# EFFECT OF TILES WASTE AND FLY ASH BRICK WASTE ON PERMEABILITY AND STRENGTH OF LOWER GRANULAR SUB-BASE MATERIAL

Mishra Pooja Mangalprasad [1] and Hrishikesh Ashok Shahane [2][0000-0003-3339-2234]

[1] Assistant Professor, Department of Civil Engineering, JESITMR, Nashik, Maharashtra-422222, India.

[2] Doctoral student, Applied Mechanics Department, S. V. National Institute of Technology, Surat, Gujarat-395007, India.
poojams01@gmail.com;shahane.hrishi@gmail.com

**Abstract.** As there is growth in the construction industry, construction and demolition (C&D) waste generation is also growing with higher rates in India and hence dumping this waste is a major problem. The construction industry generates 12-15 million tonnes of C&D waste per annum. This C&D waste can be effectively utilized for construction of road pavement. Granular subbase course (GSB) acts as an important layer in the structure layer as well as a drainage layer in the pavement. Most of the pavements in India fail prematurely mainly due to the ineffective functioning of this drainage layer. In this study, engineering properties of fly ash brick (FAB) waste and tiles waste (TW) in a combination of murum to serve it as granular sub-base materials were investigated. The objective is to compare the permeability as well as strength characteristics of GSB gradations prepared with different C&D mixes. Modified Proctor tests were conducted on different mixes of FAB waste and murum as well as TW and murum for determination of compaction characteristics. Proctor test result shows that as FAB waste content in murrum increases, the MDD value decreases, and the similar results were obtained for TW content.CBR test was conducted on the various mixes of waste material and murum from which CBR value of 70M+30FAB was found to be highest. From Permeability test it was observed that the k value goes on increasing after the addition of FAB and TW in soil murrum mix. The permeability test indicated that FAB and TW materials are effective to drain off the water from the sub-base layer. From the study, it was noticed that the strength parameter of FAB waste was found to be more effective than that of TW and both the material shows improvement in drainablity property.

**Keywords:** Granular sub-base, Fly-ash brick waste, Tiles waste, CBR, Permeability

## 1 Introduction

India is the fastest-growing economy in the world. The Indian construction industry is an essential part of the economy and people's expanding expectations for a better quality of living. As per the smart cities mission of the Government of India, strategic components of area-based development in the Smart Cities Mission are city improvement, city renewal and city extension (Ministry of Urban Development, GOI, 2015). The renovation will result in a replacement of the current built-up environment and enable co-creation of a new layout with enhanced infrastructure using mixed land use and increased density. In such missions, a large quantity of C&D is expected to be gendered as some existing infrastructure will going to replace with new infrastructure which will give the more intensive infrastructure service levels and a large number of smart applications. In this journey to maintain the equilibrium between demand and supply of materials, ensuring material prices stability, and conformance of materials to quality standards are the biggest challenges. Reuse of recycled C&D materials in civil engineering practices will decrease the demand for virgin natural resources and at the same time reduce the quantity of this waste material destined for landfills (Arulrajah et al. 2013). This will affect in a low carbon solution, considering that recycled materials have noteworthy carbon savings compared with virgin quarried materials (Disfani et al. 2014). C&D materials have been used in recent years in various civil engineering applications such as highways, embankments, concrete, and backfilling (Arulrajah et al., 2011; 2013; Mohammadinia et al. 2015; 2016; Arisha et al., 2018).

In India, approximately 12-14.7 million tonnes of C&D waste is generated per annum as reported by CPCB (Gupta and Malik, 2018). According to Shen et al. (2004), C&D waste is a combination of surplus constituents generated from the construction, renovation, and destruction activities such as site clearance, land excavation, and roadwork and demolition. Unfortunately, the C&D waste is usually dumped on the sides of canals, on minor roads, and at the entrances of cities and towns, even though there are allocated landfill areas for dumping this kind of waste; that causes environmental problems and affects people’s daily lives (Arisha et al. 2018).

