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Original Research Article

A PRELIMINARY COMPARATIVE STUDY OF SEEPAGE BEHAVIOUR BEHIND RETAINING WALLS WITH CRUMB RUBBER AND GEOCOMPOSITE

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A b s t r a c t

A retaining wall is built to provide support to the soil when there is a change in elevation of the ground. Weep holes present in the retaining wall help water to seep through it. Filter protection should be made behind the weep holes to prevent soil erosion around the weep holes**.** The classic filter material that is widely used is gravel, which is packed according to Hudson's law. Laboratory experiments were conducted to understand the seepage function of alternative material such as crumb rubber and geocomposite (fabricated) in a homogenous sand layer and in-situ soil. The time taken by the water to reach the weep holes was calculated and compared. From the results, it is suggested to use crumb rubber as an alternative packing material behind the weep hole.

Keywords: crumb rubber, geocomposite, permeability, experimental study

1. INTRODUCTION

A retaining wall is constructed to retain the soil on one side and making the other side convenient for human purposes. It is designed for the following stability conditions; safety against overturning, safety against sliding, safety against allowable soil bearing pressure and stress within the components that are

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within codal provisions (Brooks, 2010). The main cause of the retaining wall is due to improper design and poor construction practice (Figure 1).

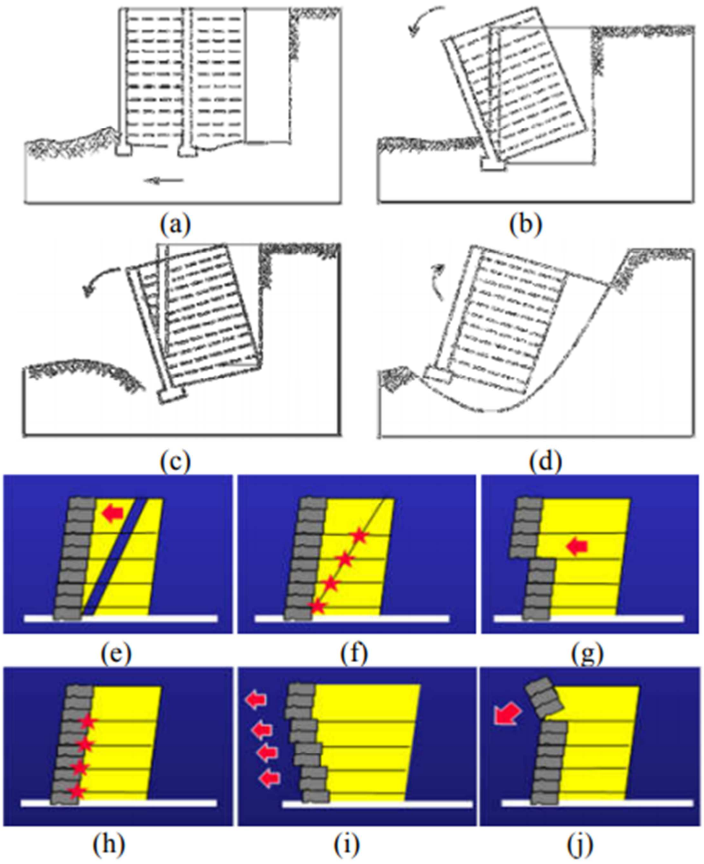

Fig. 1. Failure modes of reinforced earth wall (External failure (a) basal sliding, (b) overturning, (c) bearing capacity failure, (d) overall sliding; internal failure (e) pull-out failure, (f) breakage of reinforcement, (g) internal sliding, (h) breakage of connector, (i) shear failure of facing wall, (j) failure of upper facing block) (Shin et al., 2011)

Soil and water interaction behaviour leads to various problems. When the water penetrates into the voids of the soil, soil erosion takes place. Permeability is defined as the velocity of flow under a hydraulic gradient of unity (Ranjan and Rao, 2005). The piping effect occurs if the permeability of material used in drains is not studied to a maximal extent. Hence, soil permeability behaviour should be understood clearly.

During rainy seasons, water tends to penetrate into the retained soil and seeps through the weep holes. The purpose of these weep holes is to drain the water into a proper drainage system, which is constructed along the bottom of the retaining wall (Figure 2). If the water is not drained properly, hydrostatic pressure built behind the retaining wall increases, where the retaining wall may not be designed to carry that pressure. Due to high generation of hydrostatic stress, the face of the retaining wall tends to crack (Figure 3) where the backside of weep holes will have a soil packing from smaller particles to larger particles towards the face of the retaining wall. In a recent trend, geocomposite material is widely used as the cost reduces by 35% compared to a conventional system (Pietro, 2013).

