CBR Properties of Sand Mixed with Modified Waste Expanded Polystyrene Foams (EPS)

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Abstract: The impact of using recycled waste expanded polystyrene foams (EPS), as a lightweight fill material by mixing with river sand were presented in this study. The waste EPS were thermally modified. The modified expanded polystyrene (MEPS) were gained by putting the waste EPS into an oven at 130°C for 15 minutes. The California Bearing Ratio (CBR) values of sand mixed with MEPS was studied. To conduct the test, five series of specimens were prepared that have a replacement of MEPS by weight which were 0%, 5%, 10%, 15%, and 20%. For each ratio CBR test were conducted. Unsoaked condition was used to perform the tests. By increasing the percentage of MEPS the values of CBR of the mixture were decreased. However, the minimum CBR value at 20% MEPS is still within subbase tolerance. Results of the tests demonstrate that addition of 20 % MEPS in sand makes the reduction of the density of mixture almost 50 %. MEPS can be an alternative light weight fill material for geotechnical application such as embankment of abutments.

Keywords: River Sand, Lightweight Fill, Geofoam (EPS), Unit Weight, Recycling Waste, California Bearing Ratio (CBR)

1. Introduction

Human kinds have been trying to keep the environment clean for many years. Research gives us the concept of how we can maintain the natural balance of life and recycling. Large amounts of waste are generated due to natural devastation, population increase, and urbanization. Iron, wood, glass, ceramics, rubber and EPS (i.e.; expanded polystyrene) are some examples of the wastes. After distinguishing materials according to their types, then materials can be recycled in order to make it productive (Kan & Demirboga, 2009a). Unmodified EPS foam has a cellular microstructure with closed cell membranes made of expanded polystyrene and its density is typically less than 50kg/m3. Today, EPS is actually used as an involution and insulating materials in various industrial fields around the world. Large amounts of EPS are consumed and wasted. Many environmental issues come from the waste of EPS, such as water and land pollution, because it cannot be degraded in nature. Thermosetting is applied to change the behavior of the material in addition to softening and hardening. The useful service life of EPS can be obtained by the process of converting the characteristics of EPS to a useful form, e.g., density, strength properties, or some other desirable properties, e.g., water absorption and thermal conductivity. Heat treatment is used in many industries to make the physical properties of waste efficient. In field of geotechnic, the application of geofoam (EPS) as lightweight materials has increased.

There are various promising advantages to using modified expanded polystyrene containing river sand as backfill material for retaining walls. The weight of the material is light which makes the EPS very special. In site construction where the underlying soil is soft, a mixture of low density foam and sand stratifies the minimum normal stress than conventional backfilling which leads to a smaller settlement and overall stability improvement. Since the horizontal stress applied to the retaining wall is lower than that of conventional backfilling, the design of the retaining wall becomes less expensive. In many countries, due to the surge in raw material prices and the continuous reduction of natural resources, the use of waste may be an alternative in the construction industry. Waste, when well processed, has been shown to function as construction material and can easily meet design specifications (Kan, Demirboga, 2009b). The frost penetration will be reduced due to insulation qualities of EPS. In addition, their high permeability will provide kind drainage. Table 1 shows the density and sacrifice cost of Geofoam (EPS) along with the corresponding values of other widely used lightweight materials.

In this paper, after crushing the EPS waste to certain size and heat treatment were applied to make hardened. The well graded (SW) sand mixed with MEPS particles at 5, 10, 15, and 20 % by weight. Standard Proctor, modified proctor and CBR tests were carried on the mixes. The impact of modified EPS content on maximum dry density and optimum moisture content was reported. The objective of this research is to find the effect of using waste material (i.e., geofoam) on California Bearing Ratio (CBR) characteristics.

Table 1: Density and price of different lightweight fill material

Lightweight material	Unit weight(KN/m3)	Approximate cost ($/m3)
Geofoam (EPS)	0.1-1	35-65
Shredded tires	5.5-6.4	20-30
Wood fiber/sawdust	8-10	12-20
Expanded shale and clay	3-10	40-55
Fly ash	10-14	15-21

Source: Yoon et al. (2006). Construction of a test embankment using a sand–tire shred mixture as fill material.