The objective of this paper is to study the effect of tiles waste and fly ash brick waste on engineering and geotechnical properties of sub-base material. As Granular subbase course (GSB) is provided above the subgrade of pavement to serve both as a structural member of flexible pavement layer system and as a drainage layer in pavements. The Ministry of Road Transport and Highways (MORTH, 2013) recommend 6 types of GSB mixes, to be laid in different combinations. It is recommended that gradings III and IV shall preferably be used in lower subbase. However, grading V and VI shall be used as a sub-base cum drainage layer. The specification includes the strength requirements, liquid limit (LL) and plasticity index (PI) values but has no specific criteria or requirements for effective drainage based on an estimation of permeability/ hydraulic conductivity (k) is given. These specifications often fulfill the requirements of the layer as a member however it is not clear whether these gradations fulfill the drainage requirements. Hence there is a need to check the permeability of the recommended GSB mixes. In most of the national highway development projects in India, modified specifications of GSB material using crushed aggregates with quarry dust for the fines, to avoid the use of gravelly soils with fines having plasticity, are being adopted in order to ensure adequate drainage. Hence in the present study, GSB mixes with non-plastic C&D waste (tiles waste and fly ash brick waste) have been used to study the drainage characteristics. While the standard permeameter for measuring vertical permeability in the laboratory is used for materials of size less than 4.75mm, there is no standard test by which the permeability of GSB mixes having greater aggregate sizes can be checked.

## 2 Background

Several researchers studied various types of C&D waste materials in an attempt to investigate the usage of it in several civil and geotechnical engineering applications. Arulrajah et al. (2013) have done a comprehensive laboratory evaluation of the geotechnical and geoenvironmental properties of five predominant types of construction and demolition (C&D) waste materials. The C&D materials tested were recycled concrete aggregate (RCA), crushed brick (CB), waste rock (WR), reclaimed asphalt pavement (RAP), and fine recycled glass (FRG). In terms of usage in pavement subbases, RCA and WR were found to have geotechnical engineering properties equivalent or superior to that of typical quarry granular subbase materials. CB at the lower target moisture contents of 70% of the OMC was also found to meet the requirements of typical quarry granular subbase materials.

Mohammadinia et al., (2015) investigated the reclaimed asphalt pavement (RAP), recycled concrete aggregate (RCA), and crushed brick (CB). The geotechnical properties of cement-treated C&D materials were evaluated to assess their performance in pavement base/subbase applications. The RAP exhibited the highest strength in all cases, with the same cement content and for the same curing duration, followed by RCA and CB. The resilient moduli of C&D materials increased with an increase in cement content, curing duration, and confining pressure. It is also indicated that cement-treated C&D materials are viable construction materials for pavement base/subbase applications. The behavior of C&D materials, when stabilized with geopolymers, was studied by Mohammadinia et al., (2016). Fly ash (FA) and ground granulated blast furnace slag (S) were used as pozzolanic binders and a different alkaline activator solution to pozzolanic binder ratio was tested. Both the resilient modulus of the C&D materials and compressive strength were found to increase as a result of geopolymer stabilization. Geopolymer stabilization was found to be most effective for RCA. Higher compressive strength will be achieved by slag-based geopolymer stabilization when compared with fly ash-based geopolymer stabilization. Arisha et al., (2018) investigated the suitability of recycled concrete aggregate (RCA) materials and recycled clay masonry (RCM) brick in pavement construction in Egypt. The preliminary recommendations after assessing the effect of RCA and RCM mixes on pavement performance were suggested. The recycled materials showed better pavement performance in terms of rutting and fatigue cracking in comparison with the typical virgin aggregate. Dungca & Jao (2017) has determined the optimum blending proportion of fly ash and bottom ash to the conventional road base materials used as highway embankments. Results show that the optimum strength can be produced at a blend of 100% bottom ash. However, permeability tests show a considerable decline in hydraulic conductivity with the addition of coal ashes to the typical aggregates. Thus, proper drainage must be carefully applied to these blended embankment materials so as to avoid substantial ingress of water. Richardson (1997) has undertaken a study to determine the drainability characteristics of several types of unbound granular materials that are used in pavement bases. Hydraulic conductivity and effective porosity were determined for aggregates from two sources of crushed stone and two sources of gravel. For each material, two open gradations were tested in a rigid wall permeameter. Typical dense-graded gravel and crushed stone pavement base materials are relatively slow draining and effective porosities that average 27% of nominal porosities for a range of expected field compacted densities.

