Reduction of Dynamic Earth Pressure on Retaining Wall Backfilled with STC: A Review

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Abstract

Now-a-days the disposals of waste tyres have become a tremendous problem due to increasing number of vehicles on the roads day by day. Since, it is non-degradable so it may create large human problems as well as environmental impacts and vulnerabilities. To reduce these vulnerabilities, it may be used in many civil engineering constructions and geotechnical applications like tyres include embankment fill, retaining wall and bridge abutment backfill etc.

The shredded tyre inclusion with soil is used as backfilled for earth-retaining structure to find out the responses of the structure under seismic condition. The seismic performance of a retaining wall depends upon on the total pressure (i.e. static plus dynamic pressure). Dynamic earth pressure is the most important factor to analyse the retaining wall in seismic areas. Seismic design of retaining walls is generally based on seismic pressure or allowable displacement.

From the present study, it has been noted that inclusion of sand tyre mixture as an backfill material as considerably reduces seismic earth on wall and lateral displacement of wall compare to the case when only soil has been used as a backfill material. Moreover, a parametric study has been conducted to evaluate the effects of these parameters on reduction of lateral earth pressure and lateral displacement of the wall.

Keywords - *Dynamic earth pressure, Displacement, Sand, Tyre Chips, Retaining Wall*

I. INTRODUCTION

In India top 7 large tyre companies are responsible for 85% tyre productions. The sale of automobile tyres was 8.8 million units in 1982 which had increased to 17.7 million in the year of 1991, representing the growth rate of more than 100% in ten years. The disposal of these used tyres has become a global problem. A huge volume of scrap tires has been stockpiled in many countries (Genan Business & Development A/S 2012) causing adverse impact on the environment. The volume of waste tyre generated is 1.5 billion per year owing to the increase in the number of vehicles worldwide (ETRMA 2011). About 266 million waste tyres are generated annually in the United States (RMA 2011). Disposing of these waste tyres became a global problem for every countries because the stockpiling of theses tyres threats to health hazard as well as environmental hazard (C clark et al. 1991, Liu H et al. 1998, C Hermann et al. 2001) due to the following three reasons: (1) they occupy large volumes (2) waste tyre storage can be a dangerous fire risk (3) waste tyre dumps provide the breeding ground for vermin, including rats and mosquitoes. So, it is very essential to recycle of these waste materials as an alternative source of construction material for various applications. Several researchers are exploring the possibility of using different by-products or waste materials like fly ash, fibre, rice husk ash and recycled tire materials as geo-materials.

Fig. No. 1 (Stockpiling of waste tyres)

Different lightweight materials like shredded tire chips, geo-foam, fly ash, plastic bottles, tyre derived aggregate and tyre crumbs etc are used as a backfill material in various civil engineering applications (Humphrey et al. 1992, Tweedie JJ et al. 1998, Cecich et al. 1996, Ravichandran et al. 2014, Graettinger AJ et al. 2005), road embankment construction (Eldin NN et al. 1992, Bosscher J et al. 1997, Vinot V et al. 2013) and as a lechate collection layers (Bhalla G et al. 2010, Warith et al. 2004) etc.
Scrap-tire derived materials are being used in civil engineering applications in three forms as per ASTM D6270 (ASTM 2008), namely tire crumbs (length < 10 mm), tire chips (length = 10-50 mm) and tire shreds (length > 50 mm). The use of waste tyre (tyre

shreds, tyre chips and tyre crumbs) has been found to be increasing in various geo-technical engineering applications. Table 1 present a summary of various studies on use of STD materials in different geo-engineering applications.

