# USE OF MUD CONCRETE IN COLD CLIMATIC REGIONS

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**Abstract -** *Vegetation and moisture trapping soils that make up the natural surfaces absorb solar energy to aid evapotranspiration. Evapotranspiration makes the surrounding air cooler as water vapours are released during the process. But built surfaces absorb significant amount of solar energy as they are made up of high percentages of non-reflective, water resistant materials. Eventually this absorbed solar energy gets reflected as heat to the microclimate. Built environment is made up by replacing the natural environment by artificial one. In reducing the hazards faced by the natural environment the modern concrete technologies are inadequate. Consequently the world should look for more natural and environmentally-sound materials that can be employed for construction works. Soil being such a building material that can be used for environment friendly constructions. Heat absorbance by earthen materials is comparatively higher than that in case of concrete and hence they can be used as thermal mass. Also evapotranspiration of water is facilitated in a better way by earth materials than by concrete.*

***Key Words***: Solar energy1, Evapotranspiration2, Environment3, Microclimate4, Thermal mass5, etc.

## 1. INTRODUCTION

This Concrete is the most popular man-made construction material being used in the world and is the second most utilized substance in the world. Concrete can be procured by blending of cementing materials, water and aggregates and sometimes admixtures as well. When we place this mix in forms and allow it to cure, it hardens into a firm solid material known as concrete. It is the chemical reaction between water and cement that lead to the hardening of concrete. As this reaction lasts for a long time, hence concrete grows stronger with age. The properties of the ingredients, the propositions of mix the method of compaction and other controls during placing, compaction and curing, are the factors on which durability, strength and other characteristics of concrete relies.

Making concrete is not just about intermixing the materials to fabricate a plastic mass but a high standard concrete has to satisfy all the requirements in plastic or green state as well as in hardened state. Concrete should be workable and free from segregation and bleeding when in plastic state. Also it should be impervious, enduring and durable and should not show bulging when in hardened state. Of all the properties of the concrete, its compressive strength being the most important one is taken as the measure of its overall quality.

Mud-concrete is a fresh approach and it is like cement concrete. It is produced by blending together soil, cement and water. The materials like the soil fraction perform the function of aggregate and small quantities of cement act as a stabilizing agent here. The compressive strength of the mud concrete is governed by the range of gravel and the percentage of soil used. For the hydration of cement water is used in excessive amount. The high amount water allows the material to flow and amplifies its self-compacting quality and also helps with the self-consolidation, provides the material ability of passing, filling and stabilizing itself without any external influence. But for attaining more strength and durability, operations like ramming and consolidation can be done. Mud concrete was basically evolved to produce same strength and durability as that of cement concrete and the fundamental idea behind mud based construction was to instigate cheap (low cost) and load bearing wall system. The construction mode employed for it was easy, simple and guaranteed indoor comfort with least impact of environment on the structure.

**Fig -1**: Mud Concrete Blocks

### 1.1 Background

Before In the ancient times mud based construction was very popular however it is not practiced much in the present world as several new methods have come into use. As reported by Cofireman Et Al (1990), 30% of the world's populations are still living in earthen structures and for the construction of various structures we have been using the materials of earth for thousands of years and are still relying upon it. Another research done be Ren and Kagi (1995) showed earth as inexpensive and environment friendly and readily available building material. It has been considerably used for wall construction all around the world, especially in developing countries.

Dugout, Earth sheltered space fill-in cut-blocks, compressed earth, direct shaping, stacked earth, Moulded earth, Extruded earth, Poured earth, straw clay and Daubed earth are the various construction techniques which have likely evolved through time and are still used around the world. Due to social beliefs on the strength and durability parameters of earth based techniques, use is becoming unpopular day by day. Although these products get eco manufacturing process but on the basis of its factors of durability and strength, presently "Concrete" is the most widely used construction material.

