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Permeability Characteristics of Construction Waste as a Column material in Expansive Clay

Sivapriya S.V[1][0000-0002-9818-1393][1],Dhanushvarman J[2] and Gokul S[2]

[1] Associate Professor, Deaprtment of Civil Engineering, Sri Sivasubramaniya Nadar College of Engineering, Kalavakkam, Chennai 603110, India.
[2] Students, Deaprtment of Civil Engineering, Sri Sivasubramaniya Nadar College of Engineering, Kalavakkam, Chennai 603110, India.
sivapriyavijay@gmail.com

Abstract. India generates 120 -150 million tonnes of construction and demolision waste (CDW) every year and this make-up 25% of the landfill waste. Considering the availability of the waste, laboratory studies are performed to understand the functions of the construction waste as a column member in- stalled in a permeability mould with expansive soil under soft (0.4) and medi- um-stiff (0.6) consistencies (I_c). In this test two different CDW materials are chosen; M 30 grade concrete waste and demolished bricks. The soil is filled in the permeability mould of desired consistency and a column is formed with the chosen CDW of 31.75 mm and the permeability characteristics of the modified soil are found by conducting a variable head test. The formed column makes a unit-cell, where the column is allowed to cure for three days and the permeability characteristics is found; it is further compared with the virgin soil and the conventional column material installed in expansive clay under similar conditions. The permeability characteristics of virgin clay with 0.6 I_c showed higher values than the soil with 0.4 I_c. With the inclusion of bricks and concrete waste, the permeability value decreases in a large range for a higher I_c

Keywords: Construction waste material, Consistency, Column Study, Permeability, Curing.

1 Introduction

The infra structure development leads to have comfortable life where construction and demolition are intergeral part of the process. During construction and demolition, large quantity of concrete waste is generated in addition to wooden, metalic and plas- tic wastes. It is found India generates around 150 million tonnes annually which can be avoided if the engineers plan for reuse of the waste. The country has the facility to recycle around 6500 tonnes only everyday, which is only 1.3% of the total generated waste [1], hence the effective use of the waste has become the *'state- of – the- art',* meeting the sustainable goals.

Researchers started studying the function of demolished waste in concrete. The study comprises of usage of construction and demolision waste (CDW) in beam, column, shear wall, frame structure, frame shear wall of structures etc extensively

[2]–[4]. To utilize it further, it can be use as an alternative filler material in highway construction[5],[6], this has proved that it reduces environment load to 79.52% [7].

Considering its various application, the CDW is also used as a reinforcement material in soil stabilization in improving the expansive clayey soil's behaviour. The atterberg's limit reduces with increase in percentage of CDW addition to the soil. It also increases the CBR value of the soil which is actually unfit for future construction by 20%. CDW not only improves the behaviour, it also reduces the swell pressure by 80% compared to th untreated soil [8]. The compaction, strength and the permeability characteristics of the soil improves with addition of CDW, when the added CDW percentage is 24% [9],[10].

Considering the advanatges of usage of CDW in coil stabilization characteristics, the permeability characteristics is studied for two different consistency of soil with brick and demolished concrete waste under free flow of water.

2 Materials and Methodology

2.1 Properties of Soil

The expansive soil is taken near Thaiyur lake, Kalavakkam, Chennai. The soil posse liquid limit of 75.8%, plastic limit of 23.49% and showed characteristics of CH clay from the A- line chart [11]–[13]. The differential free swell index of the soil is more than 100% [14].

The materials used for constructing stone column in this study were conventional aggregate, demolished concrete and brick waste. The material were procured from the local construction site. The angle of internal friction (ϕ) of the respective material was found using IS code [15] and the values are given the table 1.

Table 1. Material properties

Material	**Φ, degree**
Aggregate	42
Concrete	41
Brick	29

2.2 Experiment Methodology

To stabilize the expansive clay, one of the mechanical stabilisation method is column reinforcement approach. In laboratory scale, the study is carried out in unit cell concept. Here is the study focuses on permeability characteristics of aggregate columns inside apermeability mold having 100 mm diameter and 120 mmof height. [16]. Out of the various laboratory tests available in finding the permeability characteristics, a falling head method is adopted in this study as the chosen soil is less permeable in nature.