## 3 Material Characterization

Murrum is the coarse-grained soil mixed with fines which is used for road and embankment construction widely all over the world. The murum (M) used in this study was obtained locally from Nashik. On the basis of the particle size range, Cu (6.78), and Cc (2.14) the murrum was classified as clayey sand (SC) as per IS 1498 (IS, 2016). Tiles waste (TW) material and fly ash brick (FAB) waste material was collected from the waste generated at a locally available construction site in Nashik, the tile waste, as well as fly ash brick waste, were classified as poorly graded gravel (GP) category as per IS 1498 (IS, 2016). The TW and FAB materials were pulverized in the laboratory, as shown in Fig. 1(b-c), with a maximum particle size of 20 mm to meet the requirements of specification for granular subbase grading III (MORTH, 2013). From direct shear test on murrum soil shear paprameters were evaluated, cohesion (c) = 0.09kg/cm² angle of friction (φ)=23.51°. The geotechnical properties of recycled C&D materials are presented in Table 1.

**Table 1. Geotechnical Properties of Recycled C&D Materials**

| Property | Murrum (M) | Tile Waste (TW) | Flyash Brick Waste (FAB) |
|---|---|---|---|
| Type of soil | SC | GP | GP |
| Specific Gravity (G) | 2.83 | 2.47 | 2.06 |
| Plastic limit % | 26.75 | - | - |
| Liquid limit % | 51.5 | - | - |
| Plasticity Index (Ip) | 21.7 | - | - |
| MDD (gm/cc) | 1.95 | 1.78 | 1.90 |
| OMC (%) | 12 | 14.47 | 13.62 |
| $D_{10}$ mm | 1.18 | 2.5 | 0.6 |
| $D_{30}$ mm | 4.5 | 10 | 4.5 |
| $D_{60}$ mm | 8 | 10.7 | 8 |
| $C_u$ | 6.78 | 4.25 | 13.33 |
| $C_c$ | 2.14 | 3.73 | 4.22 |

a b c

**Figure 1.** Murrum and C&D Materials

## 4 Methods and Sample Preparation

To study the engineering properties of the TW/FAB blends for use in pavement construction, a sequence of laboratory tests were conducted. The laboratory tests included basic characterization tests such as particle size distribution, specific gravity (coarse and fine fraction), as well as modified Proctor compaction, CBR tests, and falling head permeability test.

Fly ash brick waste and Tile waste were added to the murrum samples to investigate the effects of these materials on permeability and strength on granular sub-base material. Certain geotechnical properties of the murrum were determined by mixing tile waste and fly ash brick waste in the different percentage like 0%, 10%, 20%, and 30% by weight of soil murrum samples (Dungca & Jao, 2017). Compaction, CBR test, permeability test were performed on each of them. The effects these wastes on soil murrum were thereafter determined.

## 5 Test results and Discussion

Materials like metal brick, Kankar, and crushed concrete are permitted to use in the lower sub-base (MORTH, 2013). The particle-size distribution curves of the C&D materials were determined from sieve analysis (Fig. 2). These plots were compared with upper and lower bound limits specified by the MORTH-2013. As shown in Fig. 2, the grading limits of the C&D materials were within the specified limits for pavement granular subbase materials, with some materials just below the marginal line.