2. Experimental

2.1 Materials

2.1.1 Soil

River sand: This soil was taken from a river which is known as river sand. The soil was put in oven, after sieving its property were well grained sand, Cu=7.83 and Cc=1. The specific gravity of the soil was 2.65. The river sand was passed through #4 sieve (4.75mm).

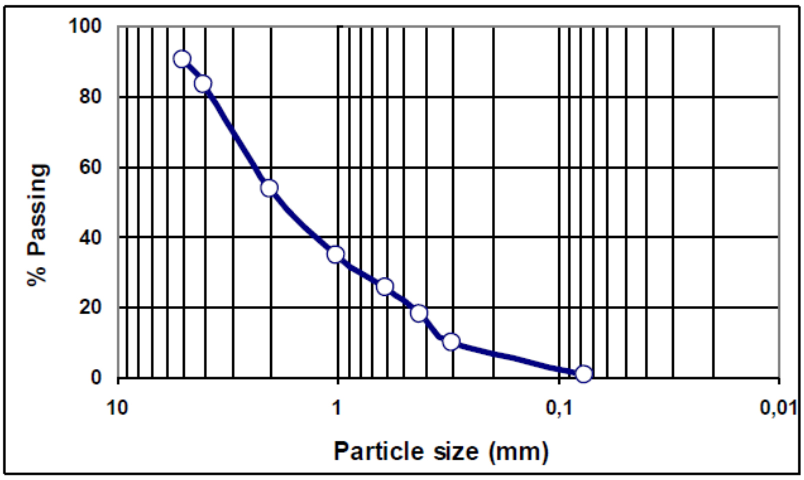


Figure 1: Particle size distribution with passing percentage of river sand

2.1.2 Geofoam

Modified expanded polystyrene foam (MEPS): EPS geofoam is a lightweight, solid foam plastic that has been used around the world as a fill for more than 30 years. EPS geofoam is approximately 100 times lighter than most soil and fully (20 – 30) times lighter than other lightweight fill substitutionals. This farthest distinction in density contrasted to other materials makes EPS geofoam an appealing fill material. Because it is a soil substitutional, EPS geofoam embankments can be coated to look like normal sloped embankments or finished to look like a wall. As mentioned before MEPS used in form of 0.5cm^3 and mixed with river sand at certain percentages. The production of MEPS was prepared by heat treatment as shown in Figure 2. The optimum time and temperature was 15 minutes and 130°C respectively.

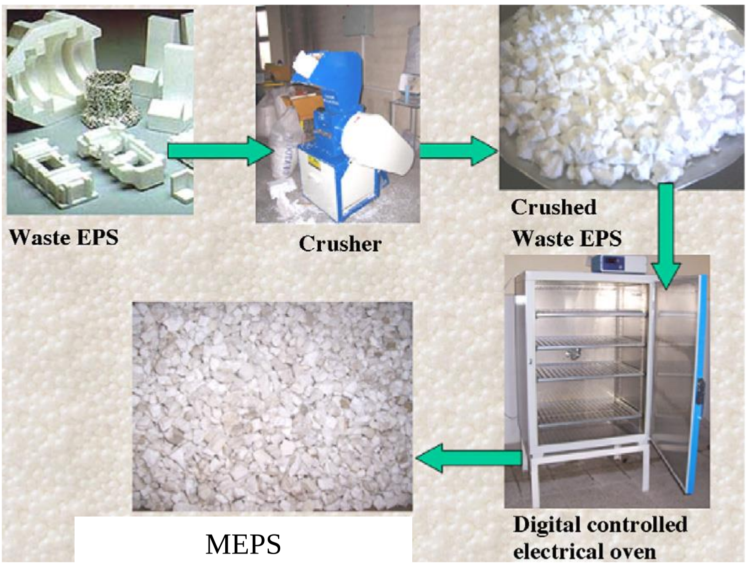
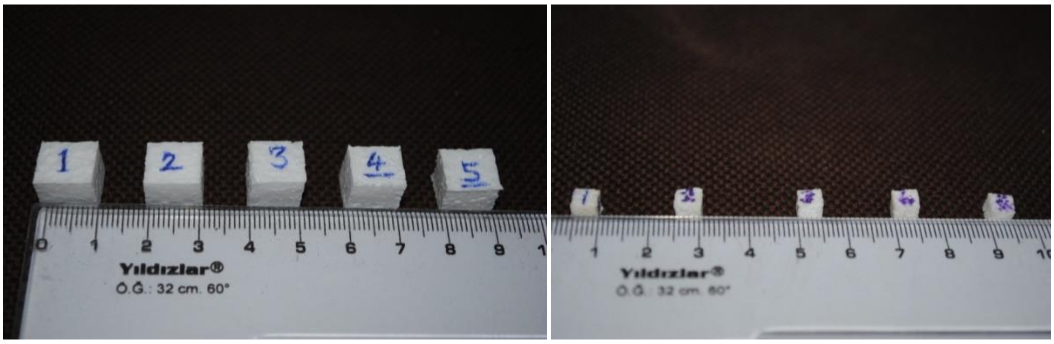


