With cement stabilization, it is recommended to cure blocks for a minimum of three weeks. Compressed stabilized earth blocks should be fully cured and dry before being used for construction.

The sample was demolded immediately after casting and it was then transferred to curing place. Three different curing conditions (Air curing in shade with water spray, Sun curing, and Polythene wrapping curing) were established. Density, unit weight, and water content of the mixture and freshly casted brick was measured and noted.

Casted bricks were marked date wise to conduct different tests after different curing age and curing condition.

2.3. Tests on CSEB

In this phase of research, mainly compressive strength test for individual block was performed for different composition and curing condition. Dry and wet compressive strength was measured for each set of blocks as per BS 3921: 1985, IS: 3495- Part-1-1992 and ARS-683:1996. Finally, masonry test was done with minimum three layers of blocks as per ASTM C 1388 and CRD C 463-01.

The result of dry and wet compressive strength tests are summarized and analyzed in the following sections.

3. TEST RESULT ANALYSIS AND DISCUSSION

3.1. Compressive Strength Test:

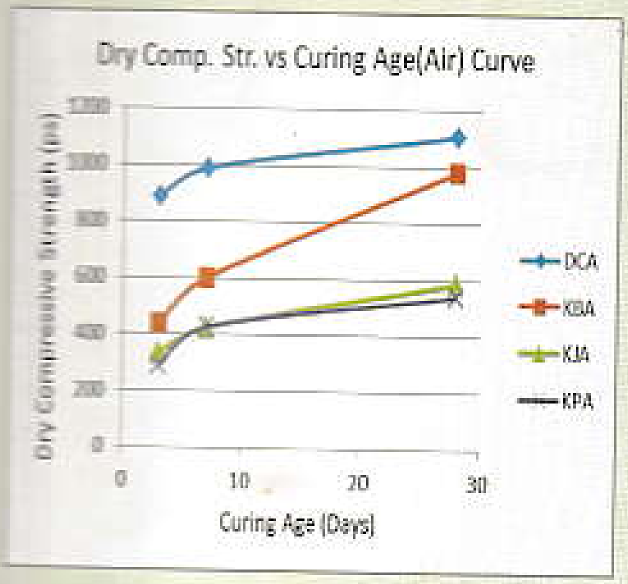
5 pcs of 3 days, 7 days and 28 days cured bricks were selected randomly from the lot and compressive strength test was performed as per NEW MEXICO EARTHEN BUILDING MATERIALS CODE 2003. Result of compressive strength test was shown in Table below.

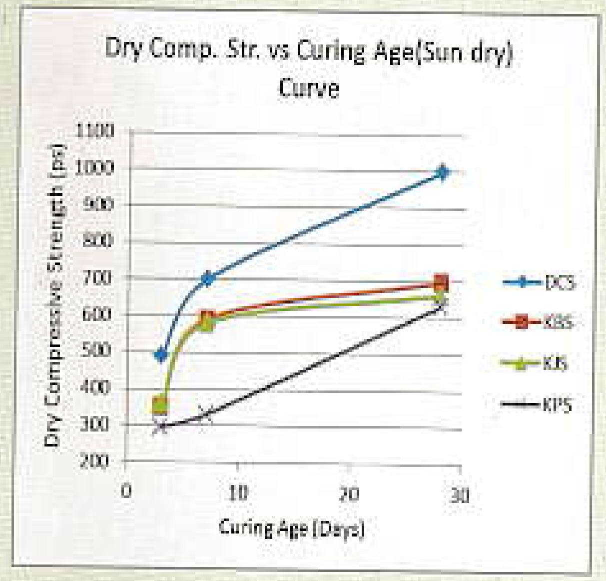
Compressive Strength Test Result

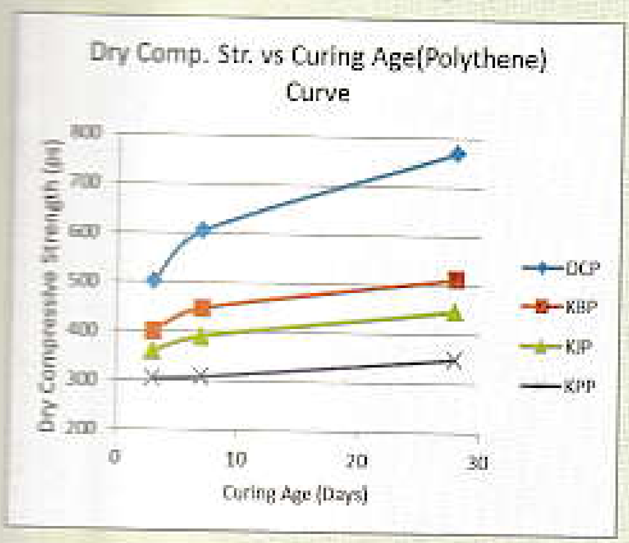
Dry compressive Strength Test Result (psi)					Wet Compressive Strength Test Result (psi)				
Sample	Curing Condition	Curing Age (Days)			Sample	Curing Condition	Curing Age (Days)		
		3	7	28			3	7	28
KP	*A	288	427	540	KP	A	187	213	229
KB	A	435	489	1100	KB	A	293	240	675
KJ	A	332	424	585	KJ	A	250	275	340
DC	A	890	990	1107	DC	A	362	391	433
KP	*S	294	330	632	KP	S	204	220	307
KB	S	350	538	557	KB	S	374	422	622
KJ	S	360	580	402	KJ	S	280	300	355
DC	S	490	1095	1062	DC	S	431	441	566
KP	*P	304	308	350	KP	P	200	216	300
KB	P	400	447	512	KB	P	353	464	590
KJ	P	360	332	447	KJ	P	242	307	380
DC	P	501	605	769	DC	P	300	354	433

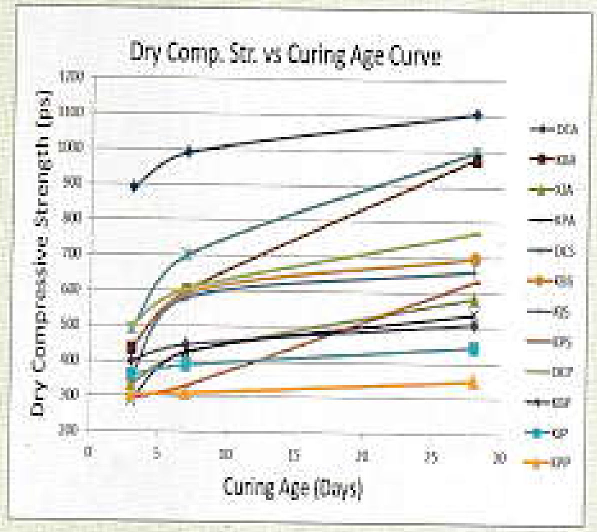
*A= Air Curing (Open air under shade), S=Sun Curing (Under direct sunlight), P= Polythene Curing (Wrapping by polythene paper)

For Dry Compressive Strength:

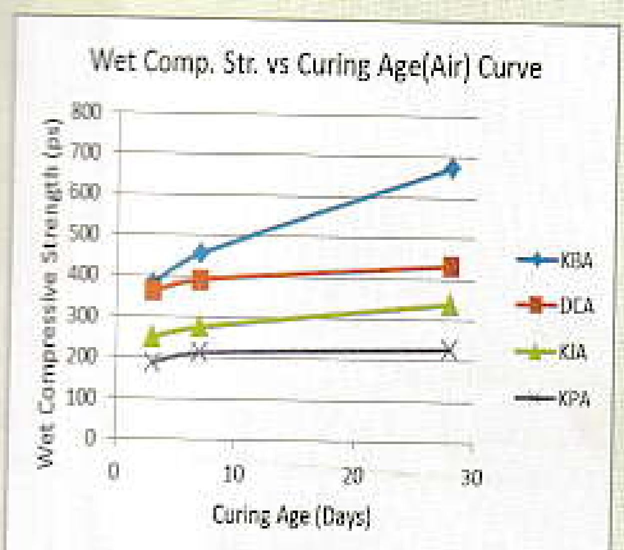


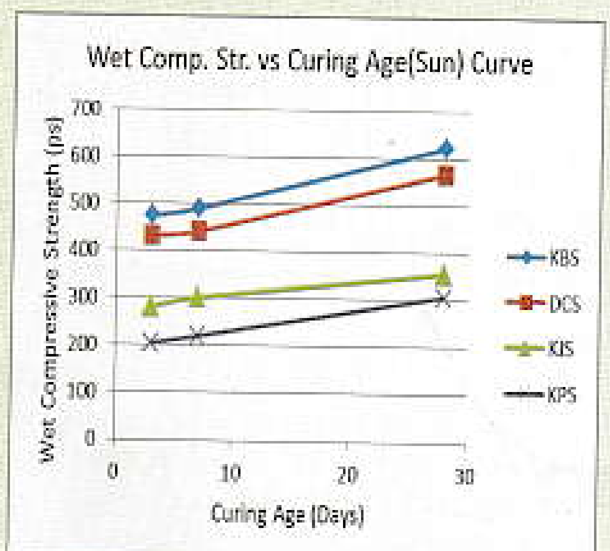


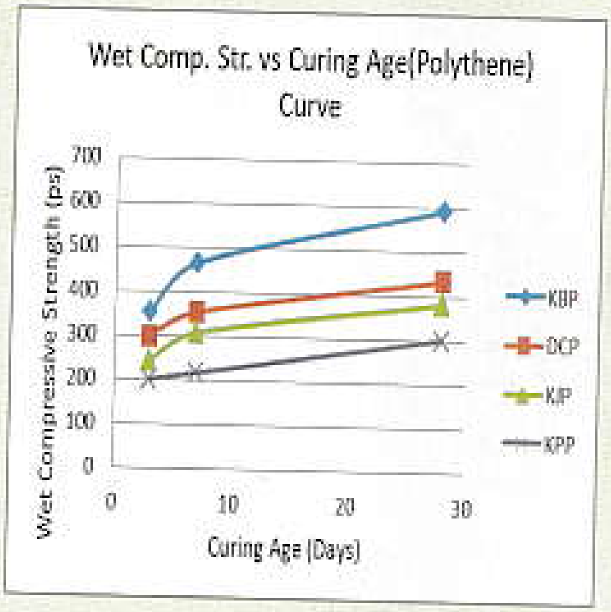


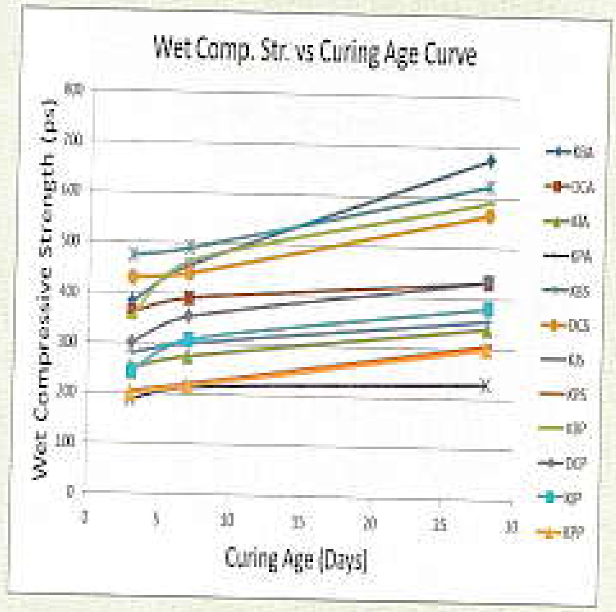


For Wet Compressive Strength:









3.1.1. Analysis of compressive strength test result:

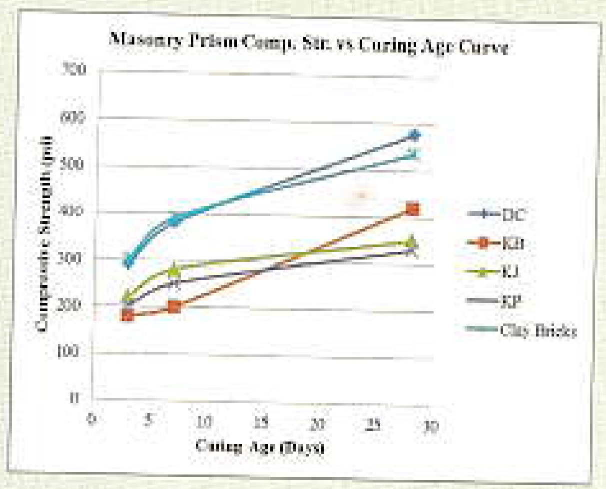
From the table and the figure we can see that compressive strength increases with increasing curing age. It was observed that dry compressive strength of CSEB made from HBRI Campus soil (DC) is superior to any other composition. This was obvious because this soil contains high amount of clay. On the other hand, the composition KB (Kapotakkho+Brahmmaputra) performs well in case of wet compressive strength. It is because of the sand content in the soil of Brahmmaputra. Also from figure it was observed that for 3 and 7 days sun curing shows good result but finally at 28 days air curing provide better result both for dry and wet compressive strength tests. Hopefully all composition of soil give satisfactory result comparing the codes and standard both for dry and wet compressive strength.

3.2. Masonry Test:

This test was performed in order to determine the ultimate compressive strength (f'm) of masonry wall. The test was conducted as per ASTM C1338-98: Standard Test Method for Compressive Strength of Laboratory Constructed Masonry Prisms. For each sample three units of blocks were casted by standard mortar (1:5). A total of 15 pieces of samples for each type of block were constructed and the samples were cured and tested for 3, 7, and 28 days. As previously air curing provided good result, so in this case only air cured blocks were tested. The average of 5 specimens for each days test was incorporated in the result book. The test result is given in the following table.

Compressive Strength of Masonry Prism

Sample	Curing Condition	Curing Age (Days)		
		3	7	28
		Compressive Strength(psi)		
KP	A	200	221	380
KB	A	180	200	420
KJ	A	210	280	350
DC	A	290	380	576



3.2.1. Analysis of Masonry Test Result:

From the table and graph we see that 28 days compressive strength of masonry prism is higher for clay bricks and HBRI campus soil. However, no prism fall behind the acceptable limit (300psi) suggested by codes and standards.

6. *Socio-Economic Considerations*

6.1. *Acceptance and Applications*

In many developing countries building standards which often rule out applications of soil as an acceptable building material, have been formulated. Earth is mostly used for buildings that are built without formal authorization, such as rural housing or squatter settlements around urban centres. Although there are some signs of change whereby compressed stabilized earth may be permitted for construction, it will first be necessary in many countries to convince the authorities of the potential of this material, especially when compared to unsterilized methods of soil construction. In practice, it is advisable to build some community buildings first so that the local people can see for themselves the quality and durability of the material, and experience, first hand, the quality of construction which this method of construction can offer. It is worth noting that a number of developed countries are reviving the use of compressed stabilized earth blocks and other forms of earth construction. For example, an international centre for the study and promotion of soil-based construction has been established in France.

6.2. *Creation of Employment Opportunities*

The production of cement stabilized earth blocks can create supreme opportunities. As the procedure requires less skill to conduct, any labor with low skill can be employed to complete the production. Developing countries like Bangladesh can create job opportunities to the increased population and provide them proper economic support by creating factories to produce such blocks. On the other hand, experience has shown that, in general, the small scale production of compressed stabilized earth blocks is much more labor intensive than that of other similar building materials such as fired clay bricks or concrete blocks.

7. *Application by HBRI*

As a part of its research and development, HBRI applied CSEB blocks in the guard room in front of the main office building. It is situated beside the main entrance. This guard room was erected as a part of the research to study the durability and structural behavior of the blocks in the environment. Two years after construction no visible cracks or other damages have been found.

CONCLUSION

Based on the review of both experimental and filed investigation on clay bricks and stabilized compressed earth blocks, the following concluding remarks can be drawn:

(i). Clay Bricks are the most frequently used constructions material through out the world; many researchers are presently looking for newer options because they need low cost materials, which are also environmentally friendly. The process of manufacturing clay bricks also requires high energy to burn due to the emission of CO_2 gas from this process.

(ii). Stabilized compressed earth blocks include; uniformed building component sizes, they are frequently use of locally available materials and required to a lesser degree of transportation. Uniformly sized building components can result in less waste, faster construction and the possibility of using other pre-made components or modular manufactured building elements. Such modular elements as sheet metal roofing which can be easily integrated into a CEB structure.

(iii). The use of natural, locally-available materials make good sustainable housing available to more people, and keeps money in the local economy rather than spending it on imported materials, fuel and replacement parts.

(iv). The earth used is generally subsoil, leaving topsoil for agriculture. Building with local materials can provide employment for local people and is definitely considered more sustainable in times of civil economic difficulties.

(v). People can often continue to build good shelters for themselves regardless of the political situation of the country.

(vi.) The reduction of transportation time, cost and attendant pollution can also make CEB more environmentally friendly than other materials.

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REFERENCES

Adam EA (2001). Compressed Stabilized earth Block Manufacturing in Sudan. United Nations Educational Scientific and Cultural Organization. Technical Note No12 comparing adobe with fired clay bricks.

Aksa Z (1984). A lime-stabilized soil building materials. Institue of Human Settlement. Bandong, Indonesia.

