Effect of Gravel Size on Strength of Mud Concrete

D.M.H.C Bandara[1], F.R.Arooz[2] and R.U Halwatura[3]
Department of Civil Engineering, University of Moratuwa, Sri Lanka

ABSTRACT: Rapid development of the world has resulted in many problems in the construction industry as well as to the environment. Because of the rapid development, resources have become limited and thereby the cost of existing resources has increased. This has greatly affected to construction industries in developing countries, especially for small-scale construction work such as houses. Also, high usage of resources in the construction industry has led to many environmental impacts. As a result, of that sustainable materials have become popular in the world. Soil can be considered as such a sustainable material. At present, many building materials have been developed based on the soil. Mud-Concrete is such a soil based novel product, which has been developed at the University of Moratuwa. Mud-Concrete can be used in different forms in building construction. First attempt was to develop mud concrete as 300mm (length) x 150mm (width) x 150mm (height) load bearing block. The second attempt is to develop in situ cast load bearing panels for wall construction. In this research, the effect of gravel size(particle size >4.75mm) on the compressive strength of mud concrete panels was checked by casting 150 x 150 x 150 mm Mud-Concrete cube for different gravel size ranges. In this experiment, both dry and wet compressive strength were checked. According to the results obtained from the experiment, 4.75mm – 30 mm gravel size range gives maximum dry and wet compressive strength for mud concrete panels.

1 INTRODUCTION

Increasing demand for materials in the construction industry has resulted in significant consumption of natural resources in the form of building materials. This increase in consumption has resulted in scarcity of materials, which has led to an increase in prices of building construction of materials (Kariyawasam and Jayasinghe, 2016). Today, 40% of world energy is consumed by building construction industry and contributes 23-40% of greenhouse gas emission (Houben and Guillaud, 1994).This situation has created a requirement of sustainable materials with low energy consumption and environmental pollution in both manufacturing process and operational level.

From the ancient time, soil has been widely used as a building material. It is one of the most prevalent natural building material in the world and available in most of the regions of the world. Today one-third of the world population resides in the houses, which were made by using soil based building materials where in developing countries, more than one-half of the people live in such houses (Daigle, 2008). As a building material, soil has many advantages such as the ability to balance air humidity, store heat, resist against fire, etc.

Many researches have been carried out to develop soil as a building material. Mud-Concrete which has been developed at the University of Moratuwa is one of the outcomes of these researches (Arooz et al., 2015). It is a mixture of soil, cement, and water. Mud concrete can be used in two different forms in building construction. First attempt was to develop 300mm (length) x 150mm (width) x 150mm (height) load bearing masonry blocks through mud concrete (Arooz et al., 2015). Several experiments have been carried out to identify the properties and the effectiveness of blocks. In this process, optimum mix proportions have been achieved with changing gravel, sand, fine and cement percentages. Second attempt is to develop in situ cast load bearing panels for wall construction.

2 OBJECTIVES

The main objective of this research is to identify the effect of gravel size on the strength of Mud-Concrete panels. Through this research, it is expected to identify the gravel range which gives maximum compressive strength for the mud concrete panels.

3 EXPERIMENTAL PROGRAM

3.1 *Soil classification*

In order to classify the selected soil, sieve analysis and Atterberg limit tests were conducted. Particle size distribution of the soil was obtained by conducting sieve analysis. Liquid limit, plastic limit,

1 Former Student 2 Postgraduate Student 3 Senior Lecturer e-mail : rangika@uom.lk

and plastic index were obtained by conducting Atterberg limit tests by using Casagrende's instrument.

3.2 *Preparation of gravel ranges*

According to the particle size distribution obtained from sieve analysis, five gravel ranges are arranged from the selected soil type. To prepare gravel ranges, soil was dried and sieved through 4.75 mm sieve to separate gravel from the soil. Retained portion on the sieve after sieving was taken as gravel (particle size >4.75mm). Portion passed through 4.75 mm sieve contained fine (particle size < 0.425 mm) and sand (0.425 mm <particle size < 4.75 mm). Then separated gravel was dividedintofive equal portions and each portion was sieved. Retained portion on the sieve after sieving was removed. After sieving, following gravel ranges were prepared.

Table 1: Prepared set of gravel ranges

	Gravel range
Portion 01	4.75 mm – 10 mm
Portion 02	4.75 mm – 20 mm
Portion 03	4.75 mm – 30 mm
Portion 04	4.75 mm – 40 mm
Portion 05	4.75 mm – 50 mm

3.3 *Preparation of soil composition*

According to previous experiments (Arooz, 2015), optimum composition of gravel, sand and fine in selected soil should be as following.