Figure 2: Characterization of the changing operation of waste MEPS foams (Kan & Demirboga, 2009b).



a.EPS before heating 1cm3 b. modified EPS after heating 0.5cm3

Figure 3: Geoafoam (MEPS) sample size

2.1.3 CBR Test

According to (Referenced Document: ASTM D 1883), California Bearing Ratio test was done for each of standard and modified proctor test (See Figures 4 and 5). CBR tests are normally performed on remolded specimens, which may be compacted to their maximum density at their optimum moisture contents. The tests have conducted on unsoaked condition at various contents of 0%, 5%, 10%, 15%, and 20% that was added to river sand. The CBR may be expressed in equation as

For 2.5 mm penetration:

%CBR={penetration load (KN)required to penetrate2.5mm}/13.5×100 [1]

For 5 mm penetration:

%CBR={penetration load (KN)required to penetrate 5mm}/20 ×100 [2]

CBR Mould and Accessories,
ASTM D1883

Figure 4: CBR test machine and CBR Mould

Table 2: Standard CBR limits

Type of Soil	CBR limit
Clay	1-3
Sandy clay	4-7
Well graded sand	15-40
Well graded sandy gravel	20-60

Figure 5: Reading Loads during CBR test

3. Results and Discussion

3.1 Water Content

When the MEPS% was increased, the optimum moisture content changes were not that much as we expected. However, the relationship between MEPS and optimum water content is not linear (Figure 6), because of the existence of more voids within the samples (i.e., MEPS were angular and equal shape (0.5cm3)) that made the permeability to be randomly occurred during compaction.

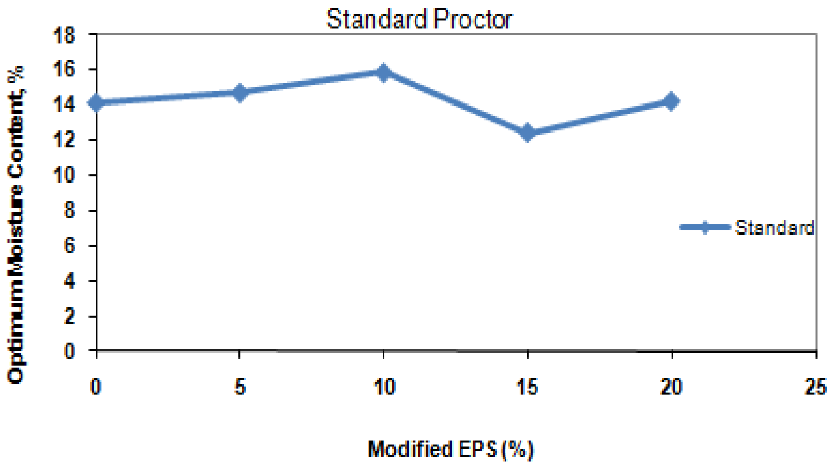


Figure 6: Optimum moisture content relations with MEPS%

3.2 Water Content

The relation between optimum moisture content and MEPS% of modified proctor was not linear and more dogleg than of standard proctor test (see Figure 7). The heavier hammer test has effects on this relation which makes more compaction of mixture within the mold. The MEPS% have great role on water content because of the size of modified geofoam pieces which were angular and same volume that made voids increase. Those voids might be a path of water discharging.

