Performance of MSE Wall Reinforced with Crumb Tire Rubber

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Abstract: Nowadays, Walls and embankments of highway are mostly made with the help of Mechanically Stabilized Earth (MSE). In this research, crumb tire rubber (CTR) was used as a reinforcement to analyze the changes in the stability of MSE wall. The rubber tire was acquired from Tire Rubber Factory, korangi Industrial Area, Karachi while the sand used in this research was obtained from the Indus River near Jamshoro. Direct Shear Box Test, Compaction Test and Sieve Analysis was done on the STR mixed sand to obtain parameters used to model MSE wall in finite element program, PLAXIS 2D. Direct Shear Box Test was simulated in the PLAXIS 2D to check the results and verification was also done on the Chungsik's two-tier wall. It was concluded that the 15% by weight of crumb rubber tire mixed sand shows the optimum results for the construction of MSE wall. By using rubber in wall, we can reduce the harmful effect produced due to dumping and burning of tires.

Keywords: *Crumb tire rubber, MSE wall, soil reinforcement, shear strength, direct shear box test.*

1. Introduction

Mechanically stabilized earth (MSE) wall have become one of the efficient and economical solution for the construction of road. It is mostly used in steep terrain, saving the valuable land resources especially in urban areas.

Nowadays, used rubber tires are increasing which makes it challenging job to dispose-off. Burning, dumping or stockpiling is banned in most part of the world. Tire is the highly durable and non-biodegradable material which causes problematic ecological system.

Considering the importance of MSE wall and recycling of rubber tire, it would be wise to use crumb rubber tire in MSE wall as it will not only make it cheaper and efficient but also reduce the environmental hazard induced by scrap rubber tire. Generally, different reinforcing material is used from geogrids to anchorage systems in order to increase the mechanical properties of earth mass. MSE wall is different from reinforced soil slope (RSS) as it is steeper than 70 degrees from the horizontal. Four structural components will be used in the construction of wall: 1) Crumb rubber tire 2) Prefabricated Wall facing 3) Backfill Soil 4) Reinforced Soil. The wall will resist the destabilizing earth forces produced due to external load with the help of self-weight.

PLAXIS 2D v8 is a finite element program which will be used for the numerical analysis of reinforced soil as well as unreinforced soil. Review of comparison between them will be examined in order to analyze the changes in the properties of soil.

2. Related Work

J.S Jadev [1] uses various form of end-of-life tire (ELT) such as shreds, granulates, fibers, and chips to determine its effect on the various properties of the fine-grained soil. He found that shear strength, Consolidation, permeability, California bearing ratio (CBR) increases with the increase of the ELT Content whereas Atterberg's limit, OMC, MDD, tensile strength, swelling decreases with the introduction of ELT tires in the mixture.

Umar Jan [2] used the crumb rubber tire for the stabilization of soil and found out that the CBR value of modified soil increased by 67% in an unsoaked condition. Above that he also found out that the optimum moisture content (OMC) as well as maximum dry density (MDD) decreases with the increase of shredded rubber tire content.

Hazarika et al. [3] recently conducted shake table test on gravity type caisson model shielded by a tire chips cushion and found that the tire derived aggregate (TDA) considerably reduce the effect of seismic load against the caisson wall.

Hing-Ho Tsang [4] did his research in seismic performance of backfill reinforced with crumb rubber tire. He found that the site-response of a rubber-soil mixture backfill was non-linear and it helps to reduce the effect of seismic waves with the help of shake table tests. Tsang (2008) also recommended observing the resonance effects of soil-tire backfill, which should be tested experimentally.

Tarek Abichou and Kamal Tawfiq [5] made an MSE wall reinforced with geogrid and geotextile, backfilled with crumb rubber tire mixed sand. He observed the diminishing effect of displacement with the wall depth along the face of the wall and strains increases in the geogrid and geotextile with the increase of surcharge load. He also concluded that the stress predicted by the finite element program were little less than that obtained by conventional methods.

Sompote Youwai and Dennes T. Bergado [6] performed the triaxial tests on different mixing ratio of compacted crumb rubber tire – sand mixtures as shown in the fig. The density, unit weight and shear strength of the soil-tire mixture increase with the increase in sand in the

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mixture whereas compressibility decreases. In the drained triaxial compression test, as the quantity of sand in the mixture increases the strength and the unit weight increases and deformation decreases. It was observed that the deformation decreases significantly with the 30% of sand in the mixture. The author presented hypoplasticity model which can estimate the strength and deformation characteristics of shredded rubber tire mixed sand.