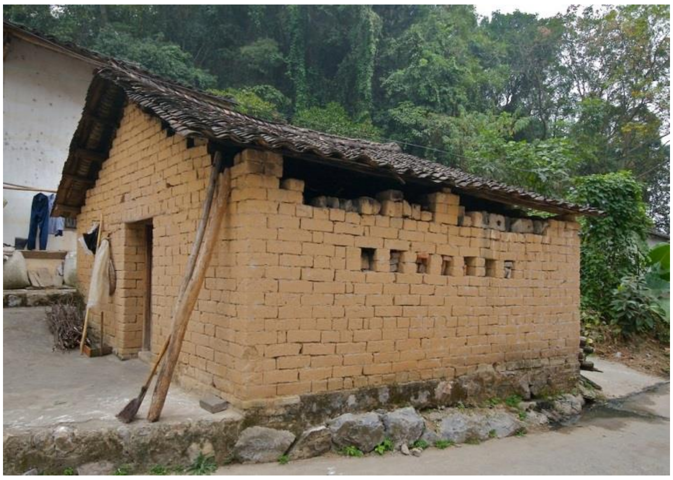

**Fig -2**: Mud Concrete Structure

## 2. CONCEPT OF DEVELOPING MUD CONCRETE TECHNOLOGY

Concrete is a building material made from cement, sand, coarse aggregate and water, the coarse aggregate in the composition determines the strength, the cement acts as a binding agent, while the sand reduces the porosity and the water acts as a reactor for the cement. In concrete technology, sand and coarse aggregates from concrete are replaced by fine and coarse aggregates from the ground. The intended functions of sand and coarse aggregates are achieved by varying the particle sizes of the soil.

The major goal of the mud concrete aggregate became to increase a self-compacting blend which could be capable to consolidate underneath its personal weight. This self-compacting blend could now no longer require any mechanical vibration or compaction after pouring and could observe the form and floor texture of the mould/shape paintings as soon as set. To conceive the dust concrete aggregate as a self-compacting blend, it became vital to manipulate its fluidity even as preserving its energy and sturdiness properties. Thus, water will become a key constituent of the blend.

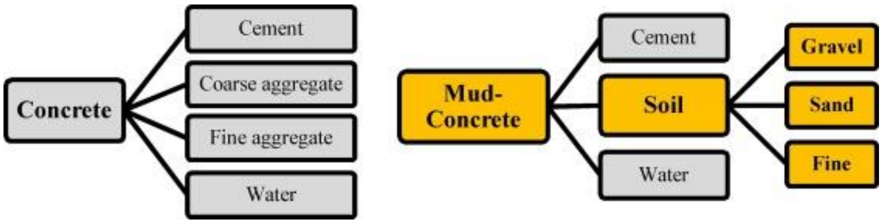


**Fig -3**: Similitude of Concrete and Mud Concrete

**3. SELECTION OF SOIL TYPE USED IN MUD CONCRETE**

Selection of soil that is desirable for use in the stabilization for modern earth construction involves various stages that are given below:

Stage 1: In this stage we identify the origin and attainability of suitable material (e.g. natural sub-soils, as-raised ballast or graded quarry waste). On the basis of initial screening for organic matter (nominally <2%wt), which is determined by the losses faced on ignition, as well as high concentration of contaminants such as chlorides, sulphates, etc., the material can be declined or accepted. If the material is proven to be ideal then its samples are taken for experimental testing.

Stage 2: Characterization based on the linear shrinkage coefficient is as follows:

Shrinkage Coefficient < 7% Favourable

Shrinkage Coefficient 7.1%-13% Satisfactory

Shrinkage Coefficient>13% Unfavourable

Stage 3: In this stage we characterize the soil on the basis of plastic limit (PL), which is the moisture content at which the soil shows plastic deformation under load (i.e. non-elastic strain) and liquid limit (LL), which is the moisture content at which the soil flows due to gravity. The acceptance of the soil is judged on the basis of plasticity index (PI), which is the ratio between LL and PL.

Favourable: PI < 16% and LL < 36%

Satisfactory: PI = 15-30% and LL = 36-45%

Unfavuorable: PI > 30% and LL > 45%

Stage 4: In this stage, we determine the particle size distribution of the soil in order to assess its texture (or grading). The suitability and acceptance of is based on the following criteria

Favourable: cohesive fraction (silt + clay) 21-35%, or sand 30-65%, or gravel 3-5%.

Satisfactory: silt + clay 36-45%, or sand 66-75%, or gravel 3-12%

Unfavourable: silt + clay < 21% or > 45%, or sand > 75%, or gravel < 3%

**4. MATERIALS AND QUALITY**

**4.1. Soil**

In order to make sure that organic matter is not present in the sample, we procured the soil from homogeneous layers 700mm blow the top of the soil. Using a 20mm sieve we removed the oversized soil particles from the sample. The composition of soil sample that was used in the experiments confirmed to the sieve analysis.

The various physical properties of the soil that was used are as follows:

Plastic limit = 36.89%

Liquid limit = 26.02%

Natural water content = 26.4%

Plasticity Index = 10.87%

Linear shrinkage = 6.82%

Specific gravity = 2.42%

**4.2. Stabilizer**

Cement was the main stabilizer used in this experiment: industrially available required lab condition prior to its utilization for the mix development. Portland cement of 43 grades was employed in this experiment. Various physical and mechanical properties of the cement are given below:

Initial setting time (min) = 25

Final setting time (min) = 500

Specific gravity = 3.35

Volume expansion (mm) = 1.2

Compressive strength (MPa)

7 days = 40.54

28 days = 51.9

**4.3. Quality of Mixing Water**

It should be made sure that the water that is being used for mixing and curing of Mud-Concrete is free from harmful amounts of detrimental substances. Majority of the objectionable conditions, that cause the distress of Mud-Concrete, are the consequence of mixing and curing water not being of suitable quality. The existence of harmful impurities in the mixing water decreases the strength and durability of the Mud-Concrete. The effects of contaminated water being used for mixing and curing can chiefly be expressed in terms of difference in the setting time of Portland cement mixes containing impure water as compared to portable water.