American Society for Testing Materials (ASTM) (1990). Standard Specification for Hollow Brick, (Hollow Masonry Units Made from Clay or Shale) United States of America, ASTM C652- 89a.

Amjad J (2000). Investigation of phases in soils used for brick –Making. M.Phil Thesis, Center of Excellence in Solid State Physics, University of Punjab pp. 1-6.

Anderson LA, Johansson BJ, Asteland J (1982). Cement–stabilized Torba. Swedish council for building Research and Swedish. Agency for research Cooperation with Developing Countries. Lund University. Lund Sweden. pp. 78 -79.

AS, 1225 (1984). Clay Buildings Bricks. Australia Standard. British Standards Institution (1985). British Standard Specification for clay Brick. London, BS, p. 3921.

Carmen MJD, Ignacio CG (2006). Earth building in Spain. Construction and building Materials, Elsever pp. 679-690. CDE Guides (1998). „Technologies Series? No. 11, Compressed Earth Blocks – Standards, p. 47.

Conville CJ, Lee EW (2005). Micro-structural development on firing illite and smectite clays compared with that in Kaolinite. J. Am. Ceram. Soc., 88: 2267-2277.

Egbert P (1993). Status and development issues of the brick industry in Asia. The regional wood-energy development programme (RWEDP) in Asia, p. 30-34.

Fullerton RL (1979). Building Construction in Warm Climates. Vol 1,2 and 3. Oxford Tropical Handbooks. Oxford University Press. Oxford , England.

Grimm CT (1996). Clay Brick Masonry Weight Variation. J. Architectural Eng., 2(4): 135-137. Healthcote KA

(1991).Compressive Strength of Cement Stabilized Compressed Earth Blocks, Building Res. Inf., 19(2): 101-105.

Hendry AW (1990). Structural Design of Masonry Buildings. ISBN 0333497481.

Higgins D (2007). GGBS and sustainability. Proceed. ICE, Construction Mater., 160(3): 99-101.

Houben H, Guillaud H (1994). Earth Construction: A Comprehensive Guide. CRATeer-EAG. Intermediate Technology Publications. London, England.

Hughes R (1983). Materials and behaviour of soil constructed walls. In Technique and Materials. London England.

International labour organisation (1987). Small-Scale Manufacture of Stabilised Soil Blocks, p. 204.

Jayasinghe C, Kamaladasa N (2007). Compressive strength characteristics of cement stabilized rammed earth walls. Construction Building Mater Elsevier Khalaf FM, De Venny AS (2002). New Tests for Porosity and Water Absorption of Fired Clay Bricks. J. Mater. Civil Eng. Lee S, Kim YJ, Moon HS (1999). Phase transformation sequence from kaolinite to mullite investigated by energy-filtering transmission electron microscope. J. Am. Ceram. Soc., 82: 2841-2848.

Lenczer D (1972). "Elements of Load-bearing Brickwork". Oxford, New York, Toronto, Sydney, Braunschweig.: Pergamon Press.

Oti JE, Kinuthia JM, BAI J (2008a). Using Slag for Unfinred-clay Masonry Bricks, Proceedings of ICE, J. Construction Mater. DOI: 10. 1680/coma.2008.. 161.4.147. 161(CM4): 147-155.

Perera AADAJ, Jayasinghe C (2003). Strength characteristic and structural design methods for construction earth walls. Masonry Int., 16(1): 34-38.

Peters T, Iberg R (1978). Mineral changes during firing of calcium –rich brick clays. Ceram. Bull., 57(5): 503-509.

Reddy BV, Jagadish JS (1989). Properties of soil – blocks masonry. Masonry Int BR Masonry Soc., 3(2): 80-84.

Sahlin S (1971). Structural Masonry. Practice – Hall. Englewood cliffs. NJ.

Schumacher EF (1973). Small is Beautiful: A study of Economics as if People Matterd. Blond and Briggs Ltd. London, England.

Singapore Institute of Standard and Industrial Research (1974). "Specification for Burnt Clay and Shale bricks." (Singapore Standard, 103: 1974).

Construction process of Ferrocement sandwich panel Wall: Instigating an orderly approach in Bangladesh

Abstract

This paper reviews the construction process of Ferro cement sandwich panels as non-load bearing units of buildings. The cast-in-situ construction process, on a small scale pilot project including materials and the steps of workmanship, will be explored in this paper. The sandwich panels consisted of two thin Ferro cement layers reinforced with woven wire mesh. The core was 56 mm thick and made of lightweight expanded polystyrene sheets. Steel wires were used to tie the two layers of iron meshes together. A total of 100sft sandwich panel was constructed. The proposed panels were lighter in weight relative to the conventional brick walls. This kind of lightweight construction process would elevate the construction industries for having a green and earthquake resilient environment.

Keywords: Ferro cement, Sandwich Panels, Wall Panels.

1 Introduction

The customary building construction trend in Bangladesh usually focuses on the use of burnt clay bricks for the infill or, to certain extent, as load bearing walls which are heavy in weight. In the long run they prove themselves to be uneconomic. It has become a matter of emphasis to use more lightweight materials in any construction, to make the process more cost effective by reducing the load of the structure. On the other hand, using burnt brick as the main component of construction has severe damaging impact on the environment. Production of burnt bricks has negative effects such as cutting of trees for burning fuel, and degradation of soil near rivers where the brick fields are located. Emission of huge quantity of toxic elements from brick kilns are causing serious health hazards. There are about 45000 of brick kilns in Bangladesh that have been found to be producing 79% of CO_2 in the last 10 years. It is also found that among the 692 acres of agricultural lands that are diminishing, 17.5% is due to the brick fields.

This particular paper concentrates on the construction technique of Ferro cement sandwich panel, which is an improvised adaptation of Ferro cement, emerged as an alternative to burnt bricks. Ferro cement is a type of thin walled reinforced concrete; commonly consists of cement mortar reinforced with closely spaced layers of continuous and relatively small wire mesh. The closely-spaced and uniformly-distributed reinforcement in Ferro cement, transforms the otherwise brittle material into a superior ductile composite. Thus, Ferro cement has been regarded as highly versatile construction material possessing unique properties of strength and service ability. Its advantageous properties such as strength, toughness, water tightness, lightness, durability, fire resistance, and environmental stability cannot be matched by any other thin construction material. Ferro cement is the promising composite material for prefabrication and industrialization of the building industry.

On the other hand, development and construction of lightweight pre-fabricated sandwich elements is a popular trend now a day in construction industry all over the world. It contributes to a cleaner environment at a project site and a lower total construction time and cost. The post occupancy period involves less energy consumption due to its heat insulating quality. It also has distinct advantages over conventional structural sections because it promises high stiffness and high strength to weight ratios. The introduction of new materials such as laminated composites; Ferro cement, for the face sheets and low density materials open- and closed-cell-structured foams like polyvinylchloride, polyurethane, polyethylene or polystyrene foams, balsa wood, syntactic foams, and honeycombs are commonly used as core materials. Open- and closed-cell metal foam can also be used as core materials, for the core presents new possibilities in the design of sandwich construction. Additionally, the properties of the core material within the composite panels have specific impacts on insulation performance, damp and moisture resistance as well as body strength.

In the context of Bangladesh, a demand has been felt for establishing lightweight, cost effective and sustainable construction materials to meet the ever increasing demand of housing. Housing and Building Research Institute (HBRI), which is the only Government research institute to research on housing in Bangladesh, has conducted many researches for the development of Ferro cement as building material and technology. It popularized Ferro cement folded plates, channels as roofing materials and also did a huge number of productions on Ferro cement water tanks. Various studies are undertaken with the aim to develop alternative cost effective building materials among which the application of both Ferro cement Sandwich panel and Ferro cement in non-load bearing walls is made on one of the staff quarters of HBRI. The construction procedure of Ferro cement sandwich panel is emphasized and depicted in the writing that incorporates two layers of Ferro cement as the face sheet and expanded polystyrene (EPS) as the core. The sandwich panel is assumed to be a more developed stage of Ferro cement construction technique as incorporation of polystyrene will improves the insulation property of the material against heat and sound. The increase in thickness of the wall further helps to install door window frames effectively in construction. In the context of Bangladesh, this is the very first effort to accomplish and systematically document a construction technique, associating Ferro cement sandwich panels as infill wall material.

2. Significance of the Study

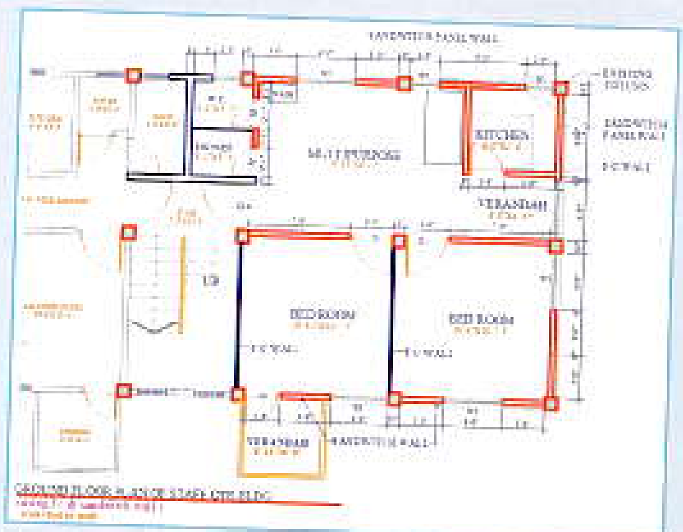
The development of lightweight, industrialized and sustainable construction techniques in Bangladesh is a need of the day. The prevailing construction trend involves Reinforced Cement Concrete and burnt brick as infill walls which are heavy in weight. Ferro cement structural elements are known as lightweight, high performance composite material which can replace the conventional heavy materials. This research and its findings will encourage the use of the new approach to produce lightweight composite wall elements. The study, surely, is a step forward in the right direction to achieve quality products. The current project is able

- produce a new potential structural composite, that is an integration of Ferro cement and expanded polystyrene for modular housing and building system which can be developed and marketed nationally and internationally.
- develop a novel method of light weight construction resulting in a cost effective production.
- help solve the housing problem of low and middle income earners.

4. Detail of the Pilot Project

As stated earlier, a pilot project has been conducted on application of Ferro cement Sandwich panel and Ferro cement wall at HBRI's staff quarter in Dhaka. An apartment of approximately 530 sft was renovated with Ferro cement sandwich panel and Ferro cement wall.

The apartment consisted of a multipurpose room, two bedrooms, a kitchen, toilet, shower and a balcony. Ferro cement sandwich panels were applied on the overall outer surface for better heat and sound insulation purposes. Few interior walls were also constructed with sandwich panels. Ferro cement walls were used in the toilet and shower areas. Fig 1 shows the detail of the design and location of the sandwich panels and Ferro cement walls.



Ferro Cement Wall

Ferro Cement Sandwich panel

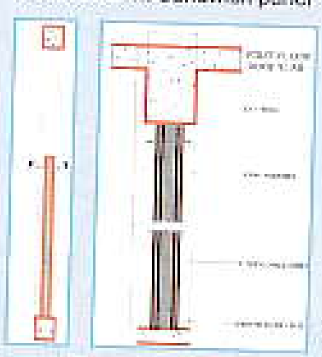


Fig 1: Floor plan and details of the pilot project

5. Construction Material and Process

5.1. Construction Materials

The following construction materials were used for the construction

- Expanded Polystyrene (EPS) sheets (2.25" thick)
- Woven wire Mesh (18 gauge)
- Portland Composite Cement
- Sylhet sand as fine aggregate (FM 2.9)
- Potable water
- Binding wire
- Chalk marker
- 3"X3" clamp
- Screw
- Royal plug

5.2. Construction Aids and Tools

The following aids and tools were used for the construction

- Masonry trowel of medium size
- Square rammer
- Nylon cord
- Aluminum scale
- Spirit level
- Plumb Bob
- Wire mesh cutter
- Mixing pan
- Binding hook
- Bucket
- Drill machines
- Spades

5.3. Construction Process

5.3.1. Preparation of mesh

At first, the length and height of the wall were measured. The opening was cleared from the measurement and mesh was cut accordingly. Two sets of meshes were prepared as per the measurement. Necessary splices were provided where there was a joint with columns and beams. The lap length was considered as minimum as three inches.

Figure 2: Preparation of mesh

5.3.2. Surface Preparation

Firstly The area was cleaned by brush and water before starting the construction. The base, top and sides of the wall were marked by chalk to make two lines with the spacing of 2.25 inch with the help of nylon cord and aluminum patty. Two lines of L-shaped angles were then fixed with the floor, wall and beams. The EPS sheet was placed inside the angle. The required opening space was made into EPS sheet as well as wire mesh. The side of the opening was strengthened by extra steel to provide protection against crack. At the edge of the opening, a 4"X4" column was made by using 4-10 mm diameter as main steel and 5mm diameter stirrup @ 6"c/c. The mesh was placed gently on both surface of the EPS sheet and was extended up to the face of the edge of the column. The mesh was fixed and held by clips that are fixed on both side of the EPS sheet.

Figure 3: Surface Preparation

5.3.3. Casting Procedure

A standard wall size of 10'-0" x 10'-0" needs at least 20 kg's of square wire mesh; size of about 144 mm2 (18 G) (2 layers) and 200 gm of binding wire. Cement mortar was prepared in a clean surface using Portland composite cement and Sylhet sand with FM value of 2.90. Mixing ratio for Ferro cement is very important and was strictly followed. The water: cement: sand (W: C: S) ratio for Ferro cement casting was 0.45: 1: 3 by weight. Sand and cement were first evenly mixed; the required quantity of water was added afterwards. For a wall size of 10'-0"X10'-0" and thickness 1/2" on both side of EPS sheet; approximately 125 kg cement, 10 cft Sylhet sand and 55 kg of water is required. Mortar was gently placed on prepared surface of EPS sheet. Firstly, mortar was placed on one side (say side 1) of the EPS sheet. Other side (side 2) was then supported by flat wood and bamboo so that no displacement occurred at the time of first mortar placement. Casting was stopped after completing 3 to 4 feet on side 1. Then casting started on side 2 of the wall after half an hour and double height of side 1 was achieved. It was then left for the next day.

Figure 4: Initial Mortar Placing

Next day water was sprayed on previous day's casted surface. After 24 hours of casting and plastering, curing with spraying water was started. Water was sprayed each hour of the day and it was maintained for continuous seven days. The placement procedure is called bottom up process and masonry trowel was used for the application. The mortar thickness was maintained slightly below ½ inch on both sides of the sheet. When the mortar was slightly hard (approximately after ½ hour of placing mortar) it was then plastered using same mortar and final thickness of 1/2" was achieved. Special care was taken to finish the top, sides and edges of the wall neatly. The edge of the opening was left for another RCC casting. Care was taken about the verticality of the wall using spirit level and plumb bob. The wall was then kept untouched for 24 hours before starting curing. Precaution was taken to make sure that nobody touches it. Curing started after the 24 hour period was over. After seven days of curing the RCC column was casted and cured for another seven days by wrapping jute bag on it.

After 24 hour of casting and plastering, curing started by spraying water. were. Water was sprayed until it overflow of each hour of the day and it was maintained for in a row seven days.

5.3.5. Finishing

After seven days of curing, the wall was left for three days to dry. Then it was cleaned by sand paper and stone and, after proper brushing, it was ready for primer coatings. A mastic paste made from chalk powder and white cement primer paint was prepared and was applied on the two surfaces. After the mastic has dried, it was sandpapered and final paint coat was applied.

6. Conclusion and Remarks

6.1. Development and Application

The above described technique was a pilot project at HBRI. Once it is mastered, several improvements can be undertaken

- Commercial plasticizer can be used to augment the workability of the mortar mix and to reduce the water content thus enhancing the mortar strength.
- Precast wall panel can be made in the factory and it can be transported to the site to fix.
- For precast panel, standard sized panel can be made and there should be groove on each panel to fix with the other.
- EPS can be replaced with any other light-weight materials such as, aerated concrete.

6.2. Problems faced during construction and some possible recommendations

- Installation of wooden frames for doors and windows are complex compared to brick masonry wall.
- Hard to control good workmanship due to manual handling of materials.
- Possibility of lateral bending during the casting procedure of is their if proper care is not taken.

Further research initiative has been undertaken at HBRI to overcome the problems associated with the practical use of sandwich panels. Comparative analysis of cast in situ and precast technique will help to find appropriate solutions to the problems.