To understand the influence of the selected two construction wastes considered in this study; two consistency of soil is selected for sample preparation. . The sample preparation includes installation of porous stone at the bottom for encouraging permeability, soil filling with the required consistency and drilling of of 30 mm diameter

hole using a hollow tube at the centre of the mould. The clay soil with the selected consistenc is placed layer by layer. For column formation, the materials considered for the study are poured layer by layer inside the hollow cylindrical tube and com- pacted to a specific density equivalent to field density. The tube isthen removed layer by layer upon the formation of column. The formed column depicts the formation of a fixed column (Fig.1). The parametric study is represented in Table. 2 with notations .

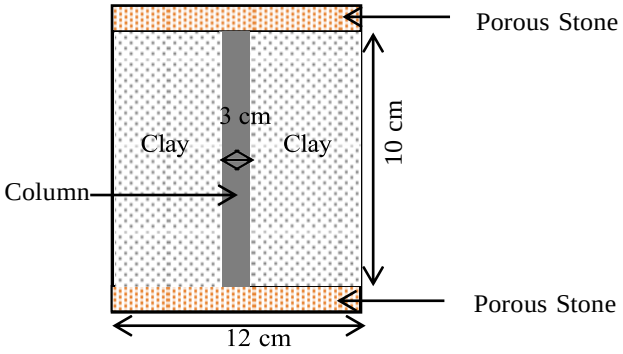


Fig. 1. Test set-up

Table 2. Parametric study

Consistency of Soil (I_c)	Clay	Clay + Ordinary stone aggregate	Clay + demol- ished concrete waste	Clay + demol- ished brick waste
0.4	C1	C1OSC	C1DC	C1DB
0.6	C2	C2OSC	C2DC	C2DB

3 Results and Discussion

Preliminary tests were conducted with clay with 0.4 and 0.6 consistency. For the soil having 0.4 consistency,54.88% and for 0.6 consistency 44.41% of water is added to the soil. The water is allowed to flow through the column and soil for a period of one hour and then the permeability characteristics are found by using equation 1.

$$k = \frac{2.303\, aL}{A(t_1 - t_0)} \cdot \log_{10}\left(\frac{h_o}{h_1}\right) \quad (1)$$

Where, k- permeability (cm/second), a – cross-sectional area of standpipe (cm^2), L- length of soil sample (cm), A – area of soil sample (cm^2), h_1 and h_0 are the water level at time t_1 and t_o respectively.

It is observed that the permeability of soil is observed as 4106 and 5861 cm/second after one hour of saturation for 0.4 and 0.6 consistency of soil respectively. The virgin soil and the composite soil are allowed to be saturated for 1, 2 and 3 days and their corresponding readings are noted.

With an increase in a day of curing the water flows through the soft and medium stiff soil and disturbs the fine particles and breaks their binding between the particles, which reduces the permeability characteristics of the soil (figure 2).

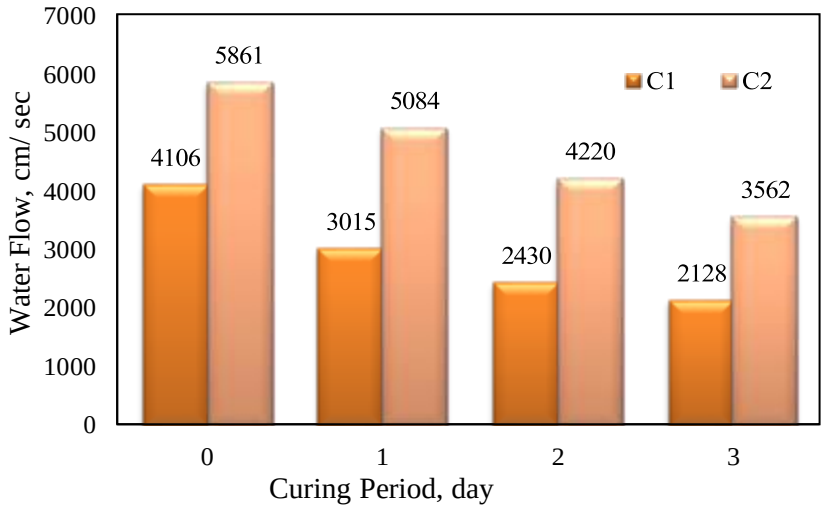


Fig.2. Water flow Characteristics of soil

To understand the similar behaviour of composite soil with column, the water is a l-lowed to flow through the column made of stone aggregate, crushed concrete and bricks under free flow conditions.

