Determination of Soil Type And Optimal Moisture Content For Soil Used For Rammed Earth Construction In Bhutan

Namgay Om[1], Kuenzang Gyeltshen[2], Ugyen Lama[3]

* E-mail: edc2011025@cst.edu.bt[1], kuenzngG@gmail.com[2], edc2011062@cst.edu.bt[3]

Abstract

Earth is used for construction of Rammed Earth Buildings all over Bhutan. This type of construction involves preparing a suitable soil mixture and ramming the soil within wooden shutters. Before proceeding with ramming it is essential to select the most suitable soil and also set the water content for the soil mixture. The soil type is usually classified based on the content. It is difficult generally define the standards of a soil for ramming as it varies from place to place. Bhutanese constructors have been relying on qualitative based method for determination of soil type and setting of water content. The efficiency of the qualitative based method is solely dependent on experience. The specifications for the soil used have not been quantified till date.

Key Words : *soil type, water content, qualitative basedmethod, standards*

1. INTRODUCTION

1.1 History

Traditional construction in Bhutan can be dated back to the 17th century during which majority of the currently existing dzongs were constructed. Rammed earth construction type is found all over Bhutan and is enlisted as a type of building in the Building Classification Scheme, 2013. Rammed Earth buildings are load bearing type structures. The walls of the building supported by the floor joist are the major load resisting components of the building. This type of construction is most preferred by farmers in Bhutan because it is economical and abundance of adequate soil for construction. Rammed earth construction also has a very important role in the preservation of tradition and culture of Bhutan.

1.2 Technique of construction

The construction of Rammed Earth involves construction of foundation up to a height of 600mm above the ground level using rubble masonry. Then the walls of thickness 600mm are constructed as lifts of thickness 600mm to 900 mm. Soil mixtures with estimated optimal moisture content is used for the construction of walls. The soil is compacted within wooden shutters using wooden rammers. The texture of the compacted soil is used to determine the uniformity of compaction and its efficiency.

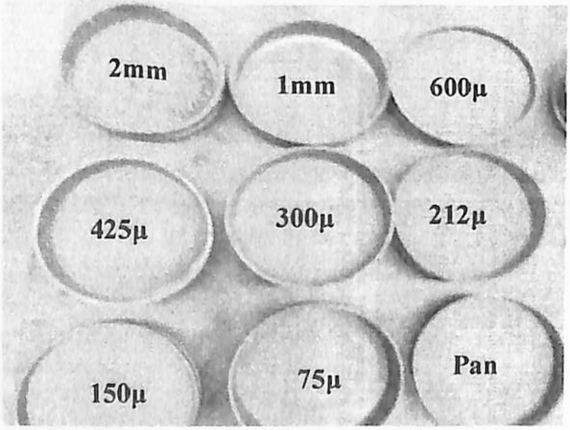
Timber is used for doors, windows, floors, joists, cornices and roof truss. Corrugated galvanized Iron sheets are used for roofing.

1. SOIL TYPE USED FOR RAMMED EARTH CONSTRUCTION

The soil is classified as content based according to the amount of gravel, sand, silt, clay and organic material present in the soil. According to the color the soil is classified into red, black, yellow, grey, white and brown. Yellow soil is considered to be the best for rammed construction. This type of soil contains the right amount of sand and clay. If red soil is used the soil mixed with white or black soil to balance the clay and sand content (DCHS, 2011). It is found that if the amount of clay and silt in the soil is 25 to 50% more than the amount of coarser materials (sand and gravel) then the soil is suitable for ramming (Easton, 2007). Also the soil suitable for ramming should be free of smell as it concludes that the soil is inorganic (Escobar, 2013). General soil characterization based on content is not reliable as the standard percentage of contents is varies in different literatures. For example the amount of sand and gravel should be 20%, silt should be 80% and clay should be 30% (Alley, 1948). Whereas Zimbabwe Standard for Rammed Earth Structures recommends a content of 70%, 30% and 15% for sand and gravel, silt and clay respectively. Therefore soil testing for material competence and construction experience may be necessary to select a suitable soil type for ramming.

2.1 Experimental analysis

To determine the type of soil used in Bhutanese rammed earth construction, soil sample was collected from a construction site in Lamgong Gewog under Paro Dzongkhag. Dry fine sieve analysis was carried out based on IS: 460-1962. The sieve size used for fine sieve analysis consists of 2mm, 1mm, 600μ, 425μ, 300μ, 212μ, 150μ and 75μ. Sieve analysis was carried out three times for different sets of soil form the same sample. The retained soil on each sieve is shown in Figure 1, the amount of sand, silt and clay in the soil is shown in Figure 2 and the average grain size distribution is shown in Figure 3.