Reference

1. Al, P. S. (2012). Fibrous Ferrocement Composite with PVC-coated Weld Mesh and Bar-chip Polyolefin Fibers. Int. J. of GEOMATE .
2. Alavez-Ramirez, R. (2012). Thermal conductivity of coconut fibre filled ferrocement sandwich panels. ELSVIER .
3. Ashraf, M. (2013). Flexural Behaviour of SCC Ferrocement Slabs Incorporating Steel Fibers. International Journal of Engineering Research & Technology .
4. G.M, N. (2012). Experimental study on light weight ferrocement beam under monotonic and repeated flexural loading. INTERNATIONAL JOURNAL OF CIVIL AND STRUCTURAL ENGINEERING .
5. Imran, M. (2014). Carbon dioxide emission from brickfields around Bangladesh. International Journal of Agricultural Research, Innovation and Technology .
6. K.Sasiekalaa. (2012). A Review Report On Mechanical Properties Of. International Journal of Engineering Research & Technology (IJERT) .
7. Mustapha, M. (2013). A Review Study On Cold-Formed-Ferrocement Composites. Australian Journal of Basic and Applied Sciences .
8. Nagesh M. Kulkarni. (2013). Analysis and Design of Ferrocement Panels an Experimental Study. International Journal of Inventive Engineering and Sciences (IJIES) .
9. Nahro Radi Husein. (2013). An Experimental Study on Using Lightweight Web Sandwich Panel as a Floor and a Wall. International Journal of Innovative Technology and Exploring Engineering .
10. Saleem, M. A. (2008). Low Cost Earthquake Resistant Ferrocement Small House. Pak. J. Engg. & Appl.

STUDY AND DEVELOPMENT OF THERMAL BLOCKS

Abstract

The main purpose of this study is to develop a type of concrete block which can serve as a thermal and sound insulator. Expanded polystyrene (EPS) was selected as an insulating materials and to protect the EPS from external effect it was covered with sand-cement mortar. As EPS can withstand against a very little amount of compressive force, cement mortar should be a rich one. The block was casted in a simple mold and demolded after 24 hours. Then it was tested followed by specified days of curing. Also, through this study, economic proportion of sand-cement mortar and usability of strength gaining admixture was investigated and it was found that 1:3 cement mortars with admixture gives satisfactory results in terms of durability and strength.

1. Introduction:

Brick is the main building material for the construction industry, which has been growing at about 5.6 percent annually between 1995 and 2005, leading to an estimated growth rate of 2–3 percent for the brick sector.

Annually about 17.2 billion burnt clay bricks are produced all over Bangladesh the output value of which is about Tk. 83 billion (BUET 2007). With about 5,000 operating kilns, brick-making is a significant industry in Bangladesh, (The World Bank, ESMAP-2011) contributing about 1 percent to the country's gross domestic product (GDP) and generating employment for about 1 million people (BUET 2007). These vast amounts of clay bricks consume 45 million tons of clay, 3.5 million tons of coal and 2 million tons of fire wood. The Fixed Chimney Kiln (FCK) dominates the brick sector in Bangladesh, despite its highly polluting and energy-intensive features. Most operating kilns consume about 18–22 tons of coal to produce 100,000 bricks (BUET 2007). Coal burning by kilns releases pollutants into the atmosphere, leading to harmful effects on health (e.g., from PM) and agricultural yields (e.g., from NOx) and contributing to global warming and climate change (e.g., from CO2). Annually 9.8 million tons of CO2 is emitted due to burning of bricks in Bangladesh (BUET 2007).

Also, the clay is being collected from agricultural land. Research indicates that about 42000 acres of agricultural land is being diminished annually due to unplanned brick field and collection of clay from agricultural top soil. If these processes continue our food security will be in danger very soon.

Considering the above facts, Housing and Building Research Institute (HBRI) has taken a number of research programs regarding alternative to burnt clay bricks. Thermal block is one of them.

The thermal block is a type of concrete block where expanded polystyrene is used to increase the thermal resistant properties of the block and to lighten the gross block weight. Cement mortar is casted over EPS and cured for specified period. As no burning is required so this block will be environment friendly, sustainable, and cost effective. The wall made of this block will provide comfortable indoor environment both in summer and in winter. Due to its lightweight characteristics this will save structural cost and uses of this block in multi storied buildings will be suitable from an earth quake point of view.

2. Literature Review:

Extensive searching of literature was performed during and prior to study process. A handful amount of literature is available on thermal blocks. Thermal blocks are widely used in the region of harsh temperature, especially in Europe where average temperature in winter is below freezing point and Middle Eastern countries where average temperature in summer is more than 40°C. We tried to follow the specifications, instructions, and standard provided by Dubai Municipality, a well-established institute in Middle Eastern region. In some cases we modified some parameter due to the local condition, especially in case of materials used.

2.1. Cement Concrete Literature:

Concrete is a composite material composed mainly of water, aggregate, and cement. Often, additives and reinforcements are included in the mixture to achieve the desired physical properties of the finished material. When these ingredients are mixed together, they form a fluid mass that is easily molded into shape.

Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone-like material with many uses. To make thermal bricks in this laboratory, Ordinary Portland Cement (OPC) is used with coarse grained sand collected from Sylhet. Different engineering properties both for cement and sand were determined prior to casting the thermal bricks. Water reducing and strengthening admixture (Daracem) was also used for another set of sample.

2.1.1. Properties of Cement:

The cement used for our research work was collected from local market. Different tests were conducted on this cement to obtain its properties. The test results are summarized below.

SL	Test conducted	Test Result
1.	Normal consistency	25%
2.	Initial Setting Time	135 Min
3.	Final setting Time	185 Min
4.	Compressive Strength	3 Days- 1986 psi 7 Days- 2990 psi 28 Days- 4142 psi
5.	Tensile Strength	
6.	Fineness	99.4% passing in #100 US sieve
7.	Specific Gravity	3.14

2.1.2. Properties of Sand:

In Bangladesh two types of sands are commonly used. Locally available sand collected from different rivers. This sand is finer in size. FM varies from 1.5 to 2.2. Building designers do not recommend this sand for structural construction. This is only used in non-bearing partition wall construction and plastering works. Other type of sand is Sylhet sand collected from hilly rivers of Sylhet. This sand is coarser in size and its size is more consistent than other types of sand. Its FM varies from 2.3 to 2.9. In this test we used clean Sylhet sand, its FM was 2.72. Figure 1.1 showed the Sieve size versus percent finer curve of Sylhet sand.

Sieve analysis of Sand and subsequent result:

Sieve No (ASTM)	Sieve Openings (mm)	Quantity Retained (gm)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Percent Passing to the nearest Sieve	Fineness Modulus (FM)
4	4.75	0.00	0.00	0.00	100.00	2.79
8	2.36	18.30	3.66	3.66	96.34	
16	1.18	100.30	20.06	23.72	76.28	
30	600 μm	194.60	38.92	62.64	37.36	
50	300 μm	138.80	27.76	90.40	9.60	
100	150 μm	39.10	7.82	98.22	1.78	
Pan		8.90				
Total		500.00	98.22	278.64		

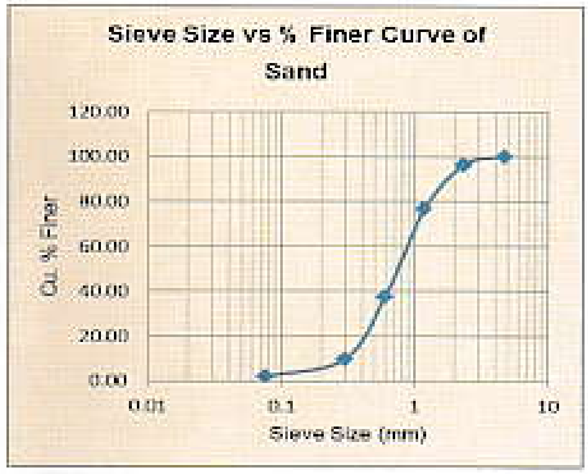


Figure: Sieve Size vs % Finer curve of Sylhet sand

2.2. EPS Literature:

EPS is a type of insulation that is molded or expanded to produce coarse, closed cells containing air. Expansion is achieved by virtue of small amount of pentene gas dissolved into the polystyrene base material during production. EPS foam products whether used for insulation or packaging are lightweight, versatile, sanitary, energy efficient, and most importantly, cost effective.

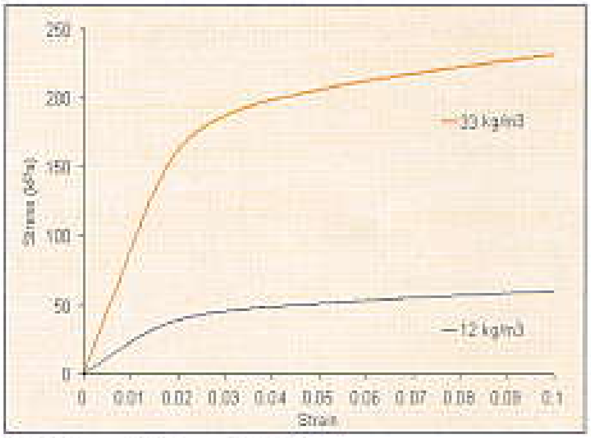
2.2.1. Density:

EPS densities for practical civil applications range between 11 and 30 kg/m3. For other applications like insulation higher densities are more efficient (van Dorp, 1988). In our test EPS25 (25 kg/m3 from Advance Technologies Ltd. was used.

2.2.2. Compressive strength and stress strain curve:

Figure 2-3 shows the uniaxial compression stress strain curve of EPS for two different densities. The two densities shown are considered the extreme values for most engineering applications done so far. Specimens are 0.05m cubes tested at a displacement rate of 0.005m/min. From the figure the stress strain curve can be simply divided into two main straight lines connected with a curved portion. The slope of the straight line portions increase with density. The stress at any strain level also increases with the density. The bead size has no important effect on the compressibility of cut specimens (BASF Corp., 1968).

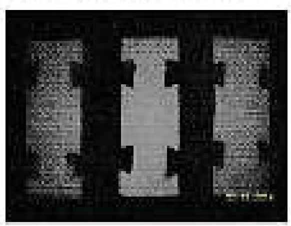
EPS under confining compression Sun (1997) reported that with increase in confining stress the strength and initial tangent modulus decrease. Sun concluded these results based on axial deviator stress strain curves, which are important for submerged EPS.



3. Making of Thermal Block

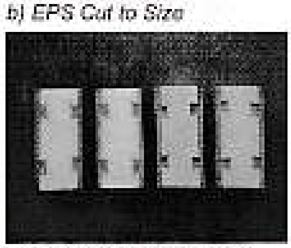
Full size (4'X8') EPS panel collected from factory is first cut to size to make thermal blocks. After proper sizing and grooving the EPS pieces are placed into the steel mold. The molds are rectangular steel box open in one side. Cement mortar is then placed in the gap between the mold wall and EPS. These are de-molded after 24 hours and then blocks are kept for curing. The blocks can be used after 28 days of proper curing with water. The complete process of making thermal blocks can be best described by the following pictorial presentation.

a) Raw EPS from Factory



b) EPS Cut to Size

c) EPS placed in the mould



d) Blocks after de-molding

e) Blocks after de-molding

f) Thermal Blocks used in Wall

4. Test Program

4.1. Compressive strength test: Compressive strength of thermal block was tested in accordance with appendix B of BS 6073: Part 2 of five samples. Average result based on the gross area of thermal block of each test was considered for the particular proportion. Compressive strength of 7 days, 14 days, and 28 days was measured for each set of samples.

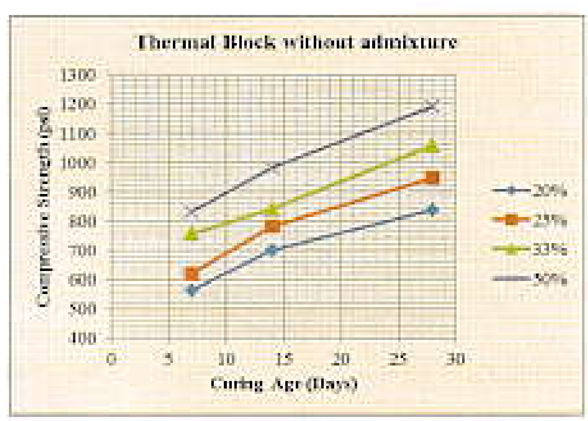
4.2. Water Absorption Test: Water absorption test of thermal block was done after 28 days of water curing and 14 days of air curing following the water curing period. The test was performed in accordance with ASTM C20-00 Standard. The percentage of water absorption by thermal blocks of different proportion was calculated for the gross weight of the blocks. Besides, water absorption test of burnt clay bricks randomly collected from local market was done to compare the water absorption characteristics of two types of block/bricks. The test result is presented in later sections.

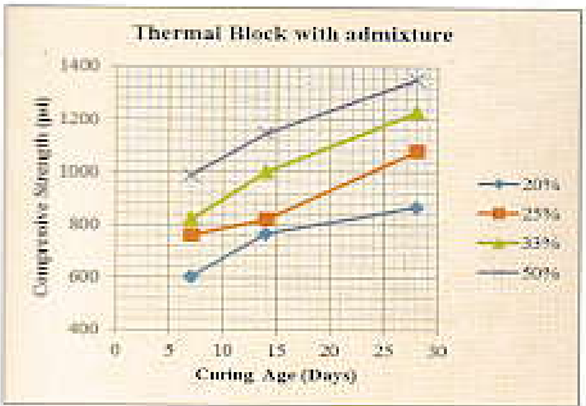
5. Test Result and Discussion:

5.1. Compressive strength test: Result of compressive strength test is shown in table below. It is observed that compressive strength of tested thermal block increased with increasing cement content. Also the compressive strength was considerably higher of the sample (1% of cement used) containing admixture although the proportion of cement is same.

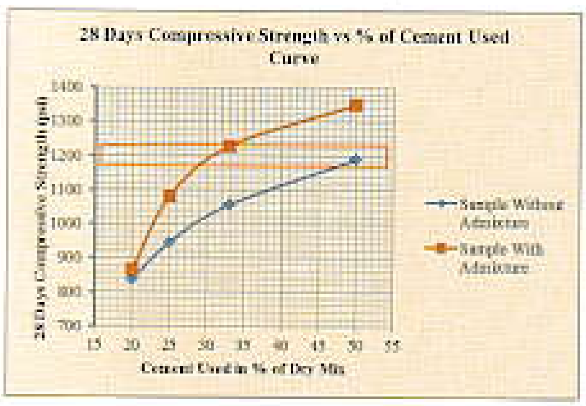
SL	Cement used (in % of Mix)	Admixture Used (in % of Cement)	Curing Age (Days)		
			7	14	28
			Compressive Strength (psi)		
1	50	0%	830	981	1189
2	50	1%	988	1145	1350
3	33	0%	755	839	1056
4	33	1%	820	1000	1228
5	25	0%	620	780	945
6	25	1%	760	820	1080
7	20	0%	562	700	836
8	20	1%	600	765	865

The discrete data can be best understood by the following figures which compared the result of compressive strength test with different proportion of cement and admixture used.





From graph-1 and chart-1 we observe that for sample without any admixture used, 28 days compressive strength increses by 13%, 26%, and 42% when cement content is increased to 25%, 33%, and 50% respectively. Almost similar Phenomena occur in case of sample with admixture used. In this case the incresing amount is 24%, 42%, and 56% when cement content is increased to 25%, 33%, and 50% respectively. We see the increasing rate in sample with admixture is higher than the sample without admixture. Almost same result can be obtained from 33% cement with admixture and 50% cement without admixture use. To understand the phenomena more clearly let us examine the follwing graph (graph-2).



In graph-2 we see the compressive strength of thermal block having 50% cement without any admixture is almost same (1200psi) as that of block having 33% cement with admixture (1% of cement). Also that compressive strength (1200 psi) satisfy the standards (Dubai Municipality as an example).

5.2. Water Absorption Test: Water absorption test result of thermal block and burnt clay bricks are presented in the table below. Ten samples were tested as per ASTM standard. Different sample was taken from different proportion of cement and admixture used. It is found that water absorption of no sample exceed 6% and average water absorption 5% for all ten samples. On the other hand, most of the burnt clay bricks soak more than 20% water of their initial gross weight.

Sample No.	Thermal Block			Burnt Clay Brick		
	Initial Weight (gm)	Final Weight (gm)	Water Absorption (%)	Initial Weight (gm)	Final Weight (gm)	Water Absorption (%)
1	1407	1470	4.47	2538	3085	21.55
2	1398	1470	5.15	2666	3296	23.59
3	1752	1820	3.88	2625	3230	23.04
4	1442	1525	5.75	2735	3225	17.91
5	1250	1305	4.40	2535	3325	28.18
6	1236	1303	5.42	2535	2960	16.76
7	1162	1228	5.50	2650	3167	19.50
8	1390	1468	5.61	2750	3280	19.27
9	1405	1485	5.69	2735	3350	22.48
10	1436	1504	4.58	2715	3210	18.23
Average	1388	1457	5.01	2658	3212	20.85

6. Conclusions:

From the test result and related literature study, following conclusions can be drawn for the feasibility of the study on thermal block.

a. As saving agricultural top soil from the aggression of brickfield is our supreme priority, we must find the alternative to burnt clay bricks. Considering compressive strength and water absorption thermal block can be a good alternative to burnt clay bricks to construct non-load bearing walls.

b. Thermal block is 50% lower in weight compared to burnt clay bricks. So usage of thermal block in high-rise building may save the cost of foundation considerably.

c. As thermal conductivity of EPS is very low compared to the burnt clay brick, usage of thermal block in interior wall will provide a comfortable interior environment.

d. At present thermal blocks are casted manually. It involves cutting the EPS sheet in pieces with groove, casting the mortar, molding and demolding etc. So cost per piece is a little higher than burnt clay bricks. Once the industrial process is adopted the cost per piece will be within the range of burnt clay bricks.