- 5% fine (particles< 0.425 mm)
- 35% gravel (particles> 4.75 mm)
- 60% sand (0.425 mm < particles < 4.75 mm)

In selected soil, fine, gravel and sand percentages were 7.96, 55.88 and 36.16 respectively. Therefore, it should be changed to above percentages. This can be done by separating fine, sand and gravel from the soil and mixing them each other to above percentages. Practically separating the fine particles from the soil is difficult. Therefore to obtain above percentages without separating fine, an additional amount of sand from outside had to be added to selected soil. According to the sieve analysis done for the soil portion pass through 4.75mm, fine and sand percentages were 18% and 82% respectively. Therefore to obtain 45kg of soil sample with above compositions, following amount of sand, gravel and sand +fine (Portion passed through 4.75 mm sieve) had to be added.

- Fine + sand (<4.75mm) = 12.5 Kg
- Sand = 16.75 Kg
- Gravel = 15.75 Kg

For above soil samples, gravel was added from prepared gravel ranges. Therefore five soil types with above percentages were prepared for five gravel ranges.

Table 2: Prepared Soil types

	Gravel range
Soil type 01	4.75 mm – 10 mm
Soil type 02	4.75 mm – 20 mm
Soil type 03	4.75 mm – 30 mm
Soil type 04	4.75 mm – 40 mm
Soil type 05	4.75 mm – 50 mm

For each soil type, sieve analysis was conducted to obtain particle size distribution of soil samples.

3.4 *Manufacturing of mud concrete cubes*

Mud concrete cubes were cast for five different soil types shown in *Table 02*. For each soil type, six cubes were cast to check wet and dry compressive strength.

According to previous experiments, optimum mix proportion of cement and soil should be 8% and 92% respectively (Arooz, 2015). After mixing soil prepared above with cement to above mix proportions, sufficient amount of water was added to achieve a workable mud concrete mixture, which could be poured into 150mm x 150mm x 150mm molds. Mud concrete mixture was poured into mold sand kept it to self-compaction.

Once the casting process was completed, cubeswere cured for 7 days and kept for 35 days to gainstrength. After 35 days from cast day, cubes were loaded by using compression testing machine to find the compressive strength of the cubes. To check the wet compressive strength, three cubes of each soil type were immersed in water for 24 hours before testing to obtain saturated surface dry conditions.

4 RESULTS AND DISCUSSION

4.1 *Soil classification*

According to the sieve analysis carried out for the soil, following particle size distribution was obtained.

1 Former Student 2 Postgraduate Student 3 Senior Lecturer e-mail : rangika@uom.lk

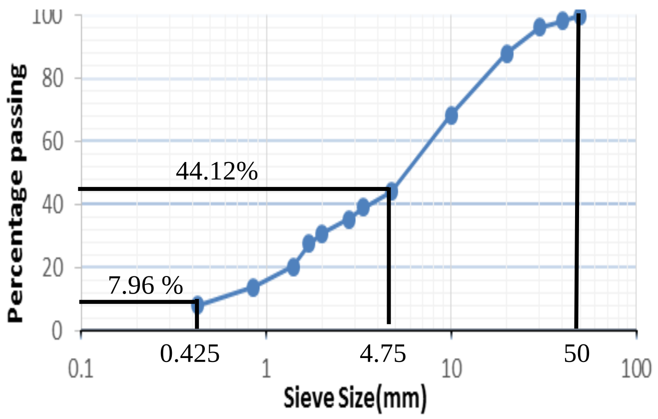

Figure 1: Particle size distribution of soil

Since the gravel content of the soil is more than 50%, it can be considered as "Well graded coarse-grained soil". According to the graph, this soil type has continuous particle size distribution. Therefore soil type can be considered as 'well graded' soil type.

According to the Atterberg limit tests, values obtained for liquid limit, plastic limit, and plastic index have been shown in the following table.

According to the results obtained from the Atterberg limit test and the particle size distribution, this soil can be classified as "GW-GC (well-graded gravel with clay)" soil according to the ASTM standards.

Table 3 Plastic and liquid limit

Description	Value %
Liquid limit	55.87
Plastic limit	38.10
Plasticity index	17.77

Table 4 Avg. dry and wet compressive strength of cubes

Soil type	Gravel Size in soil (mm)	Avg. wet strength (MPa)	Avg.dry strength (MPa)
01	4.75 – 10	1.18	2.15
02	4.75 – 20	1.45	2.57
03	4.75 – 30	1.94	3.21
04	4.75 – 40	1.70	3.00
05	4.75 – 50	1.49	2.73

4.2 *Compressive strength of mud cubes*

Average wet compressive strengths and dry compressive strength of mud concrete cubes have been shown in *Table 04.*

According to the above table, following graph can be plotted.