The coefficient of uniformity C_u was found to be 6.42 and the coefficient of curvature C_c was found to be 0.97. This concludes that the soil is sand and is uniformly graded as coefficient of curvature is near to unity.

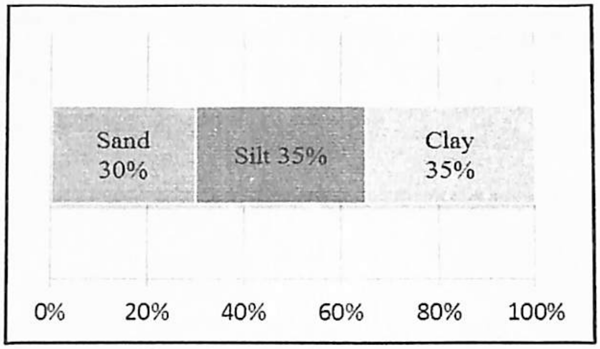
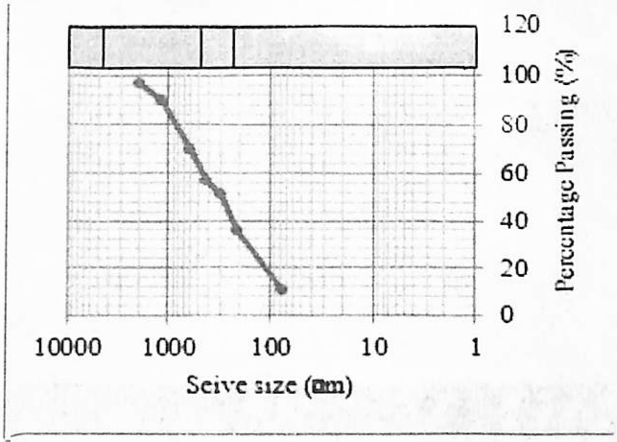


Fig. 2 Composition of soil sample

The soil content shows almost equal proportion of sand, silt and clay in the soil sample. This is also verified by the coefficient of curvature which indicates that the soil is uniformly graded.

The soil contains 70% clay and silt which is 40% more than the sand content therefore the soil is suitable form ramming based on the standards proposed by Easton. D.



Specific gravity test was also conducted and a specific gravity of value 1.94 was obtained.

3. WATER CONTENT FOR SOIL

The water content for soil is very important for ramming because the soil mixture should have adequate strength and workability. Addition of water to the soil also allows the soil to shrink upon drying.

3.1 Qualitative water content test

During the construction of rammed earth buildings the optimal moisture content of the soil is determined at the site by conducting various experiments. A ball of mud is tossed in the air or is thrown against the wall to check the cohesiveness of the soil (DCHS, 2011). The optimal moisture content of the soil is also determined by the drop ball test in which a mud ball of 30mm diameter is dropped from a height of 1.5m (NZS 4298-1998). The water content test was carried out for different set of samples. Firstly the prepared soil mixture directly obtained from the construction site was tested for water content. Then the sample was oven dried for 2 days and the drop ball test was carried out. For each set of soil sample the water content test was carried out three times to determine the average value. Table 1 shows the moisture content for the two tests.

These methods used for determining the water content are purely based on visual judgment and experience, therefore this type of methods are qualitative.

Table 1 Water content of soil samples

Sample	Water content (%)
Prepared soil mixture form site	18.071
Soil mixture obtained from drop ball test	23.544

3.2 Quantitative water content test

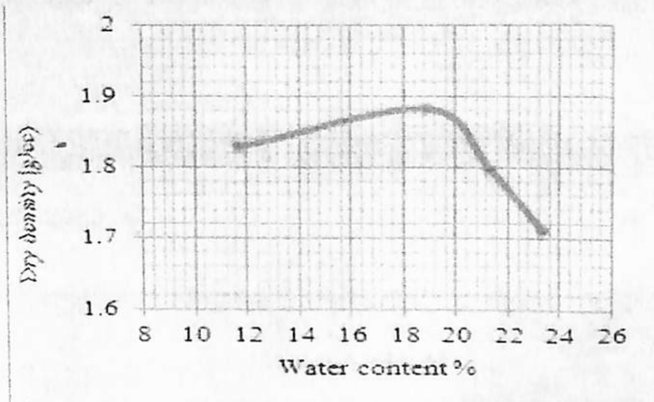
The main purpose for determining the moisture content of the soil is to prepare a soil mix which will have the highest strength. During compaction of the soil volume of air voids are reduced in the soil. When the water content is such that the soil has zero air voids and the soil reaches its maximum dry density. This water content is called optimum water content. Further increase of water content will cause the soil mixture to become plastic and will not be workable.