7. References:

1. Dubai Municipality Standard, DMS 1: Part 5: 2004
2. IS 10262: (1982) Recommended Guidelines for Concrete Mix Design, Indian Standards Institution, New Delhi.

3. K. Ganesh Babu, et al.(1992): Concrete Mix Design-An Appraisal of the Current Codal Provisions, The Indian Concrete Journal, February 1992, pp. 87-95.

4. Nagataki S, Fujiwara H. In; Malhotra VM, editor. Self-compacting property of highly flowable concrete,Vol. Sp 154,American Concrete Institute:1995. P.30114.

5. EFNARC. Specification and guidelines for self-compacting concrete, English edition. European Federation for Specialist Construction Chemicals and Concrete systems. Norfolk, UK February 2002.

6. Khayat KH, Guizani Z.Use of viscosity-modifying admixture to enhance stability of fluid concrete. ACI Mater J 1997; 94(4).

7. A Reclamation Manual Specialist Supplement: Concrete Manual, Fifth Edition 1953, Denver, Colorado, USA.

8. Santi Sridorunkatum and Chalermchai Ngourungsi: Technology Manual on Concrete Hollow Blocks, A project Funded by UNDP 1987, printed and published in Thailand and the Philippines.

STEP TOWARDS ALTERNATIVE BRICKS: INTRODUCING INTERLOCKING BLOCKS TO BUILDING CONSTRUCTION IN BANGLADESH

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ABSTRACT

Global warming and environmental pollution is now a global concern. Interlocking blocks can be used to reduce environmental pollution and global warming. This paper represents the inclusive review on the construction process which involves the use of interlocking bricks as an alternative to burnt clay bricks. Considering a part of the research and development program, a pilot project has been detailed for using interlocking bricks in the construction of one storied building. The initiative has been taken by the Government organization, Housing and Building Research Institute to promote alternative clay bricks to lessen the carbon emission percentage caused by burnt clay brick fields. This paper comprises the procedures and steps taken to assemble the arrangements to provide a kitchen and toilet service facility to the female staffs of the Institute.

Key Words: interlocking bricks, carbon emission, dredged soil, burnt clay bricks.

1. INTRODUCTION

Bangladesh, a country with a population of 160 million, is currently contributing 0.14 percent to the world's emission of carbon dioxide (CO_2). Bangladesh's share in CO_2 emissions is—despite the increasing use of alternative energy—expected to rise sharply. (Gunter, 2010) Brick-making is a significant sector in Bangladesh, contributing about 1 percent to the country's gross domestic product (GDP) (Environment, 2011). The brick kiln industry is one of the fastest-growing sectors, supporting the booming infrastructure and construction industry, with current manufacturing capacity of 12 billion bricks a year from 4,500 brick kilns surrounding all major cities of Dhaka, Khulna, Rajshahi, and Chittagong, and is expected to grow 50 % by 2020. Brick manufacturing is the fastest-growing industrial sector in Bangladesh and among the top three sectors, along with vehicle exhaust and suspended road dust, contributing to the air pollution and health problems in Dhaka. The total emissions are estimated at 23,300 t of PM2.5, 15,500 t of sulfur dioxide (SO_2), 302,000 t of carbon monoxide (CO), 6,000 t of black carbon, and 1.8 million tons of CO_2 emissions from these clusters, to produce 3.5 billion bricks per year, using energy in efficient fixed chimney bull trench kiln technology and predominantly using coal and agricultural waste as fuel (Sarath). Dust blown up from dry riverbeds, fields and roads, and choking smog from ranks of brick kilns on the edge of town helped to secure the place a spot in the top tier of the world's most polluted cities. Almost invariably, good-quality topsoil from agricultural fields with high clay 3.3. content is used in Bangladesh's brick kilns. Depletion of topsoil with high organic content for brick-making is a major concern for agricultural production. In addition, acid deposits from the sulfur dioxide (SO_2) and NOx emitted from the brick kilns negatively affect agricultural productivity. (Environment, 2011). On the other hand, the increases in material cost in the construction work has increased the need to find more cost saving alternatives so as to maintain the cost of construction houses , multistory etc, which can be affordable to all people. Due to lightweight of these blocks, there will be less dead load to act on the structure, therefore the structure became lighter. If the structure is lighter than there will be reduction in the reinforcement, reduction in the size of the member, reduction in the concrete and also by using these blocks there will be no use of coarse sand for the plastering purpose. And the building should be constructed in a most economical way. (Ghanshyam Kumawat, 2016). Housing and Building Research Institute (HBRI), the only Government research institute of Bangladesh that conducts research on housing, has been conducting many researches for the development of innovative building materials and construction techniques to support the reduction of carbon dioxide as well as reduction in construction cost. To establish the interlocking bricks in wall construction, HBRI has taken initiatives to complete a one storied building within an area of about 320 sft. The successful implication of interlocking bricks can be proved to be an exceptional substitute to burnt clay bricks. Again, Bangladesh contains over 300 rivers; many of which are heavily silted and have not been dredged in nearly thirty years. The government plans to dredge the rivers in an effort to reduce potential flooding that inevitably follows regularly occurring natural disasters and to make the rivers more navigable. Dredging helps the nation to retrieve its old heritage of river transportation and saves the economy as a whole by making all major rivers of the land navigable round the year. Dredge soil introducing in adobe is new one in our country that will help our economy definitely because of from the beginning of civilization, people, equipment, materials, and commodities have been transported by water. To do this, the channel depths of many waterways needed to be increased to provide access to ports and harbors. Most major ports in the world require dredging at some time to enlarge and deepen access channels, waterways, and turning basins, and to provide appropriate water depths along waterside facilities. These channels often require frequent and regular maintenance dredging. In the case of fluvial navigation, dredging is also required to construct and maintain vital links to inland ports and facilities. (Habib, 2015) To introduce the dredging soil in the development of interlocking bricks, dredged soil has been collected from the river Kapotakkho. Some soil from the HBRI premises has been also collected which was nicknamed as "Dhaka Clay". These two types of soil have been used to produce interlocking bricks.

2. SIGNIFICANCE OF THE STUDY

Bangladesh is the 8th largest populous country with 160 million people. Each year 3, 00,000 to 4, 00,000 rural people migrate in Dhaka. The existing people as well as new migrants need housing facility. At present in our country the annually required shelter varies from 3 lakh to 5.5 lakh units. Bangladesh will need to construct approximately four million new houses annually to accommodate the growing population. Rapid urbanization in the country has created a booming construction industry and spurred the production of

8.6 billion bricks each year, with the demand for bricks rising at an annual rate of about

5.28 percent. As per the guidelines of the Kyoto protocol, Bangladesh will get 15.20 dollars from the global Community development Carbon Fund for reducing each ton of carbon emissions (The Daily Ittefaq, 2009). From this perspective, if Bangladesh can reduce the amount of emissions at least 50% of 8.75 (4.17%) million tons through technology transfer, the country will get a huge revenue of $70 million a year from global carbon trading fund (Maksuda Hossain, 2012). Regarding this issue, the newly evolved technique of using interlocking bricks incorporated with dredging soil collected from the river Kapotakkho, can be a great inspiration for reducing carbon emission from brick fields.

3. INTERLOCKING BRICKS

3.1. INSTIGATING CONCEPT

An improved form of mortar-less blocks which is an innovative structural component for masonry building construction called interlocking block which can be produced mechanically or manually, using interlocking block production machine, particularly an improved interlocking block machine with dual mould. (Chukwudi Onyeakpa, 2014). The main features of interlocking blocks are as follow:

1) The interlocking blocks/units have very high compressive strength as compared to ordinary bricks.
2) The load bearing capacity of these units/blocks is very high as compared to normal bricks.
3) Effective cost of one block of interlocking unit is much less than that of the bricks covering up the same volume.
4) Construction of these units/blocks comprises of easy and feasible process.
5) During interlocking of a single block/unit use of mortar is not necessary as the compressive strength remains same with or without use of mortar. (Sajad Ahmad, 2014).

3.2. EXPERIMENTAL INVESTIGATION

The experimental investigation was conducted by mixing the Kapotakkho dredged soil and Dhaka soil along with 10% of cement respectively to form two types of bricks. Compressive strength test, determination of modulus of rupture and water absorption tests were carried out in the establishment of the brick.

FIGURE 1: MAKING OF INTERLOCKING BRICKS

Sample	Failure Load(Ton)	Failure Load(lb)	Compressive Strength (psi)
Interlocking Bricks with Kapotakkho dredged soil	11.27	25,237.33	525.78
Interlocking Bricks with Dhaka Soil	15.80	35,392.00	737.33

POTENTIALITY OF THE BRICK

Triple benefit of interlocking bricks can be considered as cost effectiveness, energy efficiency, and creation of new job opportunities. Interlocking concrete block is a way to build a strong wall without mortar. The flanges slope the wall back into the slope for additional strength. Interlocking-block walls don't require a footing, but some styles require setting the first course in a trench to hold the bottom of the wall in place. All these positive qualities advocate using interlocking bricks as the replacement of burnt clay bricks.

4. APPLICATION OF INTERLOCKING BRICKS

4.1. DETAILS OF THE PILOT PROJECT: COMMUNITY TOILET AND KITCHEN

Proper approaches have been taken to apply interlocking bricks, for providing community based service facilities such as toilets and kitchen for the female residents from approximately sixteen families living in the HBRI property. Some considerations were taken based on the social and environmental context and service flow. The female zone consisted of separate toilets, 2 numbers of bath rooms and a wash area. Each female toilet zone could be used by four families. Kitchen complex with 4 burners could be used by at- least four families. (Figure: 1 & 2).

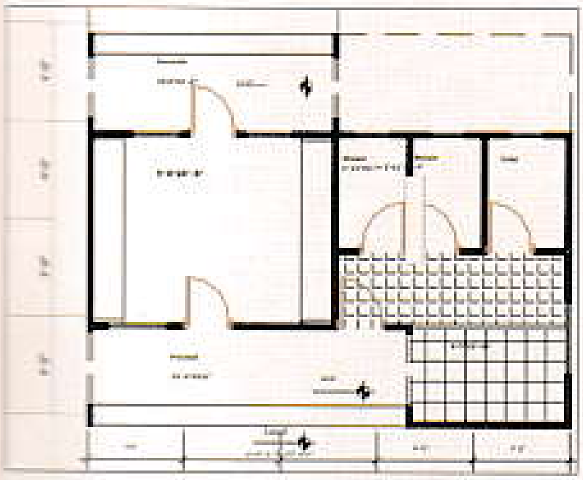

FIGURE 2: PLAN OF Model House (CSEB Interlocking Block)

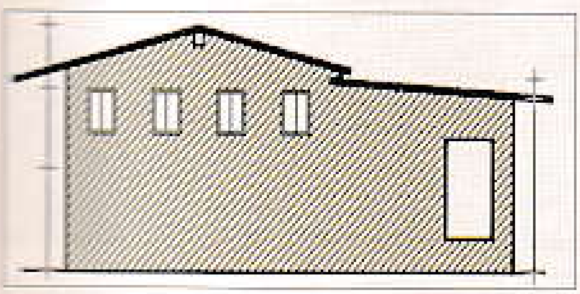

FIGURE 3: SOUTH (FRONT) ELEVATION

4.2. CONSTRUCTION PROCESS FROM FOUNDATION TO FINISH WITH INTERLOCKING BRICKS

4.2.1. FOUNDATION

The foundation was approximately 376.83 sft (the trench was about 1'3" width) which was prepared for the construction of female zone with interlocking bricks. 3" thickness and 18" width of C.C work had been provided first. The plinth area was completed by laying bricks up to 1'6".

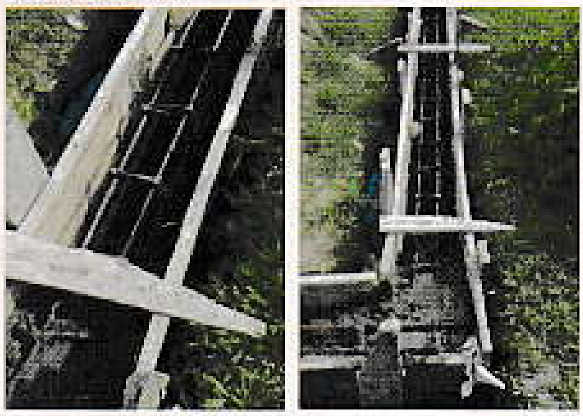

FIGURE 4: LAY OUT

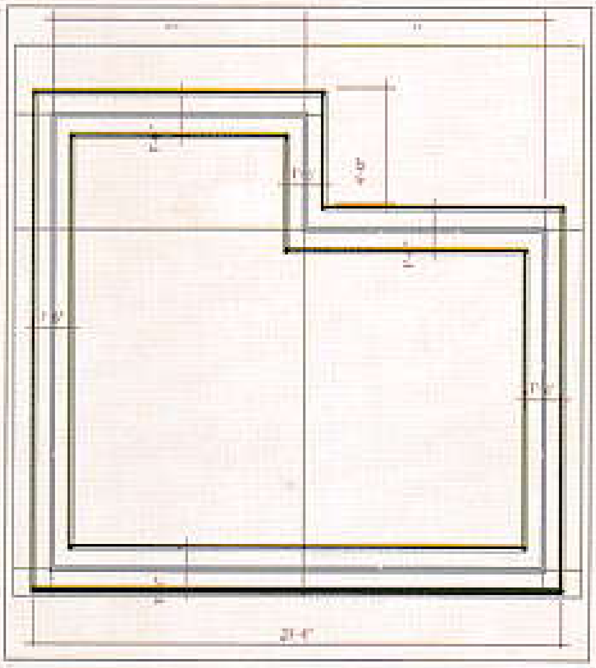

FIGURE 5: LAY OUT PLAN OF KITCHEN AND TOILET (FEMALE ZONE)

4.2.2. Completion of the Floor Area

The floor area was filled with sand cement stabilized earth and the floor finish was completed with mortar (cement-sand ratio was maintained 1:4). The thickness of the finished floor was about 2".

FIGURE 6: COMPLETION OF THE FLOOR AREA

4.2.3. APPLICATION OF INTERLOCKING BRICKS

The blocks were laid dry on the foundation around the entire building in order to ensure that they fit exactly next to each other (leaving no gaps). When laying the first course, proper care had been taken that the blocks came out to be perfectly horizontal and in a straight line, or at right angles at corners and joints (T-junction).

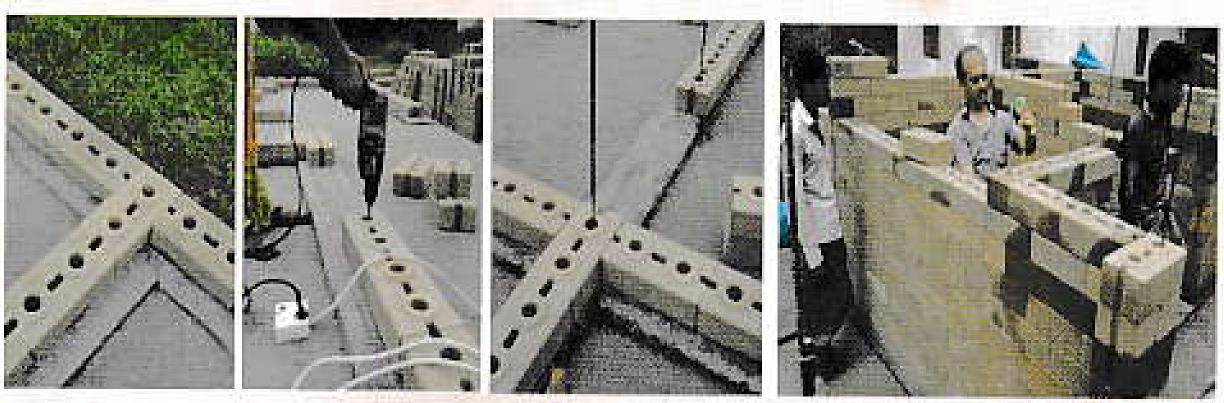

FIGURE 7: PLACEMENT OF FIRST COURSE OF BRICKS

Once the base course is properly hardened, the blocks are stacked dry, with the help of a mallet to knock the blocks gently into place. Up to ten layers can be placed at a time. Every corners and joints were provided with 10mmφ rods with 1:4 ratio of mortar in the hollow section of the wall. The rods were drilled into the floor (approximately 4" inside the floor depth). They were also placed in the middle of the long span of the walls.

Mortar (ratio-1:4) was placed continuously in the hollow area of the bricks up to the ceil height of the window. It had been provided to secure the structure from the effect of retained water outside the building. The placement of mortar would support the structure from damp as well as increase the durability of the structure.

FIGURE 8: PLACEMENT OF MORTAR UP TO CEILING HEIGHT

4.2.4. INSTALLATION OF CHOWKATH FOR WINDOWS AND DOORS

Wooden chowkath were placed for doors and windows. Chowkath was connected to the walls by placing mortar between the walls and chowkath.

FIGURE 9: PLACEMENT OF CHOWKATH

4.2.5. FINISHED BUILDING

The finished building has been adopted as toilet and kitchen area for the tenants living in the campus area. Ferrocement corrugated sheets have been used as the roofing material.