**4.4. Soil Classification for Mud-Concrete Block Technology**

On the basis of sieve analysis, using standard IS sieves, soil can be classified as:

Gravel: If particles pass from 20mm and retain at 4.75mm sieve

Sand: If particles pass from 4.75mm and retain on 0.075mm sieve

Fine (Silt and Clay): if particles pass from 0.075mm-0.002mm and 0.002mm down

**5. METHODOLOGY IN CONSTRUCTION OF MUD CONCRETE**

**CONDUCTING SOIL TESTS:**

The various properties of soil tested and identified are discussed below.

**5.1. Natural Water Content**

Soil is extensively affected by the water content present in it. Particularly the behaviour of cohesive soils is affected by this soil parameter. There are various methods to determine the water content of soil and the one which is used most frequently among them is "Oven Drying Method".

This method is used because it is a simple method that can be adopted for the determination of water content present in the soil in the laboratory. The water content is calculated using formula:

$$\text{Water content } (w) = (W2 - W3)/ (W3 - W1) \times 100\%$$

Where,

W1= weight of container

W2= weight of container with moist soil sample

W3= weight of container with dried soil sample

**5.2. Liquid Limit (Wl)**

Liquid limit is defined as that water content of soil at which the soil is almost in a liquid state. However soil has minute resistance against flow at liquid limit and it can be measured by standard methods.

Liquid limit of a soil sample in the laboratory is determined by an apparatus designed by A. Casagrande.

**5.3. Plastic Limit (Wp)**

Plastic limit is defined as the water content below which the soil stops behaving as a plastic material. The soil when rolled into a thread of 3mm diameter begins to crumble. The soil loses its plasticity and moves to semi-solid state at this water content.

**5.4. Shrinkage Limit**

The smallest water content at which the soil is saturated is known as shrinkage limit. We can also describe it as the maximum water content at which there is no decrease in the volume of soil mass even if the water content is reduced, i.e., at this water content , the shrinkage ceases.

**5.5. Plasticity Index**

The range of moisture content over which the soil displays plasticity is referred to as plasticity index Ip. It can also be expressed as the difference between the limit and the plastic limit. It gives us information about the degree of plasticity of the soil. Expression for plasticity index is as Ip = Wl – Wp.

**5.6. Specific Gravity**

The specific gravity of soil is determined for the estimation of various quantities like void ratio, degree of saturation, unit weight of solids, and unit weight of soils in various states. A device called PYCNOMETER is used for determination of specific gravity. The expression used to calculate specific gravity of soil mass is as follows:

Specific gravity of solids [Gs] = [Ws]/ [Ws – W1+ W2]

Where,

Ws= weight of dry soil.

W1= weight of pycnometer + weight of soil + weight of water.

W2= weight of pycnometer+ weight of water.

**5.7. Workability for Mud-Concrete**

In order to identify and standardize the self-compacting consistency of Mud-concrete mix we follow a simple technique. The research was first designed to determine the slump height and slump diameter of the mud concrete mix at different moisture contents while keeping the number of blows constant (25 blows). As is stated by the thumb rule, after 25 blows the mix is said to have achieved the workability if it spreads to about 500mm diameter circle.

## 6. TESTS PERFORMED ON MUD CONCRETE

### 6.1. Compressive Strength

In the assessment of mud concrete blocks compressive strength is considered as one of the dominant parameters. The values of compressive strength were taken from the best particle proposition and cement proposition. We conducted the compressive strength test, after 28 days of proper curing, on the blocks of size 150mm x 150mm x 150mm.

### 6.2. Water Absorption

In order to evaluate the density quality standard of MCB, we conduct cold water absorption test .The cold water absorption, percentage by mass, after 24 hours of immersion in cold water was determined using the following equation.

$$W = [(M2 - M1) / M1] \times 100$$

Where,

M1= weight of dry specimen.

M2= weight of specimen after 24 hours of water immersion.

### 6.3. Thermal Conductivity

Thermal conductivity is a parameter that is used to measure the heat conducting capacity of a material. Under the study temperature difference Th – Tc, thermal conductivity can be described as the thermal energy (Q) transmitted through the thickness or length (L), in the direction normal to the surface area (A). There are various methods for measuring thermal conductivity. Steady-state method is generally used in case of bulk materials.