Few case studies discuss the erosion of soil slope and the importance of drains. Leeves, an important flood protection structure, was damaged by improper seepage. When the soil is mixed with short fibre as reinforcement (length 10 – 100 mm), it shows a high erosion resistance (Furumoto et al., 2002). Rainfall intensity also plays a vital role in causing instability (Dahal et al., 2006), and therefore should be considered as an important parameter while designing. In addition, improper wall design against stability leads to failure of the retaining wall (Souza et al., 2017).

Crumb rubber is a largely produced solid waste after recycling used tyres and crumbed into uniform angular pieces. It was reported that every year, about 100 crores of used tyres were turned into crumb rubber (Thomas et al., 2014). This solid waste was used widely in pavement and concrete as a replacement material for aggregates.

In order to understand the importance of permeability characteristics of CR, a laboratory study was conducted in homogenous sand and in-situ soil with packing material as crumb rubber in single and triple layers near the weep holes. To compare it with the modern material, geocomposite material (laboratory fabricated) was used behind the weep holes.

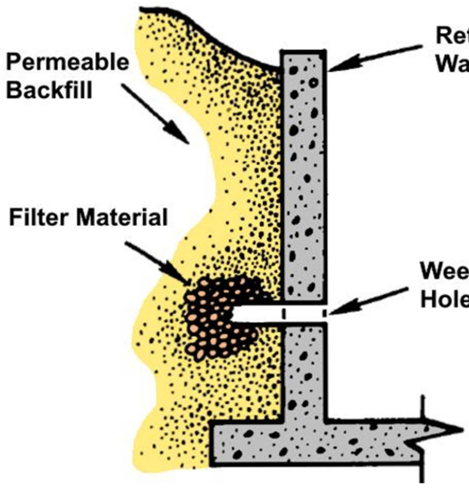

Fig. 2. Location of drains in retaining wall (Froehlich, 2017)

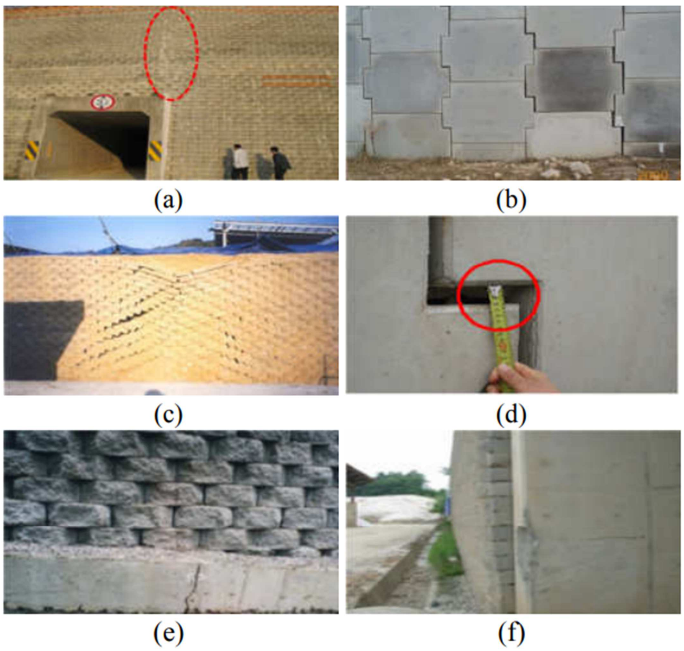

Fig. 3. Excessive settlement and deformation (a) cracking of facing wall, (b) differential settlement of facing wall, (c) settlement of REW, (d) excessive settlement of facing wall, (e) differential settlement of REW, (f) deformation of wall) (Lee and Cho, 2011)

2. MATERIALS PROPERTIES

2.1. Soil Properties

For laboratory experiments, two soils were used: pure sand (*S1*) and in-situ soil (*S2*), which were collected from the college premises. The characteristics of the soil were found using Indian Standard codes (Table 1).
The particle size distribution of *S1* and *S2* is shown in Figure 4. From the graph, Coefficient of Uniformity (c_u) and Coefficient of Curvature (c_c) is calculated by the following equation (2.1,2.2).

$$c_u = \frac{D_{60}}{D_{10}} \tag{2.1}$$

$$c_c = \frac{D_{30}^2}{D_{60} D_{10}} \tag{2.2}$$

Where, D_{10}, D_{30} and D_{60} are the particle size corresponding to 10, 30 and 60 % finer.