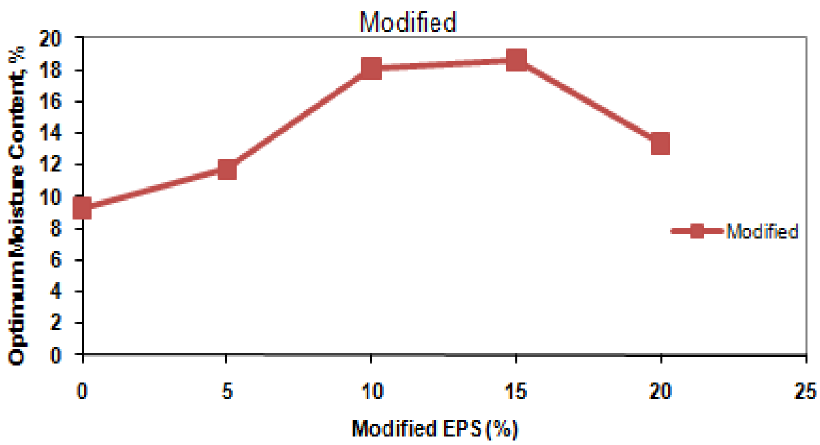


Figure 7: Optimum moisture content relations with MEPS%

3.3 California Bearing Ratio

The CBR values of the river sand without any addition of geofoam were found to be 39.9% and 48% for 2.5mm and 5mm penetration respectively for standard proctor; however, for modified proctor the CBR values were 49% and 61% for 2.5mm and 5mm penetration respectively. It is visible that the piston load reduces with increase in MEPS percentage for same penetration (for example last reading in each test which was 7.5mm). It can be also noticed that the piston load of sample with 20% of MEPS system was almost three times as low as of sample without MEPS system (see Figure 8).

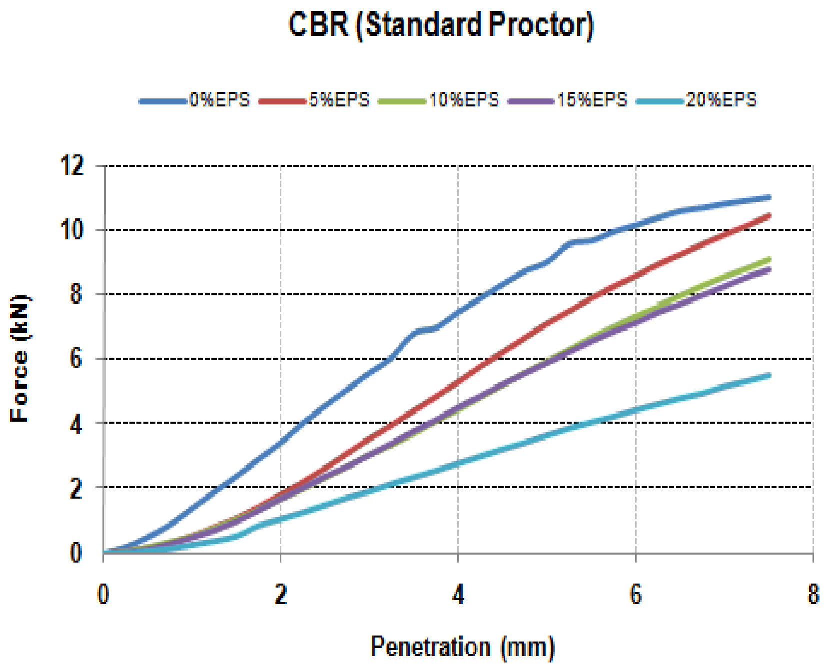


Figure 8: Relationship between load and penetration for standard proctor compaction method in CBR test