FIGURE 10: FINISHED BUILDING

5. ADVANTAGES OF INTERLOCKING BRICKS

The advantages of interlocking Block are:

(i) Construction with interlocking block saves time and ample amount of mortar concrete compared to conventional masonry block laid with mortar

(ii) Areas prone to earthquake use hollow interlocking block with the strength improved as well as with grout and reinforcement throughout the height of the wall to resist the effect of earthquake, thus, providing adequate structural stability against collapse

(iii) Having formed the base course, other course can be assembled by unskilled labor.

(iv) Dismantling of the blocks in case of temporary structure does not incur much damages as in blocks laid with mortar

(v) Cost of construction is relatively less. (Onyeakpa, 2014)

6. LIMITATIONS OF INTERLOCKING BRICKS

The disadvantages of interlocking block include

(i) A standard skilled masonry labor is required to ensure proper horizontal and vertical alignment of the blocks, and that the corner and junction (T-joints) are right angled, especially at the base course.

(ii) Due to wind and rain seepage effect the block wall need be rendered.

(iii) The mould, palettes groove or/and protrusion edge may affect the dimension of the block; consequently may be compromised the alignment and stability of the wall, if not adequately observed.

(iv). It is difficult to maintain the required tight tolerances for accurate construction of large walls or other structures through the molding and cutting steps. (Chukwudi Onyeakpa, 2014)

7. FUTURE ACCEPTANCE

From this particular study it can be said that the construction cost structure made with interlocking bricks is approximately 25% less than that of RCC construction.

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CONCLUSION

As one of the major busiest cities in the world, Dhaka is being distressed from air pollution due to regular blazing fossil energy. The situation is getting worse with the emission of fossil fuel from the surrounding brickfields. The use of non-fired bricks such as Interlocking bricks made up with partial amount of cement and dredged soil could be proved to be a better solution to lessen the use of agricultural top soil.

REFERENCES

Chukwudi Onyeakpa, L. O. (2014). Improvement on the Design and Construction of Interlocking Blocks and its Moulding Machine. 11 (2).

Environment, C. C. (2011). Introducing Energy- efficient Clean Technologies in the Brick Sector of Bangladesh. Washington DC: Manufactured in the United States of America.

Ghanshyam Kumawat, D. S. (2016). Analysis and Comparison of R.C.C. Structure Using CLC Block With Burnt Clay Bricks. 4 (3).

Gunter, B. G. (2010). The Impact of Development on CO2 Emissions:A Case Study for Bangladesh until 2050. Washington DC: Bangladesh Development Research Center.

Habib, A. (2015). Effect of stone dust on the mechanical properties of adobe brick. IJISET , 631-637.

Maksuda Hossain, A. M. (2012). Securing the Environment: Potentiality of Green Brick in Bangladesh. BUP JOURNAL , 79-89.

Onyeakpa, C. (2014). Improvement on the Design and Construction of Interlocking Blocks and its Moulding Machine. IOSR-JMCE , 49-66.

Sajad Ahmad, S. H. (2014). To Study The Behavior Of Interlocking Of Masonry Units/Blocks. 04 (03).

Sarath, G. A. (n.d.). Particulate pollution from brick kiln clusters in the Greater Dhaka region, Bangladesh.

Affordable Housing in Bangladesh : An Overview

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1. Introduction

The Constitution of Bangladesh recognizes 'Housing' as one of the three basic primary needs of man and women, and is as important as food and clothing. Housing provides shelter, safety and a sense of belonging to the owner. An adequate shelter must have security of tenure, protection from elements of nature, utility services such as safe drinking water, sanitation and other essential services; it needs to be affordable and accessible. At present, housing is considered to be central to survival and human dignity that are universally accepted. Housing status is often a major indicator for economic and social base for development status of the individual and family (Haque, 2007). However, housing affordability is a major policy concern all over the world, especially in developing countries. Bangladesh, one of the developing countries with rapid growth, has been suffering from acute housing affordability for a long time (Sarkar, 2014).

In 2011, the Bangladesh Bureau of Statistics conducted a national census in Country, which provided a provisional estimate of the total population of the country as 142,319,000 with the density of about 965 per sq. km. (Bangladesh Population and Housing Census 2011, 2015). However, the population of the country has increased in a rapid growth. Within its 147,570 km2 of area (Islam, 1991), with the current population of Bangladesh, which is 164,670,000 (World Population Prospects,United Nation, 2017), establishment of housing facilities for whole has been severely hampered. Better quality of living, availability of jobs, attract the rural population to the urban sides of the country. Dhaka zila, the capital and primate city of Bangladesh, with a density of 8,229 people per square kilometer within a total area of 1,463 square kilometers (Zila report: dhaka, BBS, 2015) is a fast growing mega-city in the world. Dhaka metropolitan, with the area of about 316 sq. km., consists a total number of household of about 20, 34,146 and population of about 89, 06,039 with the density over 28,000 per sq. km. (Area, Household, Population and Literacy Rate of the Cities 2011; BBS, 2015). The city receives an estimated 300,000 to 400,000 new migrants annually, mostly rural poor (Mohit, 2012). There is a tremendous pressure of influx of people in Dhaka city.

Current trend of urban migration is driven by rural poverty, river erosion and natural calamities forcing them to migrate to Dhaka city in search of better livelihoods. The existing infrastructure facilities developed in Dhaka megacity cannot cope with the minimum living requirements of this poor working class floating population (Shams et al., 2014). These poor migrants live in the worst possible situation in terms of housing and security of their lives. Historically, urban development in Bangladesh has been based on subsidized allocation of residential land for upper and middle class use. Access even to minimal shelter has been unaffordable for most of the poor. The poor migrants who usually find jobs in the low-paid informal sector do not have enough income to pay for housing in the formal sector (Nawaz, 2004).

On the other hand, with the increase in demand of housing, the cost of construction materials have gone out of the reach of the low and middle income group of people. The lack of available and accessible housing problems has been identified by the Government of Bangladesh (GOB) as one of the major hurdles in improving the housing conditions for middle and lower income households (Loton, 2004). The government is aware of this crisis and its magnitude. They intend to create a favorable and conducive environment in the country to provide impetus to this sector. The Government's endeavor is to make housing accessible to all citizens of Bangladesh through various measures, incentives, motivation, planning and management. Special housing schemes will be undertaken, both in public and private sectors, for the low-income groups, the disadvantaged, the destitute and the shelter less poor.

Different government organizations, under Ministry of Public Works, are mainly working for this lower and middle income section of people of the society to ensure safe, secured and affordable housing system.

2. Present Housing Conditions in Bangladesh

An adequate shelter should have minimum security of tenure, protection from elements of nature, utility services such as safe drinking water, sanitation and other essential services; it needs to be affordable and accessible. Regrettably a large segment of Bangladesh population has no access to adequate housing (Nawaz, 2004). The housing situation in Bangladesh has never been satisfactory. According to Bangladesh Grihayon Poristhiti (1991), there are some triggering factors which have influences on the housing condition:

- Population growth, mainly growth of under privilege of people
- Natural calamity
- Required land for housing
- Infrastructure for housing
- Financial support
- Required available housing materials
- Housing technology, technical personnel and skilled labor
- Housing management and institutional support and participation of citizen
- Policies and law of housing

The majority of dwelling units are temporary, sub-standard, unsafe and overcrowded. The ancillary physical, social and economic facilities and services essential for the development of healthy and harmonious community life are highly inadequate both in the urban and rural areas (Gazi Mohammad Hasan Jamil, 2010). More than two million people in the capital city of Dhaka either live in slums or are without any proper shelter.

Urban migration take place mainly for better employment opportunities especially in the ready-made garments sector and educational opportunities. While most people migrate for economic reasons, more than 26% leave for the cities because of natural disasters, river erosion and recurrent flooding (Habitat for Huminity). Housing shortage in 1991 was estimated to be about 3.10 million units which now have exceeded the 5 million units mark projected for the year 2000. Bangladesh will have to build at least 300,000 housing units a year to keep pace with the population surge. In a recent Ministry of Housing survey on the housing need revealed that some six million housing units have to be built in Bangladesh to meet the deficit. The survey suggested that the government undertake a massive housing program (Nawaz, 2004).

The problems of housing in Dhaka city as well as in other metropolitan areas of Bangladesh are very acute. Dhaka city requires between 55,000-83,000 housing units each year, whereas all public and private efforts together can only produce 25,000 housing units a year. The percentage of people living in slums in the urban areas of the country is 6.33% percent. Among them 43.60 percent floating population live in Dhaka (Census of Slum Areas and Floating Population 2014, 2015). A similar situation prevails in other cities of Bangladesh. The household stock of the metropolitans and municipalities are about 5.0 million and the deficit is around 8.5 million (Haque, 2007). Two major constraints for the housing development in Dhaka are: scarcity of land and high construction cost. The rise in construction cost with the building height is prominent where construction is labor- intensive. The inclusion of the costs of developed land, render such housing solutions inaccessible even for HHs well above the median income (Shahriar Shams, 2014).

A commonly accepted guideline for housing affordability is a housing cost that does not exceed 30% of a household's gross income. When the monthly carrying costs of a home exceeds 30% – 35% of household income, housing is considered unaffordable for that household (Wikipedia). On the other hand, the classifications of income group people in Bangladesh are mainly three types such as higher, middle and lower income group. The income groups of Bangladesh are defined from the perspective of monthly income as follow: low-income, TK 13199 or less, lower middle-income TK 13,200 – 24,999, middle-middle income TK 25, 000 – 49, 999, upper middle-income TK 50, 000 – 99, 999 and high- income TK 100, 000 or more. In Bangladesh, 50% of the people belong to middle income group (Bangladesh Population and Housing Census 2011, 2015).

High land prices have excluded the poor from ownership of land and housing. These prices make it impossible for the poor to purchase land in the open market within the city area (Shahriar Shams, 2014).

3. Government Initiatives

In this circumstance, the Government of Bangladesh has taken several initiatives to improve the housing condition of the country. With the commitment to provide housing for all, National Housing Policy 2016 has been published. The Government has adopted a program titled "one house and one farm". In addition to solving housing issue, this program aims to address the issue of food security and employment. Despite enormous constraints and challenges, Bangladesh has made remarkable strides in a host of areas including food production, safety net programs, rural infrastructure, credit provision, primary education, child immunization, family planning, sanitation, drinking water provision etc. (Bangladesh country paper for habitat-III, 2016). The major government activities towards housing affordability are described below:

3.1. Existing Housing policy

The Government of Bangladesh considers housing as an inseparable part of human settlement, cultural and economic advancement. The government took the initiative to prepare Housing Policy of Bangladesh in light of the recommendations and guidelines declared in the First Human Settlement Summit, Vancouver Canada, 1976; Second Human Settlement Summit 1996, Istanbul, Turkey and recommendations from series of seminars organized during World Habitat Day since its inception in 1986 by United Nation.

In the United Nations Conference on Environment and Development (UNCED), also known as the Rio de Janeiro Earth Summit, 1992, United Nations strongly appealed to governments across the globe to implement the recommendations and declarations related to development of human settlements. In the context of guidelines and planning objectives mentioned above, the "National Housing Policy 1993" was approved in the Ministerial Meeting on 27th September, 1993. The "National Housing Policy 1993" was revised and updated in 1999. In this respect the modified "National Housing Policy 2016" has been prepared with the view to address the increase of population, decrease of per capita land, deterioration of environment and prevailing global context.

3.1.1. Vision and Objectives

• *Vision*

To ensure accessibility of people from all strata of society to suitable housing, and to improve housing and settlements towards sustainable development, equitable living standard, improvement of working environment and access of all to basic services and amenities considering health, security and affordable price to uphold equal right of all citizens.

• *Objectives*

1. To provide guidelines from the political, economic, social, environmental, technical, moral and psychological viewpoint to ensure suitable housing for all.
2. To implement the goals of housing development in the line of religious and cultural norms and values.
3. To reflect manifestation of declarations concerning housing from National Constitutions, charters of United Nation, international acts and human rights.
4. To ensure equal access of all in housing facilities irrespective of nationality, religion, language and dogma.
5. To have sustainable human settlement development.
6. To ensure economic growth, social development, conservation of environment, equitable distribution of housing, optimum utilization of resources, protection of biodiversity and cultural diversity and wellbeing and conservation of right of present and future generation.
7. Enhancement of living standard by consideration of infrastructural and spatial characteristics of rural and urban areas, arrangement, aesthetics, nature of land use, density of population, communication system and residential and civic amenities.
8. Conservation of buildings, local environment and ambiance having archeological, historic, religious, architectural and cultural importance.
9. To recognize and strengthen the status of family as a basic unit of the society.
10. To ensure availability of appropriate housing and basic service facilities through participation and involvement of public, private and voluntary agencies, community based organization, cooperatives, NGOs, individuals and community.
11. Accommodating underprivileged, neglected and distressed population of the society.
12. Adopting specific housing facilities for working women.
13. Optimum utilization of land in housing sector needs to be guaranteed through proper land management in order to improve the socio-economic condition of the country.
14. Provision of expert consultation in order to undertake income generating activities for low and middle income people with the objective to include them in the planned housing system and for socio-economic enhancement.
15. Financial institutes of Villages, Unions, Upazillas, sub-urban and urban areas need to be incorporated in financing of planned housing. In addition to involving foreign currency earners in the management of funds, it is important to encourage and support local and international investors.
16. In this modern era of globalization, information technology needs to be used efficiently in housing industry to endow the beneficiaries with social safety measures through planned housing.
17. Development of a cooperative based society by conglomeration of population through creation of cooperatives and to address housing need of mass population with minimum use of land and other basic needs.
18. Institutional, technological and financial support in housing in disaster prone areas to reduce disaster risk.

3.1.2. Salient Features of Housing Policy

House is not only a shelter, it has a multi-dimensional significance, it provides contentment and security to people, and it is an infrastructural component which demonstrates the social status of people. It has certain market value. This concerned policy is an indicator of socio-economic stability of the country. This policy is equitably applicable to all urban and rural areas of the country and the government is gradually adopting the supporting role in housing development under the purview of this policy.

Government will assess circumstantial consequences during the execution of housing development measures and will play a dynamic role to overcome the related procedural constraints. In this context, the role of individuals and groups are as decision makers and developers, whereas the government as provider of general guidelines, supports and opportunities.

3.2. Sustainable Development Goals (SDGs) and Bangladesh

Sustainable Development Goals (SDGs) refers to an agreement of the United Nations Conference on sustainable development to develop a set of future international development goals. On 25th September of 2015 leaders of 193 countries of the world unanimously adopted the post-2015 international development agenda for the period of 2015-2030. SDGs are the framework for global development after the terminal year (2015) of the Millennium Development Goals (MDGs). With 17 goals and 169 targets SDGs represents a bold new agenda to end poverty, fight inequality, tackle the adverse effects of climate change and ensure a sustainable future for all (Sustainable Development Goals and Bangladesh, 2015). Affordable housing is one of the targets of SDG's 11th goal. Government of Bangladesh took initiatives to achieve those targets.

4. Institutions and Organizations Working for Affordable Housing: Under Ministry of Housing and Public of Work

Ministry of Housing and Public Works is mandated organ of the government for ensuring "housing for all" and to deal with affordable housing. Under ministry of Housing and public works several organizations are working with the issue of housing affordability. These organizations are as follows:

- Housing and Building Research Institute (HBRI)
- National Housing Authority (NHA)
- Department of Architecture (DA)
- Public Works Department (PWD)
- Urban Development Department (UDD)
- Rajdhani Unnayan Kartripakkha (RAJUK)
- Chittagong Development Authority (CDA)
- Khulna Development Authority (KDA)
- Rajshahi Development Authority(RDA)

4.1. Drivers and Actors Working With Housing Policy and Housing Affordability

4.1.1. Housing and Building Research Institute(HBRI)

Housing and Building Research Institute (HBRI), which is the only national research institute to conduct researches on low cost reasonable building material in terms of decreasing the cost of construction in Bangladesh. Honorable Prime Minister provided some instructions to Housing and Building Research Institute (HBRI). During her visit on 28th December 2014 at Ministry of Housing and Public Works, she instructed the followings-

- Take mass initiative to disseminate the building materials developed by HBRI.
- Initiate proper planning to use the products developed by HBRI in appropriate places.
- Introduce Ferro-cement technology in shelter projects and rural housing projects.
- Take initiative to develop hollow block using river dredged soil.
- Take initiative to develop eco-friendly block using clay soil from river dredging.

Housing and Building Research Institute focuses on bringing innovation including alternatives to traditional bricks with a target of achieving zero use of agricultural top soil for brick production, and standardization of construction materials through research. Special emphasis are given for extension services to disseminate newly developed technologies and building materials which will be agriculture and environment friendly, disaster resilient and affordable. It has updated the Bangladesh National Building Code (BNBC) and on a pilot basis steps will be taken for construction of 75 low cost multistoried residential building at different villages during the 7th 5 year plan period. Among the targets of SDG's, the 11th goal is, by 2020, substantially increase number of cities and human settlement, adopting and implementing integrating policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for disaster risk reduction 2015 to 2030, holistic disaster risk management all levels.