Table 1. Properties of the soil

Properties	Values for Soil		IS Code
	S1	*S2*	
c_u	2.857	9.2	IS 2720 (4) : 1985
c_c	1.03	0.735	
Specific gravity	2.7	2.2	IS 2720 (3)-1980
Dry Density, kN/m^3	18.36	16.79	IS 2720 (7)- 1987
Optimum Mositure Content, %	6.8	6	
Angle of internal friction, deg	38	38	IS 2720(13) -1986
Permeability, mm/sec	2.105 x 10^{-3}		IS 2720 (17) -1979
Classification	SP (Poorly graded sand)	SP (Poorly graded sand)	IS 1498 -1970

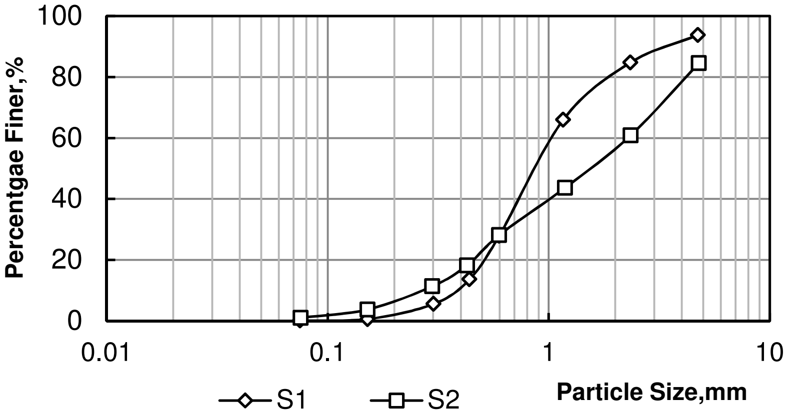

Fig. 4. Soil distribution curve

2.2. Materials used and its properties

Crumb rubber and geocomposite materials were used as drains for the experiments and its properties were listed below;

1. Crumb Rubber (CR): Recycled material from used tires and its properties are listed in Table 2. The reuse of used tires is an emerging engineering aspect. It is widely used as replacement material in concrete for fine aggregate.

Table 2 . Properties of CR

Description and Properties	Specification
Ash Content	4.0 - 5.5%
Acetone Extraction	7 - 10
Moisture Content	0.5 % Max
Carbon Black	20 - 25%
Specific Gravity	1.17
Fineness through 30 microns	100%

2. Geocomposite (GC): Due to its longevity, currently geocomposite materials are widely used in reinforcing and stabilizing the soil. In the current study, non- woven geotextile sandwiched with geogrid was used as a filter material (laboratory fabricated – Figure 5) with its properties listed in table 3.

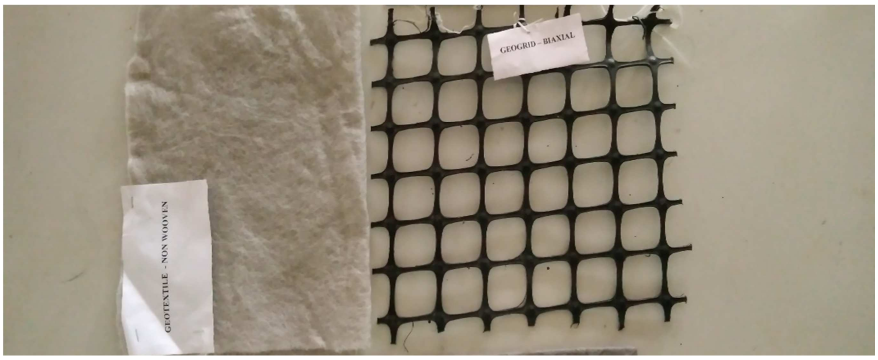

Fig. 5. Geocomposite material

Table 3. Range of values for some properties of Geosynthetics (Lawson and Kempton, 1995)

Types	Thickness, mm	Mass per unit area, gsm	Ultimate max. tensile strength, kN/m	Extension at max. load, %	Apparent opening size, mm
Non-woven geotextiles	0.25 - 0.75	100 -2000	5 - 100	20 - 100	0.02 - 0.6
Woven - Geotextiles	0.25 - 3	100 - 1500	20 - 400	10 - 50	0.05 - 2
Geomembranes	0.25 - 3	250 - 3000	10 - 50	50 - 200	≈ 0
Geogrids	5 - 15	200 - 1500	10 - 200	5 - 25	10 - 100
Geonets	3 - 10	100 - 1000	-	-	5 - 15

3. METHODOLOGY

3.1 Test Tank Set-up

An acrylic tank of 0.3 x 0.3 x 0.3 m tank was fabricated with a scaling factor of 20 as per Buckingham π theorem.