3. Material Used

Two material are used as a backfill material with the sand as a base material and rubber as a reinforcement material.

3.1 Source of Material

Materials used in this research are Indus River Jamshoro riverbed sand and crumb rubber tire. Sources of obtained materials are represented in table 01.

Material	Source
Sand	Indus River near Jamshoro
Crumb tire rubber	Tire Rubber Factory, Korangi Industrial Area, Karachi

Table 01: Sources of various materials

3.2 Material Properties

Sand used in this research is A-3 type soil according to AASHTO Standards. 50kg of soil was taken as sample from the Indus River near Jamshoro. It has 1.63 gm/cc maximum dry density and 1.29 as minimum dry density. It has the void ratio of 0.682. Cohesion (c) and internal friction (φ) was found to be 0.14 kg/cm2 and 33.89 degrees respectively. The soil is found to be fine sand A-3 type under AASHTO classification system.

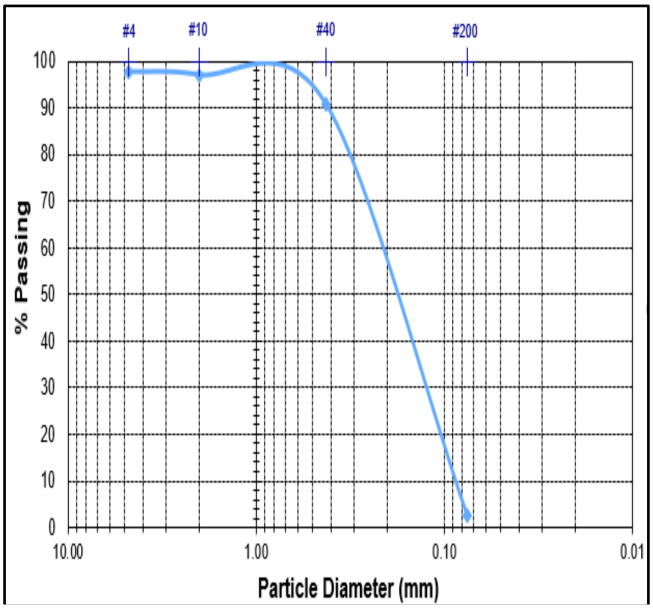

Figure 01: Particle size distribution curve

Soil	Soil Type	Name of Test	Results
Sand	A-3	Minimum Dry Density	1.29 g/cc
		Maximum Dry Density	1.63 g/cc
		Specific Gravity	2.58

Table.2. Properties of soil

Crumb tire rubber is used as reinforcement in soil. Different proportions such as 3%, 5%, 8%, 10%, 12% and 15% by weight of crumb tire rubber was used in the soil. It was obtained from Korangi No 04 near Murtaza Chorangi tire rubber factory, Karachi, Pakistan. Its size ranges from 1mm to 10mm length and 0.5mm to 1mm in thickness.

3.3 Methodology

Methodology of this research study contains various crucial steps. Literature review of various research scholars was thoroughly studied, then area to be researched was selected. Materials used in this research were collected from well-known sources after the selection of research work. Materials selected were, A-3 sand from Indus River and crumb tire rubber from Karachi. Rubber tire is used as a stabilizer in the soil in this study. 1mm to 10mm length of rubber was used in the soil reinforcement. Distinct proportions of soil were used in the sand that is 3%, 5%, 8%, 10%, 12% and 15%. In order to obtain the uniform mixture of soil-rubber sample, mixing was done carefully. Various element tests were conducted on the soil, crumb rubber tire and soil-rubber mixture. Result of different proportions of soil was obtained and comparison was made based on outcomes. The table 03 shows the details of the test that were adopted.

Material Property	Test method	Test Standard
Particle Size Distribution	Sieve Analysis	ASTM D44 – 07
Specific Gravity	Pycnometer Method	ASTM D584 – 10
Compaction Characteristics	Relative Density of Sand	ASTM D4254 - 16
Shear Strength	Direct Shear Test	ASTM D 3080 – 90

Table.3. Test methods adopted

4. Results and Discussions

4.1 Shear Strength

Shear stress versus shear strain graph of all the percentage of soil reinforcement was plotted. The following graph helped us to identify the changes with respect to changes in the amount of rubber in the soil. Following graphs have been plotted at the vertical stress of 0.68, 1.24 and 2.35 kg/cm^2.