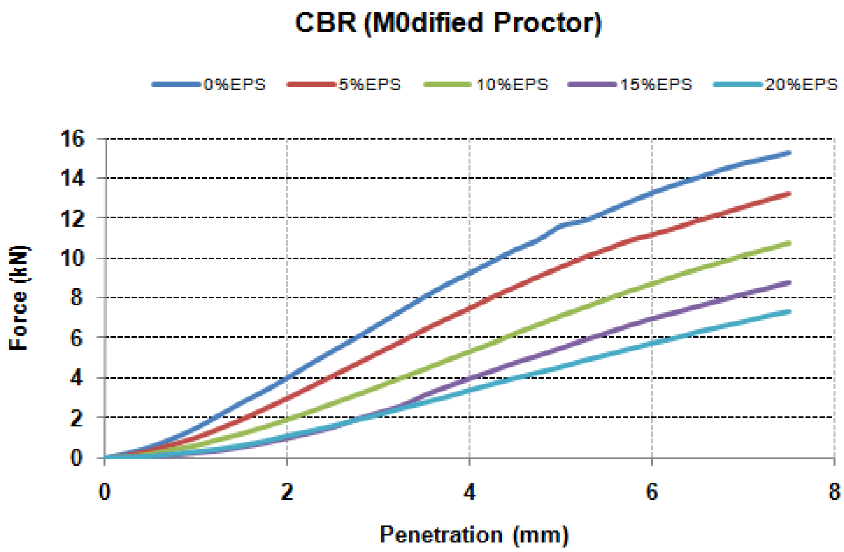


Figure 9: Relationship between load and penetration for modified compaction method in CBR test

Decrease in strength of soil due to inclusion of waste geofoam after treatment could also be expressed in terms of piston load. Decrease in piston load due to the presence of MEPS for all contents at the same reading (say 7.5mm penetration) has been presented by a dimensionless expressing known as piston load ratio (PLR), which is defined as ratio of maximum piston load at 7.5mm penetration for sand-MEPS mixture (LS+EPS) to maximum piston load at same penetration for river sand only (LS) (see Figure 9).

$$PLR=L_{(s+EPS)}/L_s \quad [3]$$

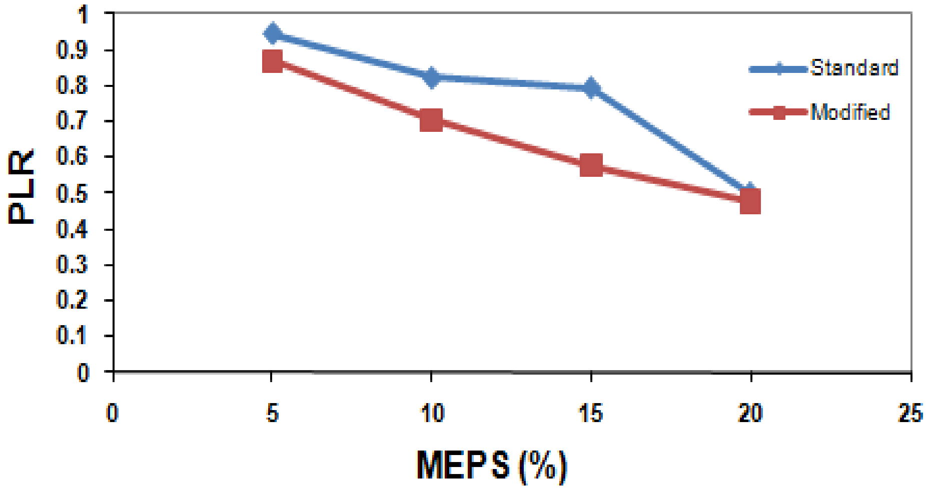


Figure 10: Relationship between PLR and MEPS% for standard and modified proctor

The CBR values after correction were decreased by increasing MEPS% for both standard and modified compaction tests as shown in Figure 9, because the MEPS has the property of re-actable, soft and absorbs the impact load during applying load which have made this decreasing of CBR values (i.e.; decrease in strength) (see Figure 10).