In response to the aforesaid target, HBRI could undertake initiatives to develop alternative Building aterials aiming to reduce the use of agricultural top oil into zero, Alternative technology and innovation, romotion and extension, promotion Of pre-cast refabricated technology for housing and building onstruction, research and developments of ustainable and affordable housing. HBRI took the rojects to fulfill SDG target that also should be atisfied affordable home requirements, to who didn't fford typical stable home. Now, HBRI has been eveloping some alternative building materials that oincide with the aforesaid projects, taking into onsideration affordability, fire-resistive properties nd earthquake resiliency. Also, most of these aterials replace the use of traditional bricks which onsume agricultural top soil and thereby, reduce the rtility of land.

Adaptation of Affordable and Sustainable building Materials and Construction techniques

he customary building construction trend in angladesh usually focuses on the use of burnt clay icks for the infill and Reinforced Cement Concrete ame structures which are heavy in weight. In a oader perspective, they prove to be economically feasible. It has become a matter of concern to use ore lightweight materials in any construction, to make e process more cost effective by reducing the load of e structure.

n the other hand, development and construction of htweight pre-fabricated blocks and structural ements is a popular trend now a day in construction dustry all over the world. In this regard, Housing and ilding Research Institute is working towards venting more cost effective construction techniques ch as sand cement hollow block, compressed abilized sand block, thermal block, coconut coir board d ferrocement technology (FC sandwitch panel wall, cket footing, sand cement pavement block, cast situ pile, cast in-situ column, cast in-situ beam, ecast floor, cast in-situ tiles, precast folded plate, uver, door frame, pile, hollow column, benches (high ow), outdoor siting, dustbin and flower pot)

Interlocking: Compressed Stabilized Earth Block (CSEB)

establish the interlocking CSEB bricks in wall nstruction, HBRI has taken initiatives to complete a e storied building within an area of about 320 sft. The ccessful implication of interlocking bricks can be oved to be an exceptional substitute to burnt clay cks.

Special Features:

- Physical Properties:
  Size- 240 X 115 X 76 mm
  Weight- 3.95 kg
- Raw Material:
  Material – Cement (10%),
  River Dredged Soil (90%)
  Source- Kopotakkho River
  Location- Jessore
- Engineering properties:
  Compressive Strength- 4.4 Mpa,
  Water Absorption - <10%,

Advantages of CSEB:

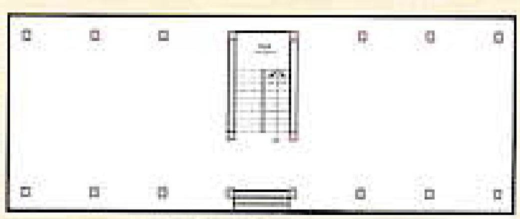
- Uniformed building component sizes.
- Use of locally available materials and reduction of transportation.
- Ferrocement Technology

A five story model house is built using alternative building materials innovated by HBRI. Not a single item of burnt brick is used in this technology. The model house has been designed with a RCC structure with fixed service zones, leaving the inner room arrangements on the user's choice. Ground floor has been kept free for multipurpose activities. Slabs, walls, doors, window frames and louvers are designed with Ferro cement technology.

Special Features 5-Storey House (Rural Type):

- Number of Floor- Five (5)
- Total floor Area-7583.30 ft2
- Foundation Cost- Tk 350.00 / ft2
- Floor Area Cost- Tk 1143.00 / ft2

- Technology used- Foundation – RC; Beam & Column – RC; Floor & Roof – Ferrocement Channel; Ground Floor– Soil-Cement Stabilized; Wall – Ferro-cement, 3D Panel & Sand-Cement Block, Staircase– Ferro-cement.



Ground Floor Plan

Typical Floor Plan

Complete ferrocement technology is used in the slab of the building instead of conventional RCC slab. The use of FC channel reduces the weight of the slab. Moreover, the process also abates overall construction cost about 30%-35% as well. On the other hand the technology is labor intensive which may create job opportunities and can contribute to reduce unemployment problem of our country. Ferrocement technology is used in the frame of door, window and in the louver of the building. Ferrocement 3D panel along with sandwich technologies are used in the walls as well. The staircase of the building also made with the ferrocement technology. Some views of staircase installation are shown in the pictures bellow.

- **Amphibious Housing System: Floating House**

The idea of using floating house allows human beings to experience life on water. Moreover, it is economic mitigation to implement in rural and low-income areas. To ensure safe housing amphibious housing system should be introduced. The concept of floating house has been originated to improve the economic and social condition of the people living under the threat of flood. This floating system has to be designed by using a suitable lightweight material which is strong enough, durable and sustainable. The house floating system need to be tested for its stability with acceptable tilting design tolerance during flood time.

To serve this purpose, HBRI has taken initiatives to combine research and housing techniques to build floating house. The system comprises lightweight materials and ferrocement technology.

➢ **EPS sheet: Floating house**

Special Features

- Wall – Expanded Polystyrene (EPS) with a Ferro-cement Cover.
- Pontoon – Expanded Polystyrene (EPS) with a Ferrocement Cover.
- Door – Ferrocement
- Window Frame – Ferrocement
- Plinth Area – 322 sft.

FIGURE: FLOATING HOUSE WITH EPS SHEET

➢ **Ferrocement Floating House**

Special Features

- Wall – Ferrocement
- Pontoon – Ferrocement
- Floor – Ferrocement Channel
- Roof – Ferrocement
- Corrugated Sheet
- Plinth Area – 15 sqm.

FIGURE: FLOATING HOUSE WITH FERROCEMENT TECHNOLOGY

➢ **Ferrocement Sandwich Panel**

A pilot project has been conducted on application of Ferro cement Sandwich in community kitchen and toilet.

Special Feature Ferrocement Sandwich Panel

- Total thickness of the concrete (water: cement: sand=0.45:1:3) on interior and exterior faces = 25 mm
- Sylhet Sand having F.M 2.2- 2.6 is used as fine aggregate.
- W/C= 0.45
- Iron wire mesh= 18 BWG with ½ " opening.
- Thickness of expanded polystyrene sheet (density-15kg/m3)= 56.25 mm
- Total finishing thickness= 100 mm

FIGURE: COMMUNITY KITCHEN AND TOILET WITH FC SANDWICH PANEL

➢ **Thermal Block**

Similar technology of Model house is used in the HBRI display center. In the partition wall, ferrocement sandwich panel and 3D panel are used but thermal block is used in the outer wall, Ferrocement Folded plate is used in the roof of the building.

Special Features of Display Centre:

- Number of Floor-Two
- Total floor Area -15,200.00 ft2
- Foundation cost- Tk 350.00 / ft2
- Floor Area Cost- Tk 1,415.00 / ft2
- Technology used-
- Foundation and frame: RCC ;
- Walls: Thermal Block, Sandwich Panel, 3D Panel; Floor: Ferrocement Channel;
- Roof: Ferrocement Folded Plate; Floor Tiles: Ferrocement
- Door/Window Frame, Water Tank: Ferrocement Technology

➢ **Other Affordable Materials Used by HBRI**

❒ **3D Panel**

Unlike concrete block, the 3D panel provides the insulation and reinforcement strength to concrete which makes it acceptable for residential or commercial construction (3D Panel). Another community kitchen and toilet has been built in the HBRI premise with 3D Panel.

Special Feature 3D Panel

- Total thickness of the concrete (water: cement: sand=0.45:1:3) on interior and exterior faces = 25 mm
- Sylhet Sand having F.M 2.2- 2.6 is used as fine aggregate.
- W/C= 0.45
- Woven wire mesh

FIGURE: COMMUNITY TOILET AND SHOWER WITH 3D PANELS

- Thickness of expanded polystyrene sheet (density-15kg/m3) = 56.25 mm
- Total finishing thickness= 100 mm

The monolithic structure of 3D panel enables it to withstand earthquakes, hurricanes and typhoons. Construction and characteristics of 3D Panel is similar to Ferrocement sandwich panel. Relatively thick mesh is used here so that it can be used as load bearing wall. In this type, mortar layer is thicker and that is why it can also be used as roof slab. This slab can be used three dimensionally.

➢ **Cellular Lightweight Concrete (CLC)**

Different trainings and workshops, organized by HBRI, would be held in this centre.

Special Features Training Centre

- Number of Floor- Two (2)
- Total floor Area- 8000 sft.
- Technology use
- Foundation – RC
- Beam & Column – RC
- Floor & Roof – Ferrocement Channel
- Ground Floor – Soil-Cement Stabilized
- Wall – CLC Block, sandwich Panel and Thermal block
- Floor Tiles – Ferrocement
- Plinth Area – 375 sqm.

4.1.2. National Housing Authority (NHA)

National Housing Authority has a vast area of development on Plot (residential / industrial); Flat (various size); Roads (connecting roads of housing estates); Play ground; Educational institutions (school / college); Health centers (Hospitals/ clinic); Community Hall and Park / Open space / Water body which led to community development. For sustainable housing development community facilities are mandatory and here NHA give equal emphasis. NHA not only fulfill housing need but also contributing towards strengthening communities through ensuring community facilities and housing development mechanism (Role of NHA for Strengthening Communities through Housing Development in Bangladesh, 2017)

Some of the other works of NHA relating housing are:

- National housing authority has been working for housing, people from all classes can afford. NHA already took some projects to ensure secure household for people who doesn't possess any home especially for slum dwellers.

- Eleven projects have been implemented in housing sector by National Housing Authority, three of those are about construction of flats and others are about plot development. From those Projects, 650 flats have been constructed and 3214 plots have been developed including 360 flats for Government officers and 180 plot development projects.*
- "Ensuring improved quality of life" project for lower income group.
- Construction of 900 residential flats for the lower income group of people in Mohammadpur F block.
- Construction of 14 storied building with 100 numbers of flats of about 1,250 sft area in number 15 section at Mirpur.
- Construction of residential buildings in Shahjalal Housing estate in Sylhet.
- Construction of 10 storied residential and industrial buildings in Dinajpur Housing Estate.
- Construction of residential building in government's land in Cox's Bazar.
- Development of 128 numbers of residential plots for low and middle income group of people in Patuakhali zila.
- Construction of 1000 number of residential flats for middle income group of people in Mirpur-9.

4.1.3. Department of Architecture (DoA)

Department of Architecture has prepared 10 structure plans of physical infrastructure projects of national importance under different ministries and departments under the ministries, which include multistoried residential buildings, court buildings, Muktijudda Bhaban at district levels, monuments at different places of liberation war and hospital constructions.*

4.1.4. Public Works Department (PWD)

During the last three years, four, 45,600 square feet new buildings have been constructed and construction areas of 23 million square meter government have been repaired. Two environment friendly sewerage treatment plants have been constructed and rain water harvesting activities of five projects have been completed. Training Academy and Testing Laboratory Buildings including ancillary constructions have been done and 1500 officers/staffs have trained in the Academy. In addition, 300 structural plans have been formulated, preservation of park/playground of 650 acres has been done and about 5 K.M. connecting roads have been built.*

Some of the other works of PWD relating housing:

- High story residential buildings construction in the government colony located in Ajimpur, Dhaka.
- High story residential buildings construction in the government colony located in Motijheel, Dhaka.
- 1064 numbers of residential flat construction for the government employees in Mirpur 6, Dhaka.
- 608 numbers of flat constructions for the government employees in Paikpara, Mirpur, Dhaka.
- 456 numbers of residential flat constructions for the government employees in Malibag, Dhaka.
- Construction of residential buildings for the Ministers of Government (Ministers apartment-3) in Baily Road, Dhaka.
- Construction of 288 numbers of flat for the officials of PWD in Mirpur 6, Dhaka.
- Construction of 398 governments residential flat in 20 different abundant plots in Gulshan, Dhanmondi and Mohammadpur, Dhaka.
- Construction of Government residential flats and dormitory in abundant plots in Chittagong.

4.1.5. Rajdhani Unnayan Kartripakkha (RAJUK)

RAJUK has handed over 12,000 residential plots at new Purbachal City, 6000 residential plots under Uttara 3rd Phase project and 700 residential plots under Jhilmil project.

- Jhilmil Residential Area: This housing project is located at Keranigonj across the Burigonga River. The Project area comprises of 381.11 acres of land.There will be about 1740 residential plots and 9,500 apartments for lower and middle income groups with available necessary infrastructure and urban services.
- Uttara Apartment Project: This Project has been accepted categorically by ECNEC under Uttara (3rd Phase) Project, RAJUK on 25th April, 2000. In line with the categorical acceptance a DPP for Construction of around 22,000 apartments for middle and lower income group of people at sector-18, Uttara, Dhaka has been recommended at inter-ministerial meeting at ministry of Housing and Public Works on 28th February, 2010. Project Duration: Nov/2011 to June/2016. It is the ever largest Planned Apartment Project in the country

having 214.44 acres of land at Uttara (3rd Phrase) Project, Sector-18, Uttara, Dhaka for Low and Middle Income group of people. Approximately 240 nos. 16 storied Apartment Building including one basement floor comprising about 20,160 nos flats were supposed to be constructed.

- Detailed Area Plan DAP: The general objectives of DAP are to implement the provisions of the DMDP Structure Plan (SP) and Urban Area Plan (UAP) policies and recommendations. The preparation of DAP is to be based on detailed surveys, studies and analysis of the study area. The DAP process are to be prepared and implemented through community participation to make the planning more people oriented.

- Purbachal New Town: It is the biggest Planned Township in the country. The Project area comprise of about 6150 acres land located in between the Shitalakhya and the Balu River at Rupgonj thana of Narayangonj district and at Kaligonj Thana of Gazipur district, in the north-eastern side of Dhaka. The Township will be linked with 8(eight) lane wide express way from the Airport Road/Progati swarani crossing. The distance is only 6.8 km. There will be provision of about 26,000 residential plots of different sizes, 62,000 apartments with all necessary infrastructure and urban facilities. RAJUK intends to plan and develop the area as self-contained New Township with all modern facilities and opportunities. 38.74% land used for Residential, 25.9% for Road, 6.41% for Administrative and Commercial, 3.2% for Institution and Industrial Park, 6.6% for urban Green and Open spaces, 7.1% for Lakes and canals, 2.5% for sports, 6% for Education, Health and Social Infrastructure.

- Uttara Residential Model Town (3rd phase): Site development: About 92% site development works is completed. Remaining works shall be completed by March, 2018.

- Construction of high storied "Green Building" in Mohakhali, Dhaka.

4.1.6. Rajshahi Development Authority (RBA)

Rajshahi development authority has completed land acquisition work for its own financed project titled 'Expansion of Banalata Commercial Area and Development of Residential Area' and 193 residential plots have been distributed to the people."

Conclusion

Bangladesh has recently been upgraded from low income country (LIC) to lower-middle income country (LMIC) as per the World Bank's classification in 2014. Per capita income of Bangladesh finally rose to US$1,316 in the last fiscal year, up from provisional estimate of $1,314. According to the World Bank criteria, Bangladesh will be recognized as a middle-income nation if it achieves at least an average per capita income of $1,045 for three consecutive years. Per capita income was $1,190 in FY14 and $1,154 in FY13. With this tremendous news there is another side which describes the high cost of construction techniques. With high population growth the challenge of housing affordability is not new. Affordable housing means when monthly housing cost is in between 30% of total monthly earnings. Present housing system exceeds this limit for the people willing to build or rent a house for them. High construction price as well as high rate of building materials exacerbates the situation. However, the conventional brick production process damages the agricultural land, emits greenhouse gases as well as threatens the food security of the country. To keep up the pace with the modern propensity development of lightweight, cost effective as well as enduring materials for future construction has turned out to be a requirement for the construction system of Bangladesh. In this circumstances, Housing and Building Research Institute, the only government research institute, is working for the development of alternative, cost effective, environment friendly and disaster resilient building materials and construction techniques. HBRI promotes the motto of moving towards alternative materials and construction techniques, which can promote more sustainable and affordable housing.

References

1. Sadeque., M. A. (2016, October 3). Affordable Housing for All. World Habitat Day- Housing at the Center, pp. 46-52.
2. Souvenir: Alternative Building Materials 2017, HBRI.
3. Bangladesh Country Paper for Habitat III. Dhaka: Urban Development Directorate, 2016.
4. Islam. N. (1991), Bangladesh Grehayon Poristhiti.
5. National Housing Policy 1993, Ministry of Housing and Public Works.
6. National Housing Policy, 2016, National Housing Authority.
7. Ministry of Housing and Public Works. (2016). Retrieved from https://www.mof.gov.bd/en/budget/16_17/mtbf/en/32_Ministry%20Housing_English.pdf

8 Bangladesh Population 2017. (2017). Retrieved from World Population Review: http://worldpopulationreview.com/countries/bangladesh-population/(2017).

9 Role of NHA for Strengthening Communities through Housing Development in Bangladesh. Dhaka: NHA.

10 Gazi Mohammad Hasan Jamil, M. A. (2010). Housing for Low Income People in Bangladesh: Problems and Prospects. Dhaka: Daffodil International University.

11 Habitat for Huminity. (2017). Retrieved from Housing poverty in Bangladesh: https://www.habitatforhumanity.org.uk/what-we-do/where-we-work/asia-and- pacific/bangladesh.

12 Haque, M. S. (2007). Shelter Design and Development- Bangladesh Perspective: In search of Sustainable Shelter for the Urban Poor. Ministry of Housing & Public Works, Bangladesh.