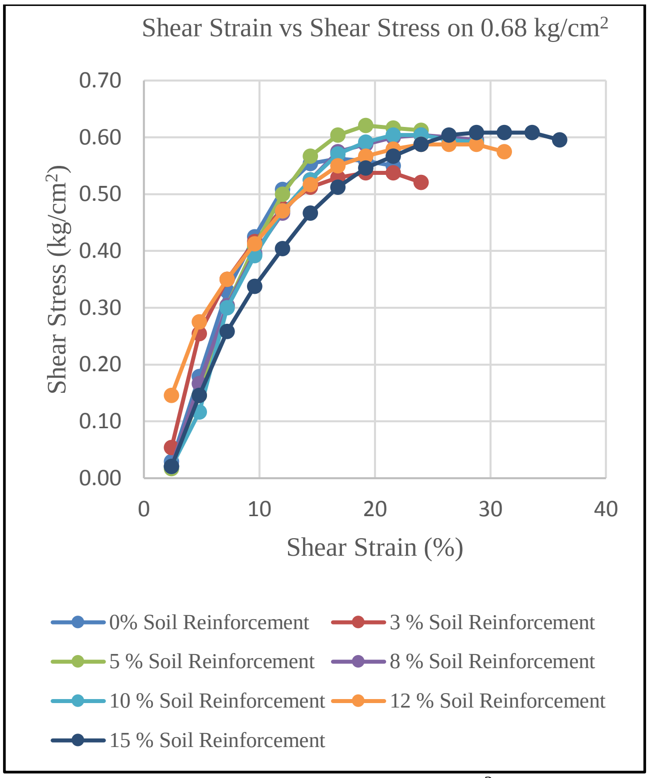

Fig 02: Normal vs shear stress at 0.68 kg/cm^2 normal stress

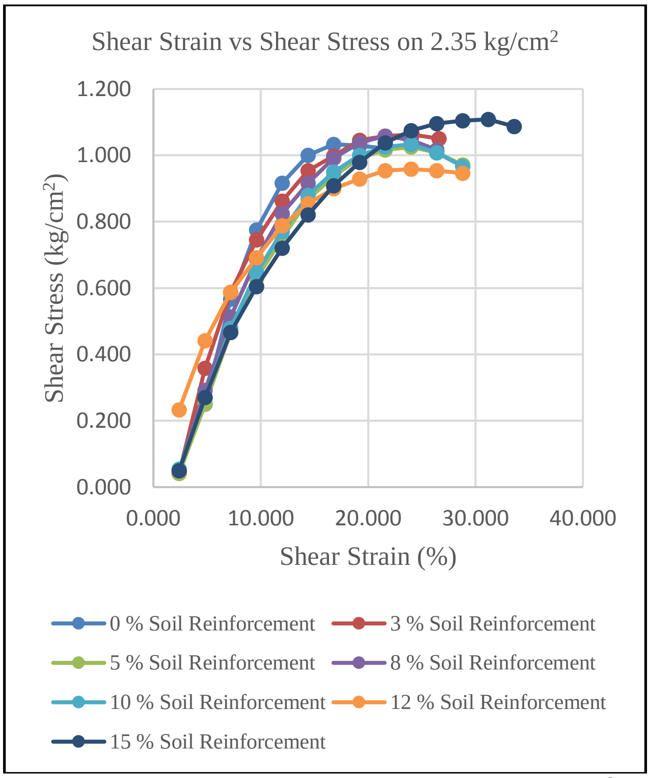

Fig 03: Normal vs shear stress at 1.24 kg/cm^2 normal stress

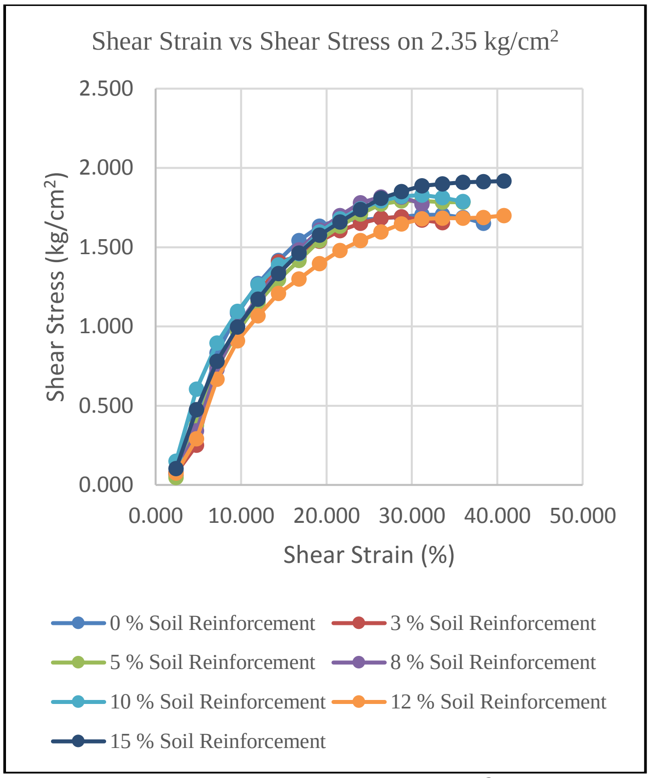

Fig 04: Normal vs shear stress at 2.35 kg/cm^2 normal stress

4.2 SUMMARIZATION OF TEST DATA.

The maximum shear stress of soil is known as shear strength of soil. Compilation of shear strength of different proportion of soil was carried out and presented in a table and graph as shown below.

Percentage of CTR	**Shear Stress in kg/cm^2**		
	At σ_N = 0.68 kg/cm^2	**At σ_N = 0.68 kg/cm^2**	**At σ_N = 0.68 kg/cm^2**
0	0.56	1.03	1.7
3	0.54	1.06	1.69
5	0.62	1.02	1.8
8	0.6	1.06	1.82