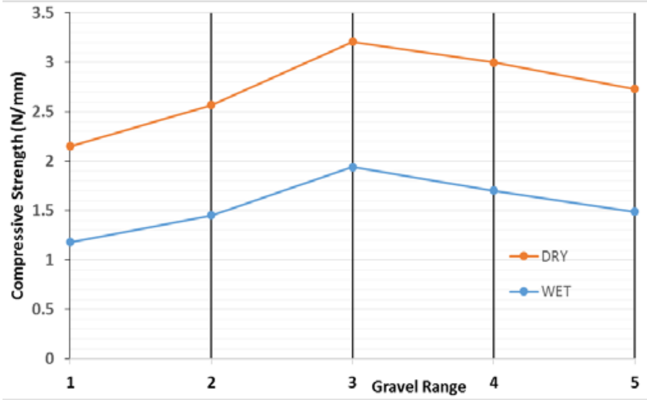

Figure 2: Variation of wet and dry compressive strength

Figure 2 shows the variation of dry and wet compressive strength of mud concrete cubes against different gravel size ranges (soil types). When the size of gravel in soil is increased from 10mm to 50mm, the compressive strength of cubes increases gradually and then decrease as shown in Figure 2. According to the Figure 2, cubes cast by using soil type prepared with 4.75mm to 30mm gravel range (Soil Type 03) has shown highest wet and dry compressive strength. Cubes which were casted by using soil type 1(prepared with 4.75mm to 10mm gravel ranges) has given the lowest wet and dry compressive strength. Therefore, it is concluded that compressive strength of mud concrete will not always not proportional to the gravel size.

According to above results, there is a considerable effect from gravel size to the strength of mud concrete. When gravel range is changed from 4.75 - 10mm to 4.75 – 30mm, dry strength of cubes has increased 49% and wet strength has increased by 64%.

According to the sieve analysis conducted to the soil types (prepared according to *Table 2)*, following graphs can be plotted (Figure 3).

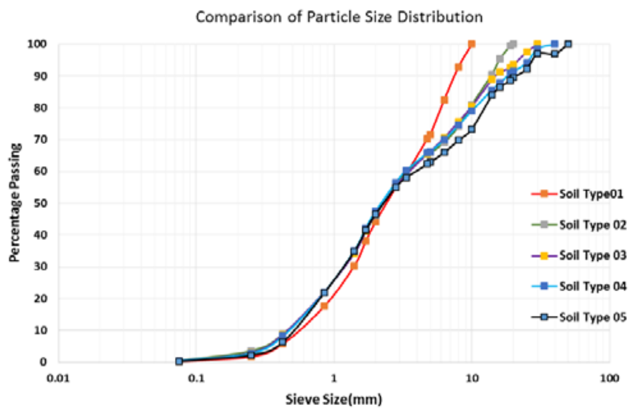

Figure 3 comparison of particle size distribution

1 Former Student 2 Postgraduate Student 3 Senior Lecturer e-mail : rangika@uom.lk

4.3 *Effect of particle size distribution on compressive strength*

Particle size distribution of soil has a great effect on the compressive strength. It affects to form a packed soil structure with low voids among particles. If soil has continuous particle size distribution, then soil particles have a higher ability to contact each other and form pack structure than soil with gap graded particle size distribution. By compacting such soil, further packed soil structure with low permeability can be obtained.

When particle size distributions in *Figure 3* are considered, continuous particle size distribution can be seen in each soil type. According *Figure 3*, distribution of particle size of soil type 01 is lesser than other soil types. This can be a reason for the lower compressive strength of cubes cast by using soil type 01.

According to the *Figure 3*, when gravel size is increased beyond 30mm, compressive strength of cubes decreases gradually. When size of gravel is increased, amount of water has to be added to obtain a workable mixture has to be increased. Addition of water can cause to increase porosity of cubes. High porosity leads to decrease compressive strength ofcubes.

5 CONCLUSION

According to the results of this research, it can be concluded that compressive strength of mud concrete panels depends on both gravel size and the particle size distribution of the soil. Also, it can be seen that increasing gravel size does not lead to increase the compressive strength of mud concrete always and both particle size distribution and gravel size affect the compressive strength. Continuous particle size distribution provides soil particles to form a packed soil structure with minimum voids. This enhances the compressive strength of mud concrete.

In this case, mud concrete panels cast by soil type 03 prepared by adding 4.75mm – 30mm gravel, gives maximum compressive strength. Therefore, in future research, this finding can be used.

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1 Former Student 2 Postgraduate Student 3 Senior Lecturer e-mail : rangika@uom.lk