Table No. 1- Application of Waste Material in geo-engineering Application

Reference	STD material	Application	Remarks
Cecich et al. (1996)	Tyre chips	Reataining structure	Cost analysis was presented to reataining wall using tyre chips in backfill
Tweedie et al. (1998)	Tyre shreds	Field retaining wall model backfill	Reduction of lateral earth pressure were reported
Yang et al. (2002)	Shredded tyres	-----	Mechanical properties of shredded tyres were found
Salgado and Prezzi (2004) Lee and Roh (2006) Rao and Dutta (2006)	Tyre shreds Recycled tyre chips Sand- tyre chip mixtures	Embankment Retaining wall backfill -----	Field model study was done using tyre shreds Compressibility and strength behaviour were evaluted
Yoon et al. (2006) Hazanka and yasudhara (2007)	Sand-tyre shred mixture STD material	Embankment Different geo-application	---- Application such as foundations, slopes, retaining wall, seismic isolation, liquefaction mitigation and so on were discussed
Anbazhagan et al. (2011)	Tyre crumbs soil mixture	---	Dynamic properties such as damping, shear modulus and so on were studied
Hazarika et al.(2012)	STD material	Different geo-engineering application	STD materials were used as ground improving geomaterials
Sheikh et al. (2013)	Sand-tyre crumbs soil mixture		Shear and compressibility behaviour was studied
Ahn and Chang(2014	TDA	Retaining wall backfill	Dynamic response of retaining wall was determined
Baluaini et al.(2014)	Tyre chip-sand and tyre shred-sand mixture		Shear strength properties were found
Ayothiraman and Soumya (2015)	Tyre chips	Stone columns	Tyre chips using as aggregate in stone columns
Boominathan et al.(2015)	Soil-rubber tyre scrap mixture	foundations	Study was focused on seismic base isolators for foundations
Dammala et al. (2015) Ready and Krishna (2015) Raddy et al. (2015a, 2016b)	Sand tyre chops mixtures	Retaining wall backfill	Focused on optimum mixture ratio of sand tyre chips using mechanical properties and retaining wall model studies

II. BACKGROUND

Because of their lightness they are generally used to reduce the earth pressure ad lateral displacement of the retaining walls. Performance of retaining walls under static and dynamic loading conditions depends upon the types of backfill soil. Most of the geo-technical engineers find out the different properties of scrap tyre chips and sand-tyre chips mixtures by conducting different tests.

The range of specific gravity values for shredded tire chips was reported to be 1.02-1.24 (Ahmed 1993, Humphrey et al. 1993, Ghazavi et al. 2011, Sheikh et al. 2013) which is less than normal soil. The hydraulic conductivity of compacted tire shreds was reported to be 2.0 to 0.75 cm/s (Ahmed 1993). Dry unit weight values of shredded tyre chips were reported to be in the range of 5.2-6.8 kN/m^3 (Ahmed 1993, Humphrey et al. 1993, Foose et al. 1996, Gotteland et al. 2008, Xiao et al. 2012). The shear strength of tyre-derived materials determined using tri-axial tests was found out by Bressette (1984), Ahmed (1993), and Benda (1995)and using direct shear test by Humphrey et al (1993), Cosgrove (1995), Gebhardt (1997) and Yang et al. (2002). Friction angle values in the range of 15-38^0 and cohesion values up to approximately 20 KPa were reported.

III. OBJECTIVE

1. Elimination of the need for disposal of scrap tyres in landfills.
2. Mitigation of the problems of fill settlement and instability due to the lighter weight of tyre chips.
3. Reduction of the use of valuable natural aggregates.

IV. MATERIALS USED

A. Sand

Generally sand was used as a backfill material in retaining wall to reduce the lateral earth pressure. The grain size distribution of sand is shown in figure 1 and the property of sand shown in table no.2.

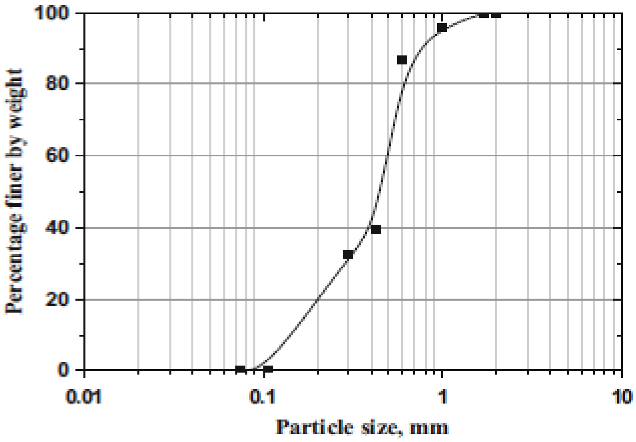


Figure 1.(Grain size distribution of the sand)