10	0.6	1.03	1.83
12	0.59	0.96	1.78
15	0.61	1.11	2.02

Table 4.23: Shear stress of all samples at 0.68, 1.24, and 2.35 kg/cm^2

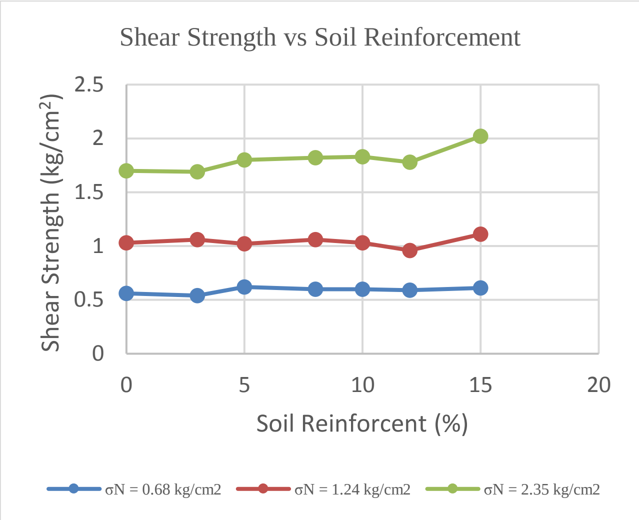

Fig 4.11: Shear Strength w.r.t percentage of Soil Reinforcement

Increase Percentage	Percentage Increase in 0.68 kg/cm^2.	Percentage Increase in 0.1.24 kg/cm^2.	Percentage Increase in 2.35 kg/cm^2.
3	-3.57	2.91	-0.59
5	10.71	-0.97	5.88
8	7.14	2.91	7.06
10	7.14	0	7.65
12	5.36	-6.8	4.7
15	8.93	7.77	18.82

Table 4.24: Shear stress changes with the increase in the amount of percentage.

4.3 Calibration of Direct Shear Box Test.

The Direct Shear Box Test was calibrated with the help of finite element program, PLAXIS 2D. The results are shown in the fig 05 and 06.