3.1 Conventional Ordinary Stone Column

With the installation of column containing stone aggregates, the rate of flow of water reduces with time. Similar to the water flow characteristics of soil, the dispersed soil particles travel along the flow of water and gets clogged that reduces the water flow. The water content of the soil places a major role in understanding the flow of water; for higher consistency (0.6) the permeability characteristics is very less compared to 0.4 consistency of soil which is almost 1000 times less (Figure 3).

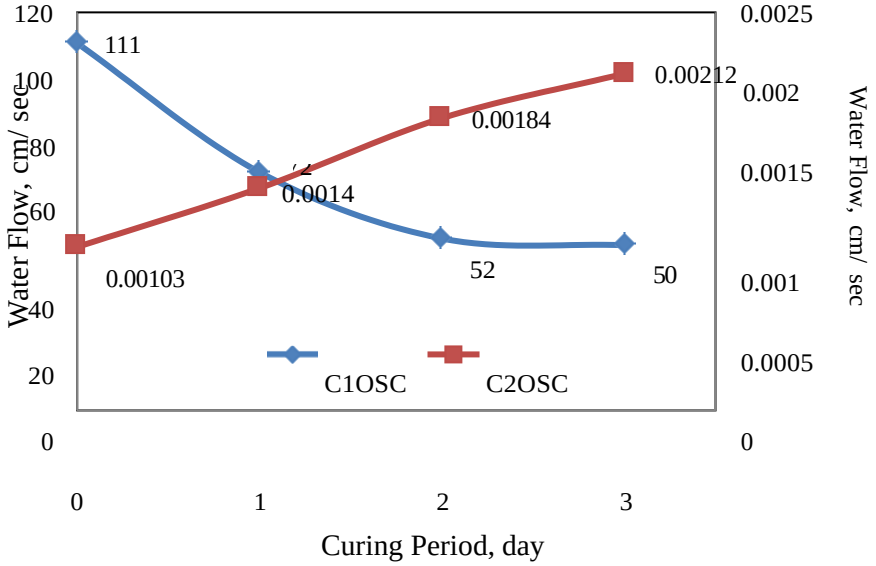


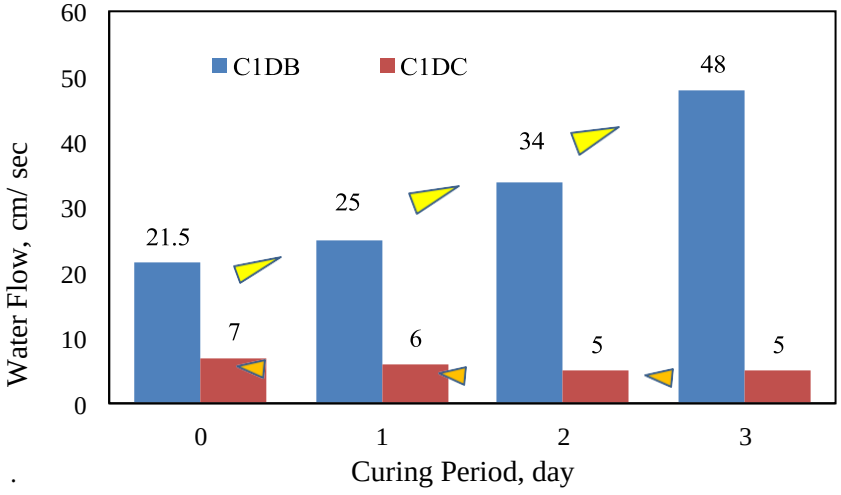
Fig.3. Permeability characteristic of composite soil with OSC