The determination of optimum moisture content and maximum dry density for the sample was carried out according to the standard proctor test of IS: 2720 (Part VII)-1980. The test was carried out carried out by gradually increasing the water content of the soil. After every increase in water, water content test was also carried out. For determination of maximum dry density a metal rammer of 2.6 kg was dropped from a height of 310mm for 25 times on the sample which was contained in the cylindrical mould of diameter 10cm. **Figure 4** shows the chart obtained from proctor test. The optimum moisture content at is 19% and the maximum dry density is 1.88 g/cc. The dry density of the soil sample lies in between the standard value of 1.7g/cc to 2.2g/cc according to Standards Australia and is suitable for ramming.

In Bhutanese rammed earth construction wooden rammers are used for ramming which is contradictory to the metal rammer used in the standard proctor test. Also the metal rammer is dropped for 25 times on a very small volume of sample which creates a large difference in compactive effort compared to normal construction practice.

Therefore the density of the soil block obtained after the construction may be lesser than the maximum obtained from the standard proctor test.

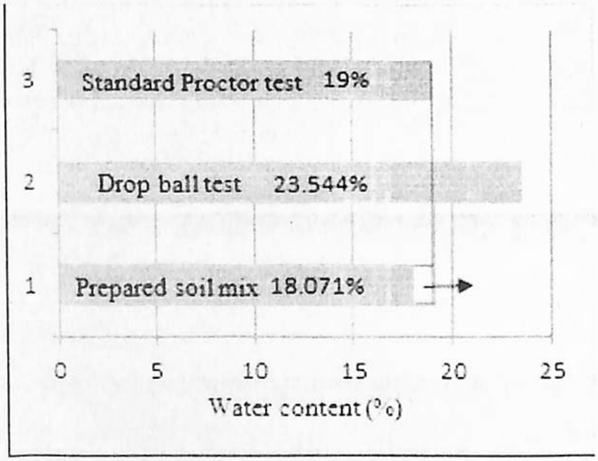
This method of water content determination has theoretical background and can be represented in terms of numerical equations. Therefor this method is a quantitative method of water content determination.



3.3 Comparison of water content

The water content obtained from prepared mix from site, drop ball test and standard proctor test were compared against each other. It was found that the moisture content obtained from the drop ball test was highest and that of prepared soil mix from site was lowest. The water content of the drop ball test exceeds optimum moisture content from the standard proctor test by 23.91%. And the water content of the prepared mix form the site is 4.89% less than that obtained from standard proctor test. The excess in the water content for the drop ball test may be due to over estimation as the test is qualitative and solely depends on the experience. However, the water content for the soil mix obtained from the site is very close to the optimal value. This is an indication of the experience of the local constructors in estimating the right amount of water content.

As mentioned earlier optimum water content varies with compactive effort. Therefore the water content of the soil mixture prepared at site using qualitative method may not be comparable to the optimal water content determined form the standard proctor test.



4. CONCLUSION

The soil sample contains 70% clay and silt and 30 % sand. This is satisfactory according to few standards but caution has to be taken while classifying soil based on content as it cannot be generalized. The optimal water content for the soil is 19% with a maximum dry density of 1.88g/cc. The dry density of the soil is suitable for ramming. The water content for prepared mix obtained from the site is close to the value of optimal moisture content obtained from standard proctor test. Therefore the qualitative method of water content determination used at site is acceptable. It is also evident that maximum dry density varies with compactive effort therefore the final dry density of the rammed soil may be lesser than that determined experimentally due to lesser compactive effort.

REFERENCES

Alley, P.J.(1948). *Rammed Earth Construction,* New Zealand Engineering

Division for conservation of Heritage Structures (DCHS), 2011, *Damage Assessment of Rammed Earth Buildings after the September 11, 2011 Earthquake,* United Nations Development Programme (UNDP)

Easton, D.(2007). *The Rammed Earth House,* US: Chelsea Green Publishing

Escobar, M.D.(2013). *Earth Architecture, Building with Rammed Earth in a Cold Climate,* Chalmers University of Technology, Gothenburg, Sweden

IS: 2720 (Part VII-1980). *Methods of test for soils, Part VII Determination of Water Content-Dry Density Relation Using Light Compaction,* Bureau of Indian Standards

NZS 4298-1998. *Engineering design of earth buildings,* Earth Building Association of New Zealand *[Building Code Compliance Documents B1 (VM1), B2 (As1)]*

Standards Australia.(2002). *The Australian Earth Building Handbook,* Sydney