13 Loton, S. H. (2004). Low-Income Communities: Facing the problems of adequate housing in Bangladesh agenda: Emerging issues. Adequate & Affordable Housing for All: Research, Policy, Practice. Toronto: University of Toronto.

14 Mohit, M. A. (2012) 'Bastee settlements of Dhaka City, Bangladesh: a review of policy approaches and challenges ahead', Procedia-Social and Behavioral Sciences. Elsevier, 36, pp. 611–622.

15 Nawaz, R. (2004). Right to shelter: Bangladesh. Adequate & Affordable Housing for All: Research, Policy and Practise. Toronto: University of Toronto.

16 Official Documentation: Retrieved from habitat III: http://habitat3.org/the-conference/official-documentation/

17 Sarkar, M. (n.d.). Urban Housing Sector in Bangladesh: A Law and Policy Review in the Context of Affordable Housing for the Low- and Middle-Income Households in Dhaka. Dhaka: Bangladesh Infrastructure Finance Fund Limited.

18 Shahriar Shams, M. M. (2014). Housing Problems for Middle and Low Income People in Bangladesh Challenges of Dhaka Megacity. Environment and Urbanization Asia, pp. 175- 184.

19 Dhaka Population 2017. World Population Review. [Online] http://worldpopulationreview.com/world-cities/dhaka-population/.

20 2011 Bangladesh census, Wikipedia: https://en.wikipedia.org/wiki/2011_Bangladesh_census.

21 Bangladesh Geography 2017, https://theodora.com/wfbcurrent/bangladesh/bangladesh_geography.html

22 Bangladesh Population and Housing Census 2011(June 2015). Bangladesh Bureau of Statistics.

23 Census of Slum Areas and Floating Population 2014 (2015). Bangladesh Bureau of Statistics (BBS).

24 World Population Prospects,United Nation (2017) United Nations, Department of Economic and Social Affairs, Population Division. doi: 10.1017/CBO9781107415324.004.

25 Zila report: dhaka, Bangladesh Bureau of Statistics (BBS) (2015).

AMPHIBIOUS HOUSING SYSTEM FOR THE PEOPLE LIVING IN FREQUENT FLOOD AFFECTED AREAS: FLOATING HOUSE

Mohammad Abu Sadeque PEng., Md. Abdus Samad, Rubaiyet Hafiza, Mohammed MasbhaUddin

ABSTRACT

This paper presents a comprehensive review on the construction process of floating house. This study is intended to contribute to risk reduction of floods, through manufactured innovation in floating house model, and develops a new setting of waterfront settlements that are healthy, safe, ecological and relatively inexpensive. The initiative has been taken by the Government organization, Housing and Building Research Institute, to construct an edifice with the facilities of toilet and kitchen. This paper comprises the procedures and steps taken to assemble the arrangements for providing living facilities for flood stricken people and especially for the people of haor areas of the country. The structure built with expanded polystyrene accompanied with ferrocement technology, is extremely light as well as rigid, so with a reduced seismic mass it could float easily on water.

1. Introduction

Since the beginning of human civilization is likely to evolve in the waterfront area, such as a river, lake or ocean. The edge of a pedestal region becomes the main human settlements. As a result of global warming the tide gauges, as well as may increase change the cycle of the seasons. In recent years the impact had the power to sink the water's edge deep into the ground. In Bangladesh, coastal cities are facing the possibility of flooding from river and sea level rise, as well as an increase in pluvial floods. Population growth and environmental aggravation by urbanization have increased vulnerability to floods. Because of the growing population in the urban areas, accommodation system has been spreading out in converting rural lands into urban domains. Furthermore, because of the global warming and climate change, the intensity and frequency of floods start to rise dramatically. Destructive behavior of this phenomenon force researchers to investigate for new solutions. The idea of using floating house allows human beings to experience life on water. Moreover, it is economic mitigation to implement in rural and low-income areas. To ensure safe housing amphibious housing system should be introduced. The concept of floating house has been originated to improve the economic and social condition of the people living under the threat of flood. This floating system has to be designed by using a suitable lightweight material which is strong enough, durable and sustainable. The house floating system need to be tested for its stability with acceptable tilting design tolerance during flood time. To serve this purpose, HBRI has taken initiatives to combine research and housing techniques to build a floating house. The system comprises lightweight materials and ferrocement technology.

2. BACKGROUND OF THE STUDY

2.1. CONCEPT OF FLOATING HOUSE

Coastal cities are facing the possibility of flooding from river and sea level rise, as well as an increase in pluvial floods. On top of this, land scarcity is another of the problems that urban planners have to face. The concept of floating house has been adapted to limit these two rising problems related to housing system of Bangladesh. Migration of coastal population to the urban areas is being caused due to the annual flooding which shatters the overall living condition of the people of those particular areas. Replacing present housing system of coastal regions with well-developed floating house structures could be a substitute solution in the time of flood. This perception helps the house to float with increased water level. After draining of flood water it can be placed wherever apposite area could be found.

2.2. PRINCIPLE OF FLOATING

The driving vertical force is due to the weight of an object on the water, such as Archimedes' principle: any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object. The balance principle applies to the floating house. The float condition is due to of the enforcement balance of vertical force, and will experience movement or shock by tensile lateral force due to river water stream pressure or flooding. The water surface is dynamic, whose condition is greatly influenced by the flow of its generator that causes the horizontal and vertical thrust force. The horizontal thrust is caused by differences in elevation, the wind blowing on the water surface that bring forth the flow of waves, and also generated by moving objects (boats, and so on). The tensile force of galactic objects, especially the sun and the moon to the earth, generates the tide of the sea, or the extreme by tsunamis that occurred because of volcanic eruptions or tectonic earthquakes at sea.

3. AIM OF THE STUDY

The aim of this research is to develop an amphibious housing system, which can float during flooding by using the special lightweight EPS pontoon within ferrocement technology in floodplain areas in Bangladesh.

- To evaluate alternative sustainable flood mitigation strategies in Bangladesh;
- To evaluate the suitability of using amphibious house system as a flood mitigation strategy in Bangladesh;
- To evaluate suitable lightweight material for pontoon design;
- To develop the conceptual design of amphibious house system.

4. SIGNIFICANCE OF THE STUDY

Housing and Building Research Institute has taken some initiatives to solve the hitches related to the housing system of Bangladesh. The prevailing construction trend involves Reinforced Cement Concrete and burnt brick as infill walls which are heavy in weight. HBRI has promoted alternative building materials to reduce the use of burnt clay bricks to save the agricultural land. In search of new housing technology, HBRI has come up with improved and well-designed floating house method which can accommodate families of flood affected areas. This study aims to achieve defined design criteria of floating house by involving recent research techniques conceived by HBRI. This research and its findings will encourage the use of the new approach to produce lightweight housing system. The current project is able

- To produce a new potential structural composite, that is an integration of ferrocement and expanded polystyrene for modular floating housing and building system which can be developed and marketed nationally and internationally.
- To develop a novel method oflight weight construction resulting in a cost effective production.
- To help solving the housing problem of low and middle income earners especially people from flood affected areas.

5. DETAIL OF THE PILOT PROJECT

As stated earlier, that a pilot project has been conducted on floating house at HBRI's pond which is situated in the west side of the main building. A living space had been provided with a kitchen and bathroomwith approximately 200 sqft floor area.

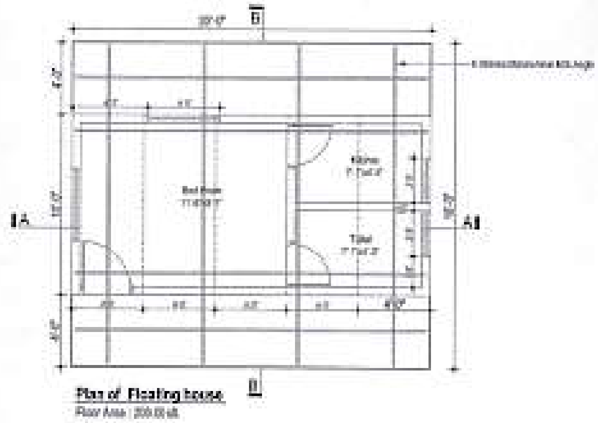


FIG 1: FLOOR PLAN OF THE PILOT PROJECT

The house consist a bedroom, a kitchenand a toilet. Ferrocement sandwich panels were applied on the overall outer surface as well as interior walls for better heat and sound insulation purposes.

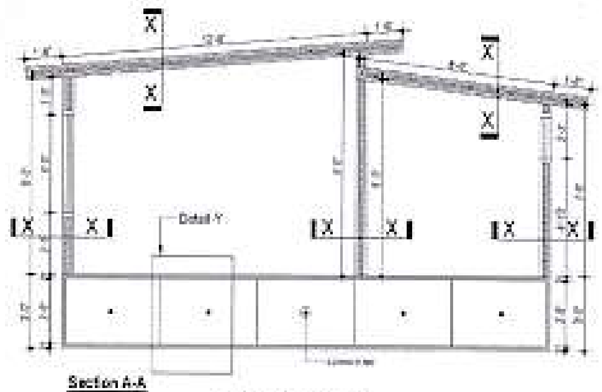


FIG 2: SECTIONS

The lightweight floor had been prepared with EPS sheet covered with ferrocement layer.

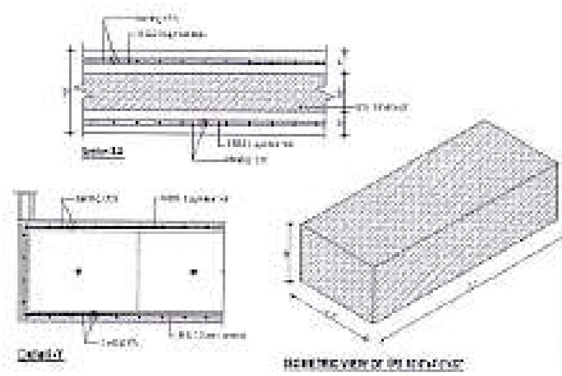


FIG 3: EPS PONTOON INCORPORATED WITH FERROCEMENT TECHNOLOGY

6. CONSTRUCTION MATERIALS AND PROCESS

6.1. CONSTRUCTION MATERIALS

- Expanded Polystyrene (EPS) sheets (with 2.25" and 32" thickness)
- Binding wire
- Woven wire Mesh (18 gauge)
- Chalk marker
- Portland Composite Cement
- 3"X3" clamp
- Sylhet sand as fine aggregate (FM 2.9)
- Screw
- Potable water
- Royal plug

The following construction materials were used for the construction

6.2. CONSTRUCTION AIDS AND TOOLS

The following aids and tools were used for the construction

- Masonry trowel of medium size
- Aluminum scale
- Square rammer
- Spirit level
- Nylon cord
- Plumb Bob
- Spades
- Drill machines
- Binding hook
- Bucket
- Wire mesh cutter
- Mixing pan

6.3. CONSTRUCTION PROCESS

6.3.1. PREPARATIONOF THE PONTOON

Several EPS sheets were joined to achieve a size of 10'×4'× 32"to make the pontoon. Five 20mmØ MS rod had been placed inside from the side of the EPS to increase the stiffness of the sheet. To prepare the outer layer first 12mmØ MS rods were placed in both ways of the sheets at 10"c/c. Thenthe sheet was enfolded with 18BWG two layer wire mesh had been positioned to prepare the ferrocement skeleton. To increase the stiffness of the joint areas, two 12mmØ MS rods had been placed both side maintaining 6" gaps from the joint. Then 12" binders were placed at 6" c/c to connect the ring rods. This procedure was continued only in the joint areas. To complete the FC layer, mortar was prepared in a clean surface using Portland composite cement and Sylhet sand with FM value of 2.90. Mixing ratio for ferrocement is very important and was strictly followed. The water: cement: sand (W: C: S) ratio for ferrocement were first evenly mixed; the required quantity of water was added afterwards. Mortar was gently placed on prepared surface of EPS sheet.

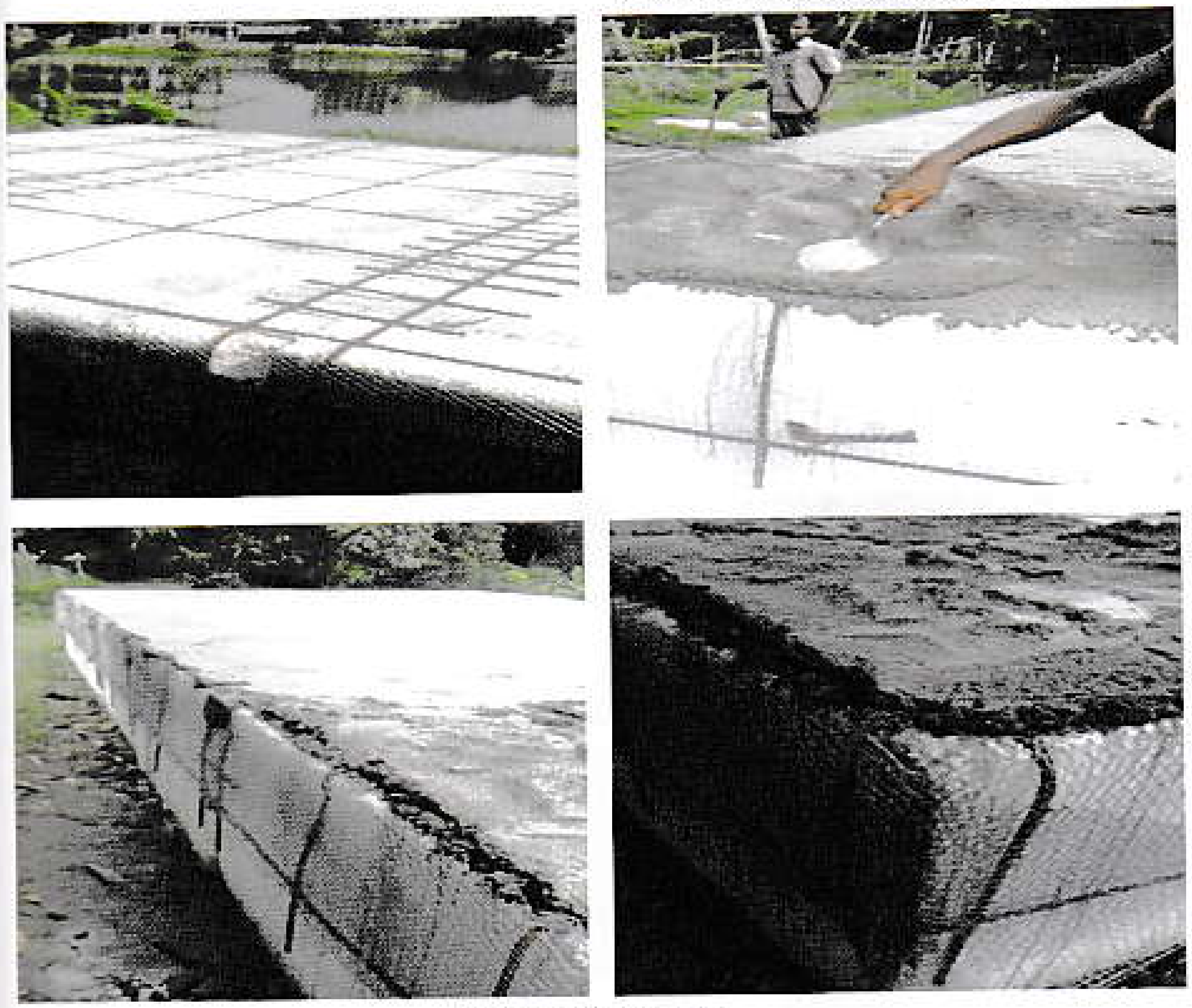


FIG 4: PREPARATION OF PONTOON

FIG 5: COMPLETE PONTOON

6.3.2. CASTING OF WALLS

The two lines of 10mmØ @12" c/c angles were used to place. These lines had at least 3.5" gap to install 2.5" EPS sheet in between the MS rods. The EPS sheets were then placed between the rods. The mesh was placed gently on both surface of the EPS sheet. Firstly mortar was placed on one side (say side 1) of the EPS sheet. Other side (side 2) was then supported by flat wood and bamboo so no displacement occurred. After completing 3 to 4 feet on one side, casting was started to side 2 of the wall after half an hour and double height of side 1 was achieved. It was then left for next day.