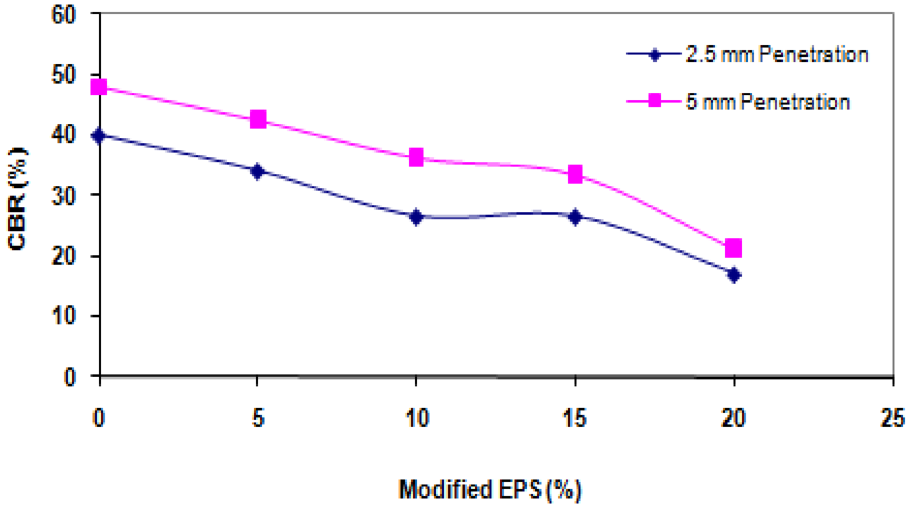


Figure 11: Decreasing CBR values by increasing MEPS% for standard compaction method

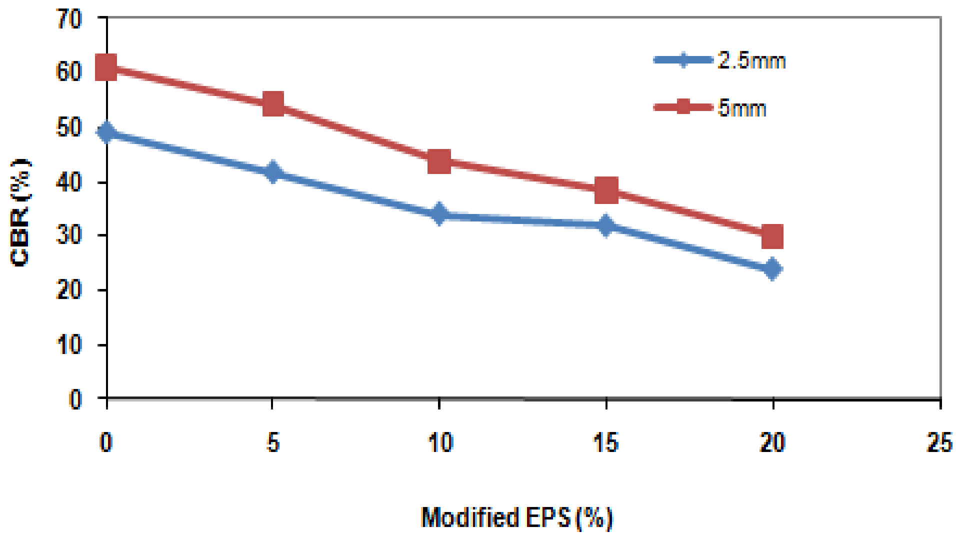


Figure 12: Decreasing CBR values by increasing MEPS% for modified compaction method

4. Conclusion

MEPS were mixed with river sand and optimum moisture content were found for both standard proctor and modified proctor samples. They were tested to determine the change in CBR values of the same mixture. The demonstration of the results concluded the followings:

For standard proctor, the CBR values were decreased from 41% to 17% for 2.5mm penetration and for 5mm penetration was decreased from 48% to 21%. However, for modified proctor the CBR values were decreased from 49% to 22% for 2.5mm penetration, while for 5mm penetration the CBR values were decreased from 60% to 29%. Furthermore, all CBR values were within the allowed limit.

The mixture can be used as fill material in abutment of bridges. However, according to unified classification system the mixture can be used as base and subbase material in roads and runways especially when soils were soft or compressible to reduce settlement. For environmental status and economy, waste materials (i.e.; EPS) can be used since most recyclable materials can be obtained easily.

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