The height of the wall was taken as 6 m, with a wall thickness of 1 m as per Indian standard 14458 -1 for masonry retaining walls, with toe drain at a height of 1 m above the foundation and central weep holes with spacing, not more than 3 m (Figure 6). A freeboard of 50 cm was left in the top of the soil. In order to understand the mean behaviour of the permeability characteristics of soil behind the retaining wall, weep holes were provided for seepage of water. Five weep holes were made in an interlaced format with two holes in the top and bottom and one hole in the centre; for the purposes of the study, a central hole was considered.

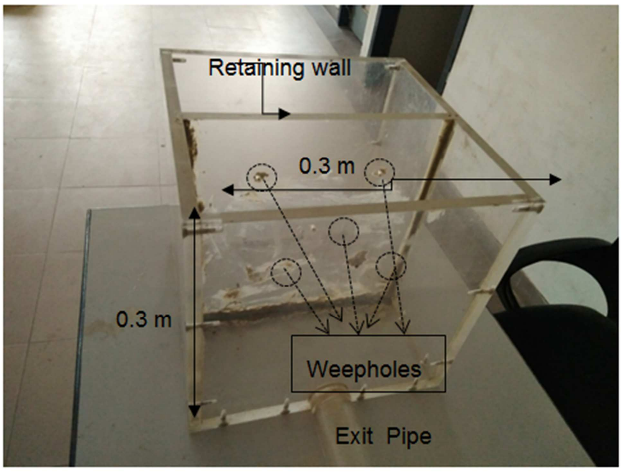

Fig. 6. Fabricated Tank

3.2 Sample Preparation

The prefabricated acrylic mould was coated with oil/grease in order to avoid wall friction and leakage of water. Sandy (*S1*) soil was filled in a mould at an optimum height of fall - 5 cm determined by relative density test for various height of fall (Figure 7). In the case of in-situ soil (*S2*), the soil was cut from an excavation pit and placed directly into the mould. The water was supplied to the sample by maintaining constant head delivered from a height of 0.3 m. Initially, all the holes were blocked, it was let open when the soil was fully saturated (Figure 8). The water draining from the soil sample through weep holes was collected and the corresponding time taken was noted.