Fig. 3 shows the compaction curves of a mixture of murum and fly ash brick waste. The Modified compaction test results indicated that murrum had the highest MDD. As the FAB waste content in murrum increase, the MDD value decreases. The fact that FAB has lower density as compared to murrum. The compaction curve of murum and FAB also shows its sensitivity to water content changes. It is also observed that the OMC value increases with the fly ash brick waste content which due to absorption of water by FAB grains during mixing and compaction.

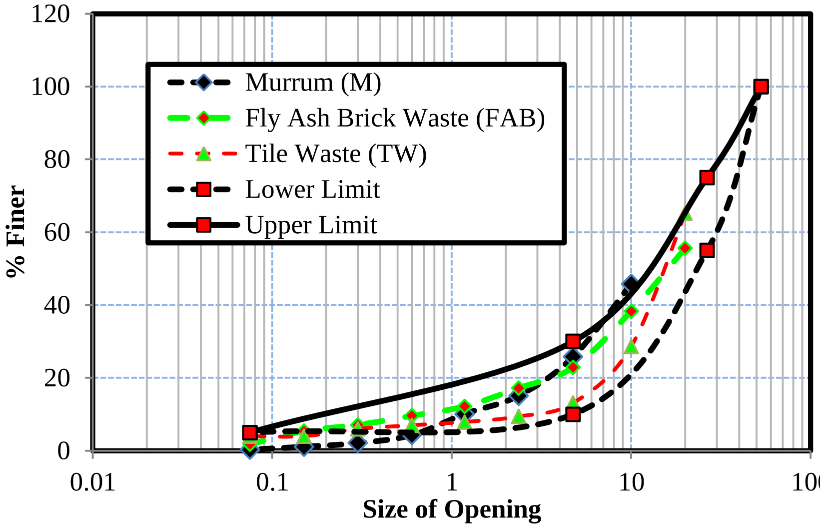


**Figure 2.** Grain Size Distribution curve of C&D Materials

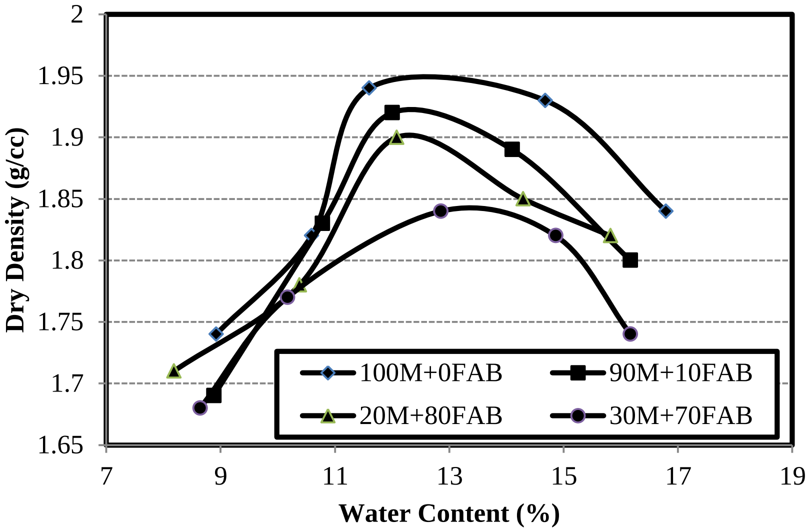


**Figure 3** Modified compaction curves of Murum and Fly Ash Brick Waste

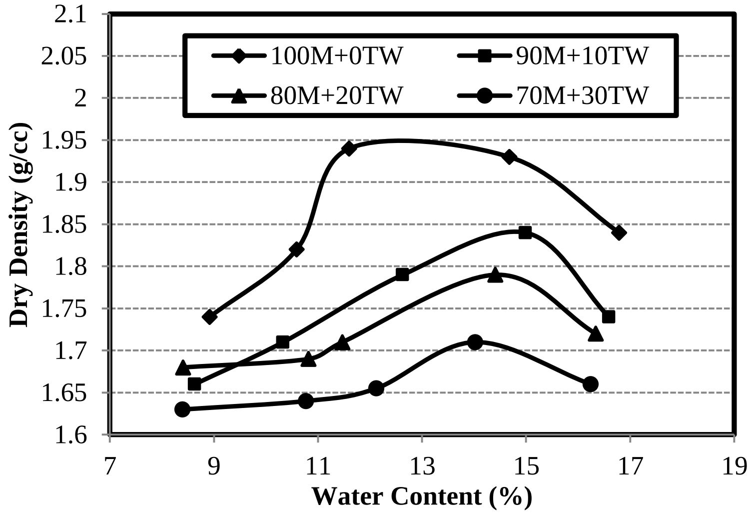


**Figure 4** Modified compaction curves of Murum and Tile Waste

Similar compaction test results were obtained in case of TW and murum mixture. Results indicated that as the TW content in murrum increase, the MDD value decreases. However, the compaction curve of murum and TW suggests its low