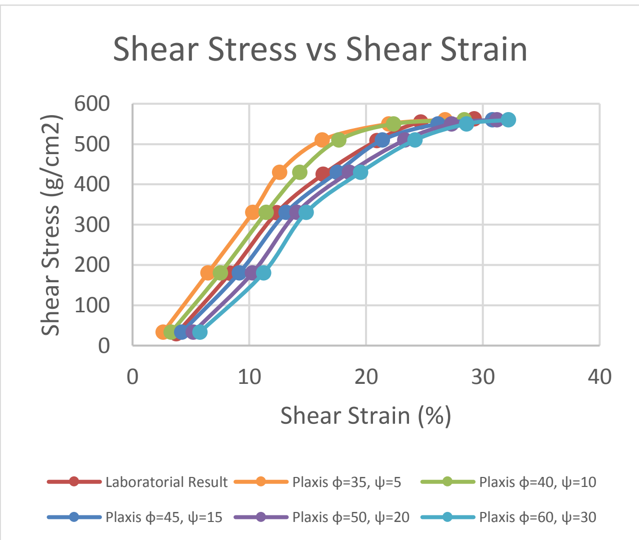

Fig 5.9: Shear stress vs shear strain graph at different internal friction angle

After analyzing the above graph, it can be said that the internal friction is somewhere between 40 degree to 45 degrees internal friction angle. The internal friction found out to be 42.92 degrees

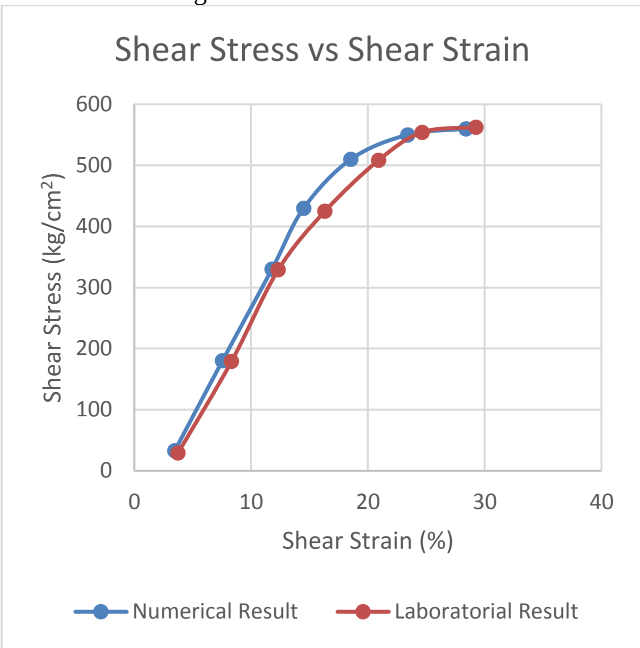

Fig 06: Shear stress vs shear strain curve obtained from Laboratory and numerical data.

After analyzing the above graph, it can be said that the laboratorial and software-based data are approximately equal.

4.4 Verification

The time-displacement curve obtained from the Chungsik's two-tier 5 m high wall field test and similar model made in PLAXIS with the soil replaced with Indus riverbed soil. The obtained results are compared as shown in fig 07.

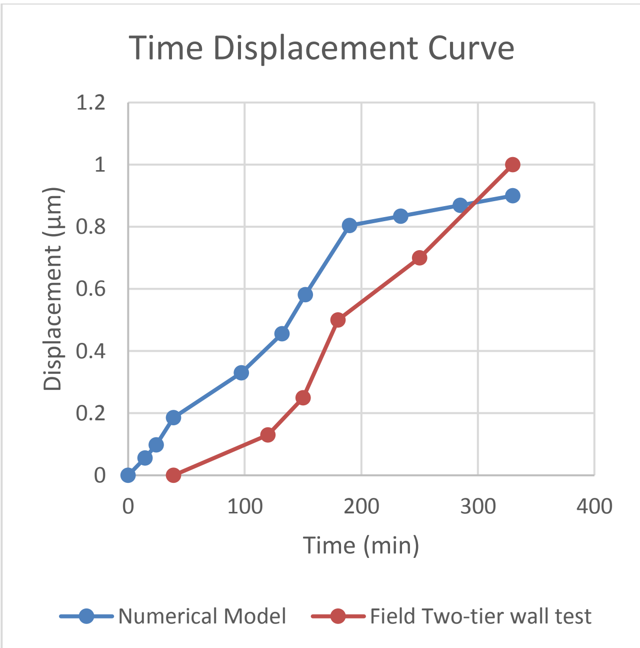

Fig 07: Comparison of results for verification purpose

4.5 Critical Height

The model of MSE wall was built in finite element program, PLAXIS 2D. The height of MSE wall was increased till the soil failed and collapses. The critical height is the height at which soil collapses, and the critical height of 0% to 15% is shown in the fig 08,