3.2 With Demolished waste

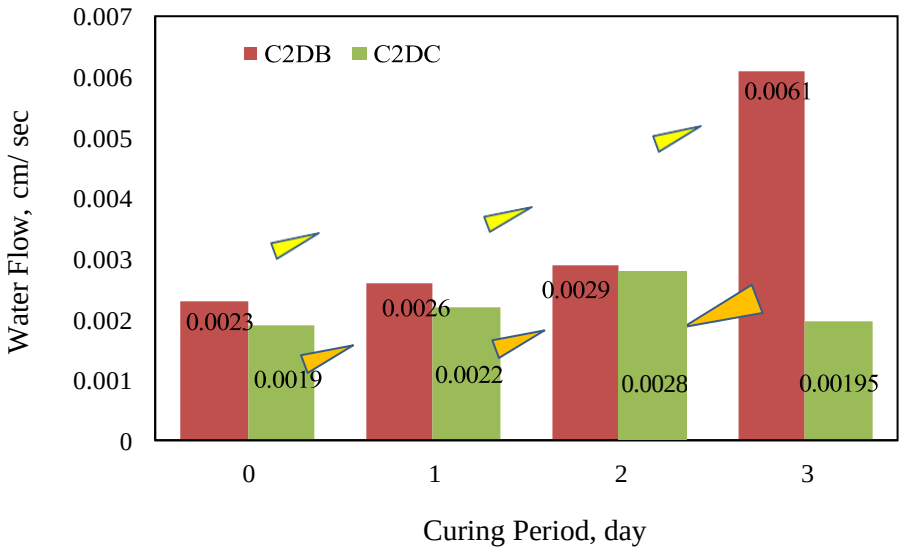
The demolished waste obtained is crushed and made to pass through 10 mm sieve and 5 mm sieve. Particles retained in a 5 mm sieve are used in the tests for making columns; where water is allowed to flow through the brick and concrete waste. The ana l- ysis is compared between the two materials for various consistencies.

The scenario changes when the conventional aggregates are replaced with DC. There is a reduction in permeability characteristics compared to C1OSC, but the value increases with increase in curing period for 0.4 consistency and becomes constant beyond 2 days. The permeability characteristics value starts with 7 cm/ second on the day of sample preparation and decreases to a value of 5 cm/ sec. The value decreases by 14.29 and 28.57% with an increase in the curing period. This value is 1/10th the value while comparing the value of OSC and DC for lower soil consistency. The con- crete being a solid material holds the water, which started leaching during continuous curing. When expansive clay is subjected to water flow continuously with top and bottom controlled, the permeability behaviour redues. Whereas for DB waste the permeability characteristics for lower consistency clay increases with curing period and it almost reaches the value of the C1OSC value. The permeability value on the day of composite soil preparation, shows a value of 21.5 cm/ sec which increases to 48 cm/sec with curing time. There is an increase in the percentage of permeability by 16.28, 58.14 and 123.26% respectively or the curing period 1,2 and 3 days. The brick can absorb more water under lower consistency having more water content which has more pores which allow the water to travel; hence it shows a higher value during the curing period (Figure 4).

The condition is not similar for higher consistency soil. The soil with 0.6 consistency has water content is 44.41% with reduction in water content by 19.08%. The permeability value is for DC and DB shows a much lower value than the virgin soil which is almost similar to OSC. With increase in curing period the permeability value shows a slight increase for both the waste. It is understood that for of stiff clay, the influence of column material is bare minimum; rather the geometry of the column can be given more importance.



. a. For Soft consistency soil



b. For stiff consistency soil

Fig.4. Permeability characteristic of composite with DB and DC

The permeability characteristics is integrated with pore pressure parameter when loaded especially in understanding the settlement behaviour after post – construction. This study mainly focussed on the permeability characteristics of soil with column made of various material under two different consistency under free flow of water, and both the ends fixed. Hence the pore pressure parameter and its related attributes are not addressed.

4 Conclusion

Permeability being a key parameter which play a prominent role in soil stabilisa- tion is studied through laboratory experiments by varying consistencies of soil and column material. The following observations are made fro the study;

1. Once the soil is fully saturated, the permeability characteristics reduces wiith time irrespective of the consistency of the soil, this proved by curing the soil for a maximu m period of 3 days.
2. The presence of ordinary stone column reduces the permeability behaviour of the soil. It is observed for lower consistency of the soil, the permeability re- duces and reaches a constant period in a minimum stipulated period. For stiff consistency, however, the results shows a increase in permeability value withtime, the value is very minimum compared to the soft soil.
3. The brick waste shows a increase in value in both the consistency, whereas the concrete waste shows a reduction in permeability value. The concrete waste can be used as a replacement for stone aggregate in column study for all types of soil. It can also be used as a toe drain material.

From the permeability behaviour, it is also observed that the use of CDW in soil stabilization helps in effective dispose of material avoiding environmental issues.

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