sensitivity to water content changes in comparison to murrum which indicates that TW gives the stable compaction behavior and good workability over a wide range of water. The various combination of M&TW shows the MDD value in the range of 1.7-1.8 g/cc and OMC value of 14-15%.

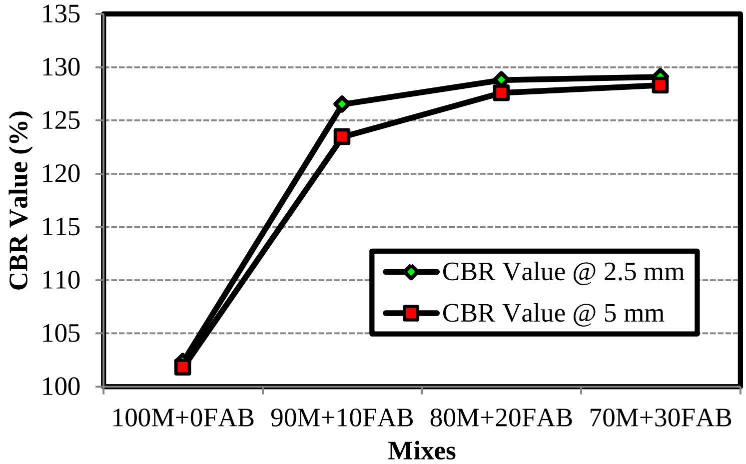


**Figure 5.** Variation of CBR value with FAB content

CBR test specimens were prepared by applying modified compaction efforts to Murrum and FAB/TW mixed at their OMC as obtained in compaction tests and then the samples were soaked in water for a period of four days. The CBR values for M and FAB mixes were found in the range between 101 to 129% and satisfy the specifications of MORTH (2013) requirements for a lower subbase material, which requires a least CBR value of 30%. The distinction in CBR results for the murum and 3 mixes is shown in fig. 5. It was observed that with FAB content the CBR value increases. The CBR value with FAB contents was found to be higher than that of murum. Maximum CBR value was observed as 129% at 2.5mm penetration value for the 70M+30FAB mix.