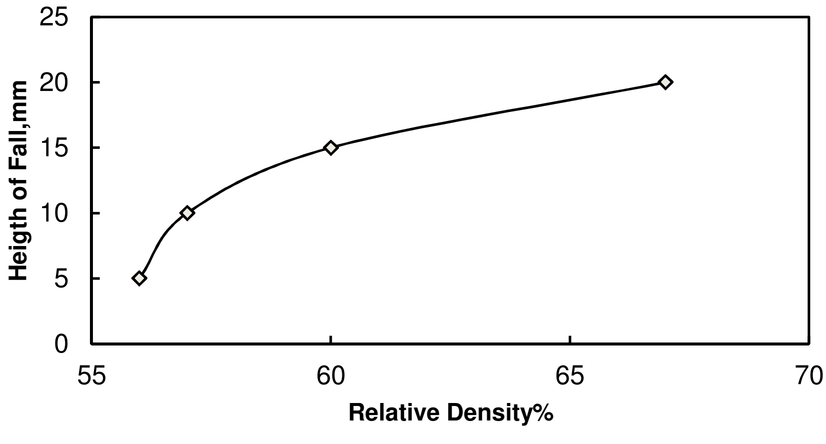

Fig. 7. Height of fall Vs relative density

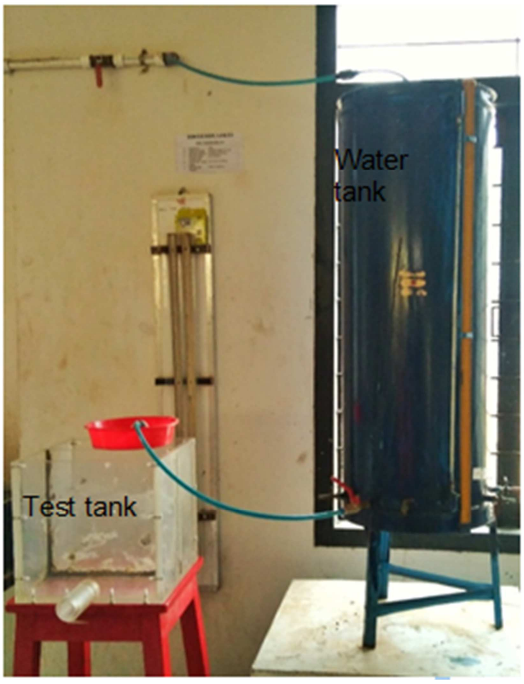

Fig. 8. Setup for the experiment

3.3 Placing of Material

CR: CR was packed at the back of the weep holes in single and three layers and allowed for water to flow.
GC: The composite materials were placed near the central weep hole and then the soil was filled.

4. RESULTS AND DISCUSSION

The test was conducted by keeping the water head as a variable – simulating the falling head permeability condition. The time is taken to collect 1 litre of water was measured.

Initially, all the tests were conducted by opening all the five weep holes upon filling the test tank and the results were observed (Figure 9). As the holes were closed initially and opened upon filling the tank, the time taken for the water to flow through 5 weep holes was reduced by 66.3% compared to a single hole. As the time taken was very quick, the central weep-hole alone was chosen for the study.

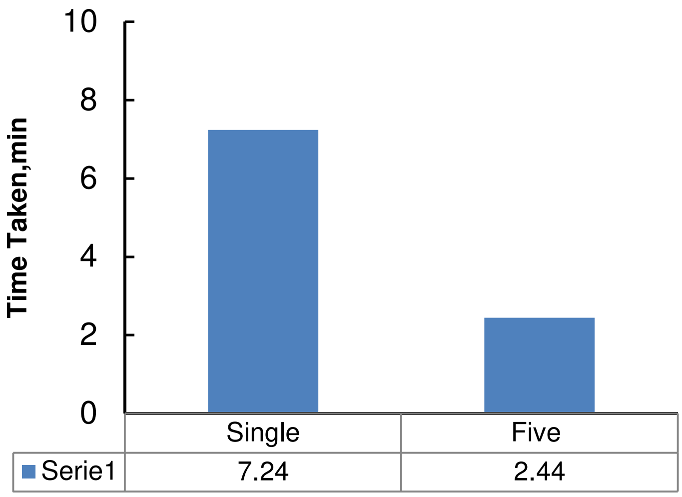

Fig. 9. Comparison of time taken between single and five weepholes

4.1 With *S1* soil

For cohesionless, homogenous sand, the time taken to collect one litre of water through single weep holes was 7.24 minutes. This value was considered as the base value for further comparison.

Crumb rubber retained on 600-micron sieve (available size) was used in the back of the weep hole, as smaller particles provided better seepage. However, usage of CR reduced the time taken to seep by 26.52% and 53.45 % respectively for single and multiple layers, for example 3 layers. It was observed during the experiment that the CR started coming out of the weep holes and subsequently, the CR packing was disturbed due to its finer particle size. In the case of GC, the time taken had a reduction of about 39.64% (Figure 10).

4.2 With *S2* soil

In order to understand the real-time behaviour of the soil, in-situ soil was used for the tests collected from the college premises. Field soil, otherwise termed as in-situ soil, showed a heterogeneous combination, which contains a negligible percentage of fine particles. The presence of organic matter in the top of the soil was removed manually, as it affects the water flow. The entire test for in-situ soil was carried out by providing single weep holes.

The time taken to collect 1 litre of water through the in-situ sample was calculated as 8.47 minutes, which was mainly due to the presence of heterogeneity. When crumb rubber was placed near the weep holes, the time was reduced to 5.58 minutes for a single layer. For multiple layers, the seepage was increased to 50 minutes. During the experiments, it was observed that the particles started moving and the larger particles clogged the weep holes, resulting high time taken. In-situ soil with GC shows an appreciable behaviour by reducing the seepage by 58.68 %, reducing the pressure acting on the wall (Figure 11).