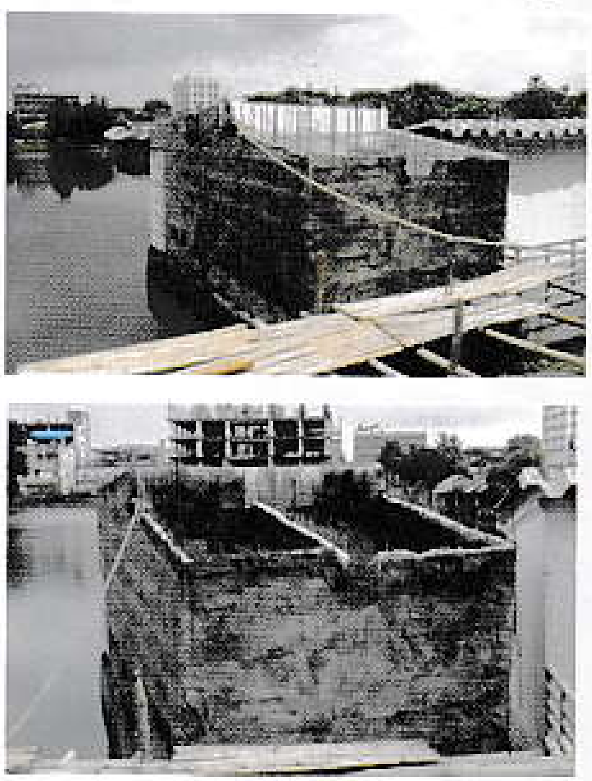


FIG 6: PLACEMENT OF WALLS AND MORTAR

Next day water was sprayed on previous day's casted surface. Water was sprayed each hour of the day and it was maintained for continuous seven days. The placement procedure is called bottom up process and masonry trowel was used for the application. The mortar thickness was maintained slightly below ½ inch on both sides of the sheet. When the mortar was slightly hard, approximately after ½ hour of placing mortar, final thickness of 1/2" was achieved neatly.

6.3.3. COMPLETION OF THE ROOF

EPS sheet were prepared same as it was for the wall. After placing those on top of the walls mortar had been smoothly placed.

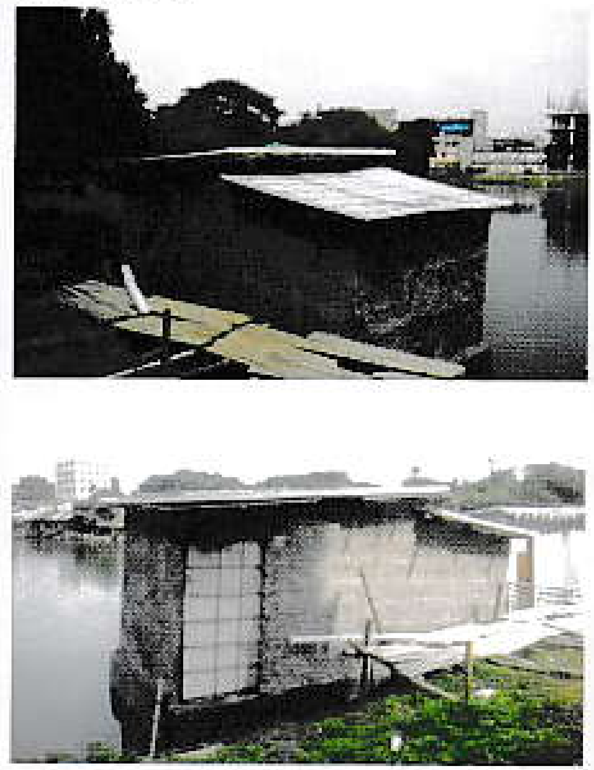


FIG 7: PLACEMENT OF ROOF

The inside mortar placement was done first then the outer roof top had been completed.

FIG 8: FINISHED FLOATING HOUSE

7. CONCLUSION AND REMARKS

7.1. DEVELOPMENT AND APPLICATION

Above described technique was a pilot project at HBRI. Once it is mastered, several improvements can be undertaken

- Commercial plasticizer can be used to augment the workability of the mortar mix and to reduce the water content thus enhancing the mortar strength.
- Precast wall panel can be made in the factory and it can be transported to the site to fix.
- For precast panel, standard sized panel can be made and there should be groove on each panel to fix with the other.
- EPS can be replaced with any other light-weight materials such as shot Crete, aerated concrete.

7.2. PROBLEMS FACED DURING CONSTRUCTION AND SOME POSSIBLE RECOMMENDATIONS

- Installation of wooden frames for doors and windows are complex compared to brick masonry wall.
- Hard to control good workmanship due to manual handling of materials.
- Possibility of lateral bending during the casting procedure if proper care is not taken.

Further research initiative has been undertaken at HBRI to overcome the problems associated with the practical use of floating house. Comparative analysis of cast in situ and precast technique will help to find appropriate solutions to the problems.

8. ACKNOWLEDGEMENT

This study was done as a part of regular research program of Housing and Building Research Institute. The authors would like to acknowledge the kind cooperation provided by the staff of HBRI.

REFERENCES

1. RAFTA 2011, the Innovation of The Manufactured Floating House Model: A New Concept of Waterfront Settlements for Flood Risk Reduction In Indonesia, Karyadi Kusliansjah, Yasmin Suriansyah. 2013, The International Journal of Engineering And Science (IJES), pp. 18-29.

ADVENT OF AN AGRO FRIENDLY APPROACH IN BANGLADESH

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ABSTRACT

Bangladesh is predominantly an agrarian entity with a rural population of 72%. Although the country is gradually shifting from rural to urban with a level of urbanization of 28% and a growth rate of 3.5% per year (Population and Housing Census 2011, BBS). Based on the UN population projection model, Bangladesh would achieve 'the tipping point' of 50% urban by 2047. Under the current trend of urbanization, industrialization, and river erosion, the country is reported losing1% of its arable land, or 82,900 hectors each year (The Daily Star, 01.11.03)and theroot causeis unplanned rural housing(approx.80%).Another 20% is due tobrick field construction(17%) andunchecked urbanization and industrialization (3%). Conventional construction trend in Bangladesh largely relies on fired bricks, which is responsible for 25% of total national greenhouse gas emission. As per COP 21, in its INDC Bangladesh pledged an unconditional 5% greenhouse gas emission cut by 2030.It is estimated that, only an alternative to fired bricks can cut the emission by 10% within next five years. Considering all these, Housing and Building Research Institute (HBRI) under the Ministry of Housing and Public Works, Government of Bangladeshis working relentlessly in this regard from its inception. The institute focuses on bringing innovation including alternatives to traditional fired bricks with a target of achieving low carbon footprint, zero use of agricultural top soiland standardization of new construction materials through applied research.As for instance alternative materials like non-fired compressed stabilized earthen blocks from river dredged soil, thermal block, sandwich panel, cellular light weight concrete, sand-cement hollow block, coconut fiber reinforced boards, water hyacinth board, ferrocement technology etc. are being developed and under constant research. Therefore this paper focuses on the intense initiatives undertaken by HBRI's act of innovation regarding alternative and sustainable building materials ensuring an agro friendly technology, providing food security, enabling disaster resilience and overall an environment friendly approach.

Key Words: agriculture, environment, alternative building material, construction technology, sustainability, disasterresilience.

1. INTRODUCTION

21ST Century has fueled a kinetic phase for Bangladesh unknown to her at any previous historic times. Here the pre-dominant agrarian economy is giving way to boosting industrialized economy; rural grounds are experiencing urbanization in an unprecedented scale and pace. The current process of unplanned and unregulated developmental activities, is taking its toll on our environment and limited natural resources.

Land,a fundamental resource base for agriculture, fisheries, industry and other economic activities, providinghuman and natural habitat as well is under constant threat of declination. However, agricultural land of the country is decreasing at an alarming rate. Indiscriminate settlement and industrialization is aggravating land conversion hence reducing farm production, leading to national food shortage for an increasing population.The customary building construction trend is another major contributor tothis phenomenon.In Bangladesh construction usually focuses on the use of burnt clay bricks and reinforced concrete which are not environment and agro friendly. It has been estimated that every year Bangladesh produces 25 billion clay burnt bricks using 60 million tons of agricultural top soil.Studies claim that, Bangladesh is losing 1% of agricultural land every year; 17% is due to clay burnt brick production and construction of brick kilns, whereas approx.80% is due to unplanned and unregulated rural housing and rest 3% is for unchecked urbanization and industrialization.A very pertinent question in this context can be whether the existing construction system has the potential to be improved and adapted to meet the perpetual extremities of nature and ever depleting natural resources?

2. AN OVERVIEW OF LAND MORPHOLOGY IN BANGLADESH:

Bangladesh is principally an agricultural country, characterized by ricepaddy agriculture dominated landscapes. So, land resource is the major asset contributing wealth and livelihood in rural areas, although land-man ratio is very low, estimated to be 0.06 hectares (ha) per person (FAO, 2013). The total area of Bangladesh has risen in the last few decades, i.e. an increase is noted from 144,873km2 in1976 to 145,306 and 145,778km2 over the years of 2000 and 2010respectively. The overall gain of land is 90,512ha primarily due to accretedlands in the southern coastal zone.The land resource of the country is divided into two categories, i.e. agriculture lands and non-agriculture lands.However, a declining trend was observed for the total agricultural lands of the country,i.e. a decrease is noted from 91.83% in 1976 to 87.69% and 83.53% over theyears of 2000 and 2010 respectively.A total of 561,380ha agricultural lands were decreased during 1976-2000 and this figure was increased to565,370ha during 2000-2010. Yearly average loss of agriculture lands were\ 23,391ha and 56,537ha during 1976-2000 and 2000-2010 respectively. The non-agriculture lands of the country were 8.17%, 12.31% and 16.47% during 1976, 2000 and2010 respectively. The extent of non-agriculture lands were increased by2.13% and 3.43% during 1976-2000 and 2000-2010 respectively. Annualland loss from crop agriculture is 68,700ha, where land gained in ruralsettlement, urban and industry, and aquaculture is 30,809ha, 4,012ha and3,216ha respectively during 2000-2010.

Table 1.1 Availability of agricultural land during 1976-77 to 2010-11 (source: BBS, 2011).

YEAR	LAND AREA OF BANGLADESH(million hector)	CULTIVABLE LAND(million hector)	% CULTIVABLE LAND
1976-77	14.28	9.39	65.75
1980-81	14.29	9.38	65.64
1985-86	14.48	9.44	65.19
1990-91	14.84	9.72	65.50
1995-96	14.84	8.72	58.76
2000-01	14.85	8.40	56.57
2005-06	14.84	8.42	56.74
2010-11	14.84	8.52	57.41

3.2 ENVIRONMENTAL IMPACT

Construction impacts last for decades and affect the lives of current and future generations. Buildings consume major global resources. Almost 50% of global energy is consumed in buildings, while 50% water, 60% materials for buildings, 80% land loss to agriculture, 60% timber products, 90% hardwoods are all directly linked with building construction. Indirectly 50% of coral reefs destruction and 25% of rain forest destruction are all attributed to buildings and construction. (U.S. Environmental Protection Agency).Brick industry emits 8.75 million tons of green gas (GHG) annually and consume 2.2 million tons of coal and 1.9 million ton of firewood annually. Around 30 percent of brick kilns use firewood illegally aggravating deforestation. (The independent)

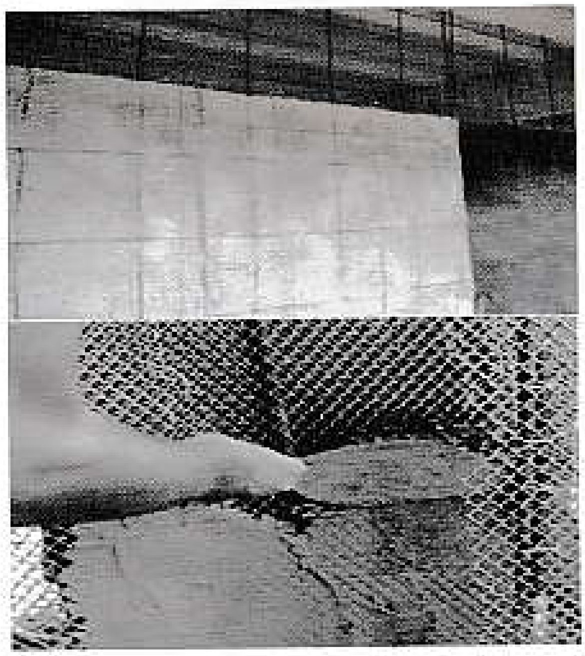
4. ADVENT OF A NEW APPROACH_ALTERNATIVE BUILDING MATERIAL AND CONSTRUCTION TECHNOLOGY DEVELOPED BY HOUSING AND BUILDING RESEARCH INSTITUTE:

Housing and Building Research Institute, HBRI, is an autonomous organization under the Ministry of Housing and Public Works, Government of Bangladesh, with a constitutional framework of 18 members of a Governing Council headed by the Hon'ble Minister in charge of the Ministry. It runs by the allocation of Government grants from the revenue fund. Since beginning, all the Divisions of the Institute rendered useful contributions in the field of housing. It renders extension services in the form of consultancy, laboratory testing and planning pertaining to building activities in both public and private sectors. The Institute is the only National Research institute, which is entrusted to conduct research in housing problems, innovation in construction materials, technology and planning.

In Bangladesh, land, a fundamental resource base for agriculture, fisheries, industry, economic activities, providing human and natural habitat is under constant threat of declination. Indiscriminate settlement and industrialization is aggravating land conversion hence reducing farm production, leading to national food shortage for an increasing population. The customary building construction trend is another major contributor to this phenomenon. Here construction usually focuses on the use of burnt clay bricks and reinforced concrete which are not environment and agro friendly. It has been estimated that every year Bangladesh produces 25 billion clay burnt bricks using 60 million tons of agricultural top soil.

4.1. WALL ELEMENTS:

4.1.1. FERROCEMENT



Specific Feature:

Raw Material:

- Cement
- Sand
- Wire Mesh
- MS Bar

Engineering & Physical Properties:

Cast-In-situ:

- Cement:Sand=1:2.
- Sylhet Sand (F.M 2.2- 2.6)
- W/C=0.45.
- Iron wire mesh= 2-layers of 18 BWG

or 20 BWG with ½" opening.

- Skeleton rod=8mmφ(both way) @2"c/c.

Precast:

- Cement :Sand=1:2
- Sylhet Sand (F.M 2.2- 2.6)
- W/C=0.38-0.45
- Iron wire mesh= 2-layers of 18 BWG or 20 BWG with ½" opening.
- Skeleton rod=8mmφ(both way) @2"c/c.

4.2. ROOFING ELEMENTS:

4.2.1. PRECAST FERROCEMENT U-CHANNEL

Raw Material:

Cement, Sand, Wire mesh, MS Bar

Physical Properties:

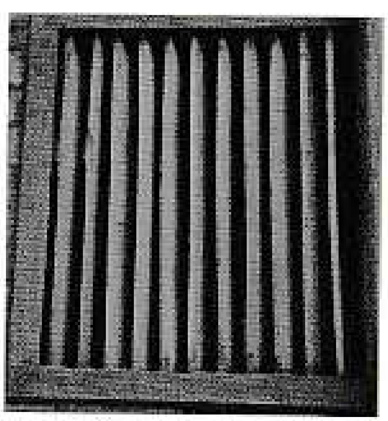
- Width:600 mm(including rib portions), Length:3800mm (Can be changed as per requirement)
- Thickness: Flange thickness:25mm Rib Thickness:50mm

Engineering Economy:

- Economic w.r.t Conventional RC Slab

4.5. MISCELLANEOUS ELEMENTS:

4.5.1. PRECAST FERROCEMENT LOUVER



5. APPLICATION OF ALTERNATIVE BUILDING MATERIAL AND CONSTRUCTION TECHNOLOGIES:

5.1. MULTISTORIED HOUSE (RURAL TYPE I)

Special Features:

- Building Type: Residential
- Foundation: RC
- Beam & Column: RC
- Floor & Roof: Ferrocement Channel
- Ground Floor: Soil-Cement Stabilized
- Wall: Ferrocement, 3D Panel & Sand-Cement Block
- Staircase: Ferrocement
- Plinth Area: 130 sqm.
- Status: Completed
- Location: HBRI Premises

7. CONCLUSION

As Bangladesh is a land hungry country, we need to think carefully regarding the optimum utilization of its natural resources. In order to do so, fostering application and improvement of alternative technologiesin the construction sector should be emphasized. Lesser environmental impact, more agriculture and environment friendly approach and promotion of a disaster risk reduction culture can offer a sustainable solution.

UBLIC TOILET & WAITING FACILITY AT HBRI

Mohammad Abu Sadeque PEng, Ar. Tamanna Rahman, Research Fellow, HBRI
Ar. Mohammad Tosnimul Hassan, Research Fellow, HBRI

LIC TOILET & WAITING FACILITY AT HBRI

ROBLEM STATEMENT:

ka, one of the fastest growing cities in world, bears a population of over 15 on. About 2 to 3 million people commute ugh this city everyday using the major y points of Gabtoli (Technical mor), dabad, Sadarghat and Uttara. Thus hnical mor (crossing), has become one of busiest arterial roads of the city, erating a huge amount of inter and intra traffic. Lack of civic amenities like sable and hygienic footpaths, public toilet waiting facility for pedestrian and long e passengers affect the physical ronment of the area. Here walkability public health concern is in serious ardy as commoners experience nveniences due to frequent open ation. In addition, the absence of any ted waiting space for daily commuters se in on-street gathering of people that uently obstructs general pedestrian and cular flow . Though walkability is an ortant concept in sustainable urban ronment, this particular urban area iates from the least minimal standard. sing and Building Research Institute RI), an autonomous research organization located adjacent to the Technical mor, upon comprehending the issue felt the necessity to think of a resolution and has formulated some context specific ideas in the form of a micro-public-hub in this busy urban scape.

TECHNICAL MOR LOCATION AND EXISTING CONDITION

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