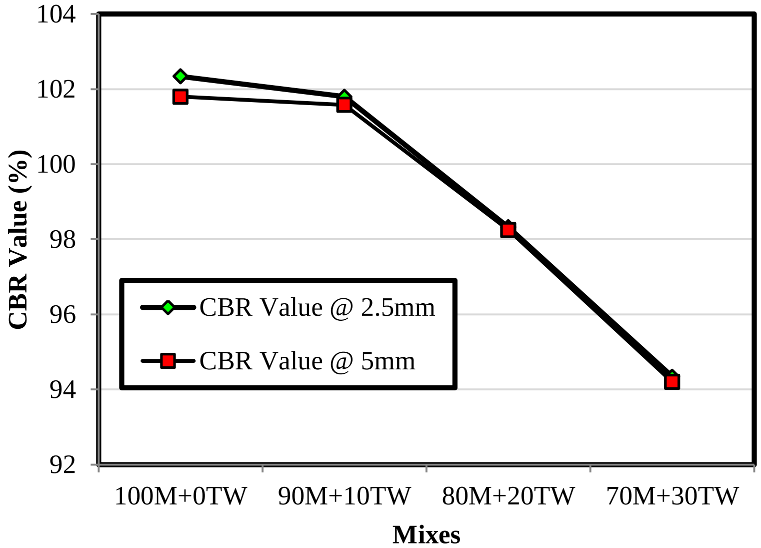


**Figure 6.** Variation of CBR value with TW content

Fig. 6 shows the variation of CBR value with TW. It was observed that the CBR value decreases with TW content, however, it meets the specifications of MORTH (2013). Similar results were reported by Poon and Chan (2006) in the investigation of crushed brick in CBR tests. By comparing CBR performance of both C&D material it was observed that the addition of fly ash brick waste gives the better replacement to the sub-base material as its maximum CBR value is about 129% for 2.5mm penetrations in soaked CBR condition of 4 days.

On comparing the results of various mixes it was observed that the permeability value goes on increasing after the addition of FAB and TW (Fig. 7). This increase in the permeability is due to an increase in the void ratio of mixes as shown in fig. 7. As the addition of FAB/TW creates the open-graded material and there was an effect of particle shape on the permeability of mixtures, thus making the mixture coarser. Test results show that both the mixes have good drainability property which is required for effective designing of a sub-surface drainage system. The permeability of granular material is a function of particle-size distribution, pore continuity, and pore shape. These are affected by particle-size distribution, particle shape, and relative density (Richardson, 1997).

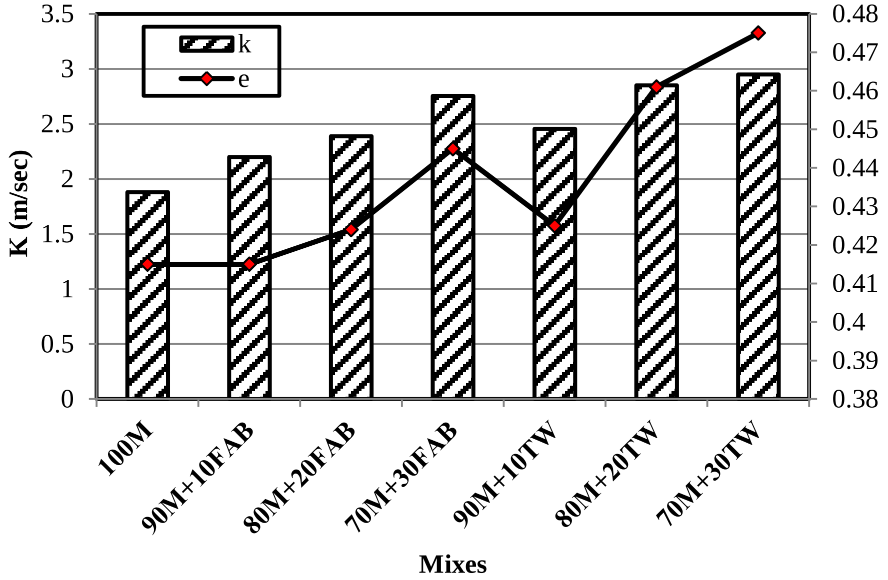


**Figure 7** Variation of 'k' value and 'e' for various mixes

## 6 Conclusions

The properties of the material and their particle size distribution was influenced greatly on OMC and MDD value. The CBR value with FAB contents was found to be higher than that of soil murum and TW mix. Maximum CBR value was observed as 129% at 2.5mm penetration for the 70M+30FAB mix, even though its void ratio was higher than that of other mixes. The FAB addition increases the frictional shear force between the matrix of murum and resists the load. Permeability result shows that both FAB and TW have good drainage property. The addition of FAB waste was found as more effective than that of TW waste as they satisfy the specifications Indian Road Congress for granular subbase layer.

## 7 References


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