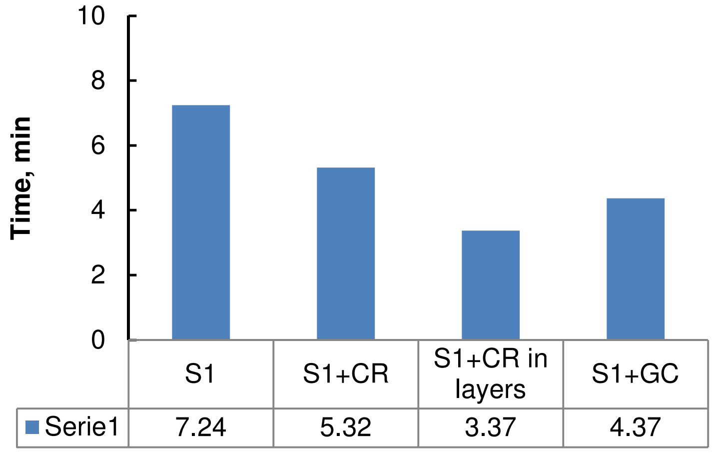

Fig. 10. Comparison of seepage for various materials - *S1*

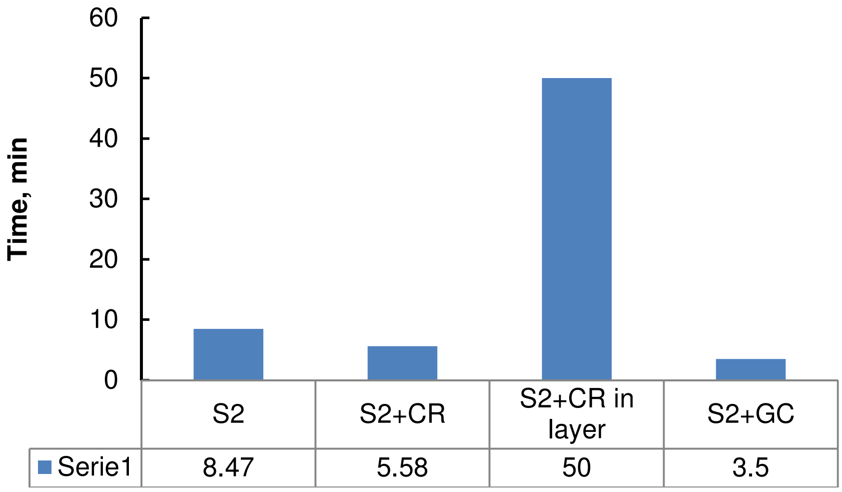

Fig. 11. Comparison of seepage for various materials - *S2*

There was a decrease in seepage time between 26 and 53.45 % for sandy soil with crumb rubber (*S1*) as its packing material behind the weep holes; for geocomposite material, the seepage time decreased to 39.64%. A non-degradable man-made material, geocomposite showed a conventional reduction in seepage time. *S1* with three layers of crumb rubber showed more than a 30% reduction in seepage time compared to *S1*+GC, which is highly appreciable. For in-situ soil (*S2*), the decrease in seepage time was 34.12% for a single layer of crumb rubber, and for geocomposite material it was 58.68%, which showed a reduction in time by 42%. Hence, CR can be ideally reused in retaining walls for drainage purposes, thus providing an effective avenue for water management. Due to the difference in seepage behaviour of single and multiple layers of CR, the function of multiple layers should be modelled in the laboratory before commencing installation work in the field.

5. LIMITATIONS

In order to get a better understanding of the water flow, the top and bottom two weep holes were closed by keeping the central hole open. The study is a basal attempt to understand the seepage behaviour, hence the intensity of the rain is not varied. As the study in this area is limited, an attempt on one to compare the parameters considered was not possible due to the almount of literature in the existing area.

6. CONCLUSIONS

From the experiment, the importance of seepage time when various materials are used behind weep holes retaining walls is important. Here, the packing of materials also showed a high degree of variation. If CR, a solid waste material, is used as a single layer, it reduces the seepage time by 34%. In the case of multiple layers, there was a reduction in time taken for homogenous sandy soil and an increase in the time taken for in-situ soil as the coarser particles present by nature itself act as a filter media and retard the seepage flow. This retardation leads to stagnation of water over its freeboard thickness and reduces the time taken. Due to the low permeability behaviour of GC, the time taken reduced for both the soil types.

The largely available solid waste material (CR) showed good improvement in seepage time, which can be used as an alternative material in the back of drainpipes to prevent erosion. Seepage time of crumb rubber in the back of weep holes was compared with conventional geocomposite material.

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