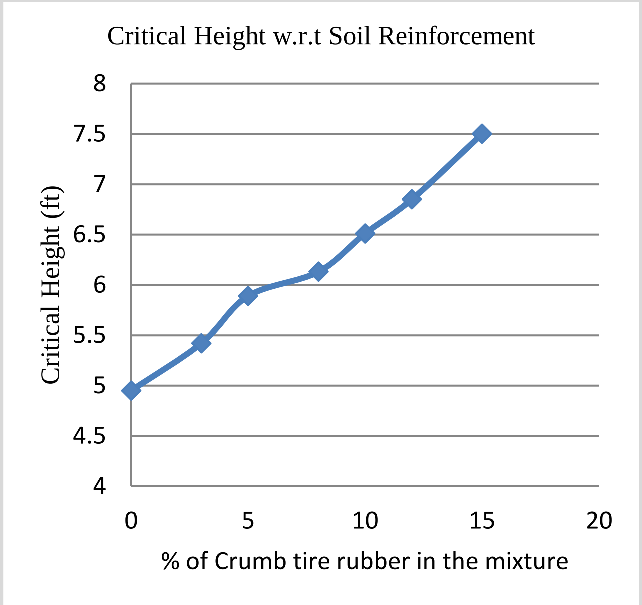

Fig 08: Critical height at different percentage of tire-sand mixture.

4.6 Horizontal Displacement

From the Literature, horizontal displacement limit for the MSE wall found out to be 15 mm. Hence, from the below mentioned fig 09, we can say that the MSE wall fails at 4.2 ft at 0% soil reinforcement and 7.6 ft at 15% soil reinforcement.

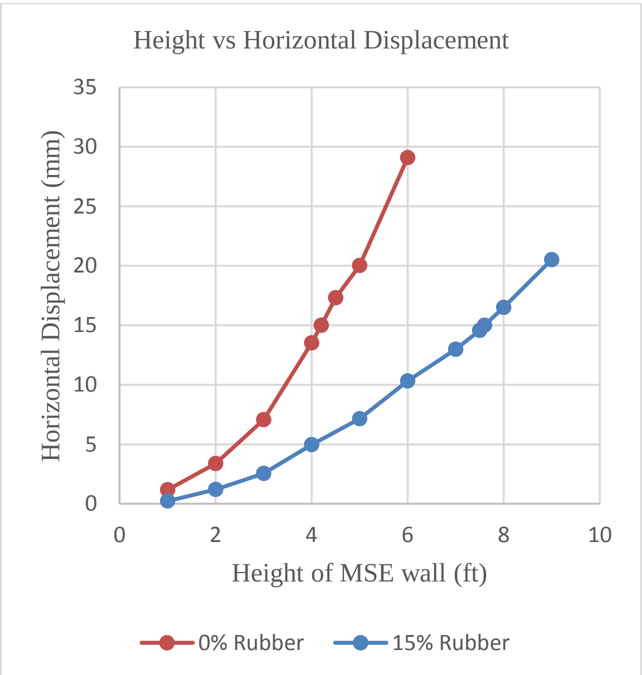

Fig 09: Horizontal Displacement curve of 0% and 15% soil reinforcement.

5. Conclusion

The conclusion can be made as following.

i. The critical height of MSE wall increases with the increasing percentage of crumb tire rubber in the mixture, with highest at 15% by weight of tire rubber mixed sand.

ii. By increasing the percentage of crumb tire rubber, the horizontal displacement decreases.

iii. The stress-strain curves obtained from laboratory and numerical Direct Shear Box tests vividly prove validity of numerical modeling. Not only a perfect qualitative match is obtained, but also a reasonable quantitative match of the curves is produced. Thus, the legitimacy of numerical simulation for this research is established.

6. Recommendation

Following areas can be studied further.

i. Size of the crumb tire rubber can be changed.
ii. Thickness if rubber can be varied.
iii. Different percentage of rubber can be used.
iv. Soil type other than sand can be used in the mixture.
v. Effect of rubber other than wall can be analyzed such as embankment and abutment etc.
vi. Different geotechnical program such as FLAC can be used.
vii. Different properties of soil can be analyzed such as seismic performance with the addition of tire rubber.

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