Thermal conductivity, $K = QL/A\Delta T$

### 6.4. Accelerated Erosion

The testing method used for accelerated erosion includes placing the sample at a distance of 500mm from a spray nozzle and then spraying water at a pressure of 50kPa horizontally.

**TEST RESULTS:**

| **Trial A1 (For 10% of cement by weight)** | |
|---|---|
| Fine | 30% |
| Gravel | 50% |
| Sand | 20% |
| Water content | 22.2% |

| **For Sample Weight 9 kg (Fine+ Gravel+ Sand)** | |
|---|---|
| Fine | 2.8 kg |
| Gravel | 4.4 kg |
| Sand | 1.9 kg |
| Cement | 0.8 kg |
| Water content | 2.2 kg |

Dimensions of Mould = (15x15x15) cm.

**RESULTS:**

| | |
|---|---|
| Slump Diameter | 305mm |
| Slump Height | 102 mm |
| Compressive Strength After 28 days. | 8.5 N/mm2 |
| Accelerated Erosion. | No significant holes. |

| **Trial A2 (For 6% of cement by weight)** | |
|---|---|
| Fine | 10% |
| Gravel | 35% |
| Sand | 55% |
| Water content | 25% |

| **For Sample Weight 9 kg (Fine+ Gravel+ Sand)** | |
|---|---|
| Fine | 0.8 kg |
| Gravel | 3.17 kg |
| Sand | 4.94 kg |
| Cement | 0.53 kg |
| Water content | 2.4 kg |

Dimensions of Mould = (15x15x15) cm.

**RESULTS:**

| | |
|---|---|
| Slump Diameter | 305mm |
| Slump Height | 102 mm |
| Compressive Strength After 28 days. | 5.2 N/mm2 |
| Accelerated Erosion. | No significant holes. |

| **Trial A3 (For 8% of cement by weight)** | |
|---|---|
| Fine | 10% |
| Gravel | 35% |
| Sand | 55% |
| Water content | 25% |

| For Sample Weight 9 kg (Fine+ Gravel+ Sand) | |
|---|---|
| Fine | 0.8 kg |
| Gravel | 3.17 kg |
| Sand | 4.94 kg |
| Cement | 0.73 kg |
| Water content | 2.5 kg |

Dimensions of Mould = (15x15x15) cm

**RESULTS:**

| | |
|---|---|
| Slump Diameter | 305mm |
| Slump Height | 102 mm |
| Compressive Strength After 28 days. | 6.6 N/mm2 |
| Accelerated Erosion. | No significant holes. |

## 7. CONCLUSIONS

This research study was conducted in order to come up with a new material, 'Mud Concrete Blocks' for constructions. The initial study was performed to understand the likelihood of manufacturing soil-based blocks. Then the prior study was carried out in order to optimize the idea of building mud concrete blocks. The objective of the preliminary test was to optimize the best particle proportion for the mud concrete blocks. After that the study was concentrated on knowing the best cement proportion to build blocks. From the outcomes that were obtained in the laboratory test series for mixed design, it was deduced that the new block can be produced using soil with 5% of fine particles, 55% of 65% sand particles, 10% cement by weight together with a moisture content of 18-20%. Moreover, this type of mud concrete block does not require any compaction. In case of typical blocks, such as concrete blocks, heavy machinery like compaction is needed to produce the block. Whereas in case of this new mud concrete block production no compaction or vibration is obligatory. This is due to the fact that the mixture of mud concrete is already malleable with water. It was concluded that to secure better outcome, it is appropriate to use mix proportions of soil with sand content of 60%, fine particle content of 5% and stabilized with 10% cement together with 18% to 22% moisture content.

After the initial discovery of mud concrete block, in order to access and improve their quality a series of standard tests were carried out on the mud concrete blocks. As the primary experiment was to upgrade the compressive strength of mud concrete blocks, the compressive strength of MCB was already up to the standard for a block. Hence we can also draw the conclusion that the newly invented mud concrete is therefore suitable for use in the construction. A cold-water absorption test, according to Sri Lankan Standards and ASTM C936, was conducted. Thus, in this soil material, the water absorption level is relatively high and the standard test for water absorption of a ASTM C936 was not successful for all blocks.

The process of production of the new blocks is manual and except for the production of cement it does not require any kind of energy. Hence, in comparison with the other materials, especially cement concrete blocks, which are the most frequently used material, the embodied energy is much less. Also it is easier to fabricate the mud concrete blocks without much skilled labour while materials are readily available. So the cost of material transportation and labour is less in contrast to other materials.

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