Table No. 2- Properties of Sand

S. NO.	Property	Value
1.	Specific Gravity	2.62
2.	Coefficient of Uniformity(C_u)	1.82
3.	Coefficient of Curvature(C_c)	1.02
4.	Soil Classification as per USCS	SP
5.	Maximum unit weight(KN/m^3)	16.1
6.	Minimum unit weight(KN/m^3)	13.6
7.	Backfill Unit Weight(KN/m^3)	15.57
8.	Friction Angle(Degree)	48

B. Tyre Chips

Tyre chips (TC) of 10 mm x 10 mm size of about 20 mm long is used which is obtained from waste tyre. The properties of tyre chips are shown in table no. 3 which is in the range of the results reported by Blunaini at al. (2009) and Humphrey et al. (1993).

Table No. 3- Properties of Tyre Chips

S. NO.	Property	Value
1.	Specific Gravity	1.08
2.	Minimum Unit Weight(KN/m^3)	5.39
3.	Maximum Unit Weight(KN/m^3)	6.45

C. Sand Tyre Chips Mixture

the tyre chips of 10 mm x 10 mm size and about 20 mm long length is mixed with sand with different proportions like 10, 20, 30, 40 and 50% manually to maintain the selected TC percentage level reported by S.Bali Reddy and A. Murli Krishna (2015). Figure 2 and table No.4 shows the particle size distribution of the STC mixtures and characteristics of different STC mixtures respectively.

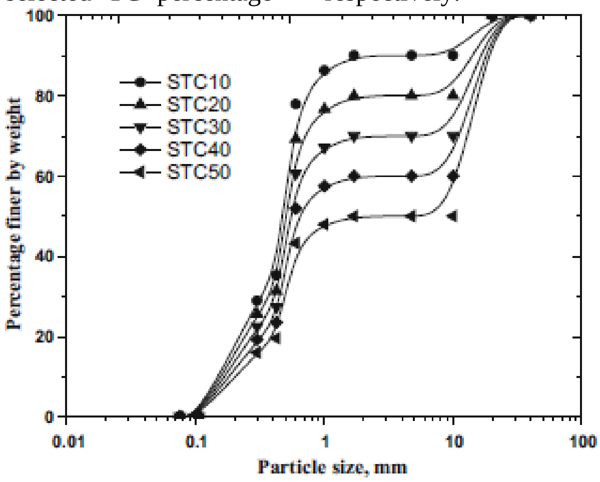


Figure 2 (Grain size distribution of San-Tyre Mixtures)

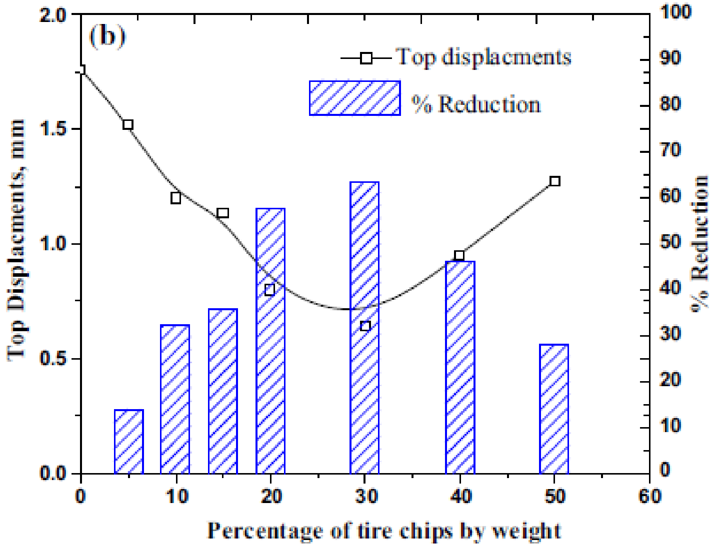
Table No. 4- Properties of different STC mixtures

STC Mixture	Specific Gravity(G)	Dry Unit Weight (KN/m^3)	Angle of Internal Friction(^{0})
STC10	2.25	14.62	51
STC20	1.94	14.12	52
STC30	1.82	13.17	56
STC40	1.71	12.29	51
STC50	1.53	10.42	44
Pure Tyre Chips	1.08	6.45	28

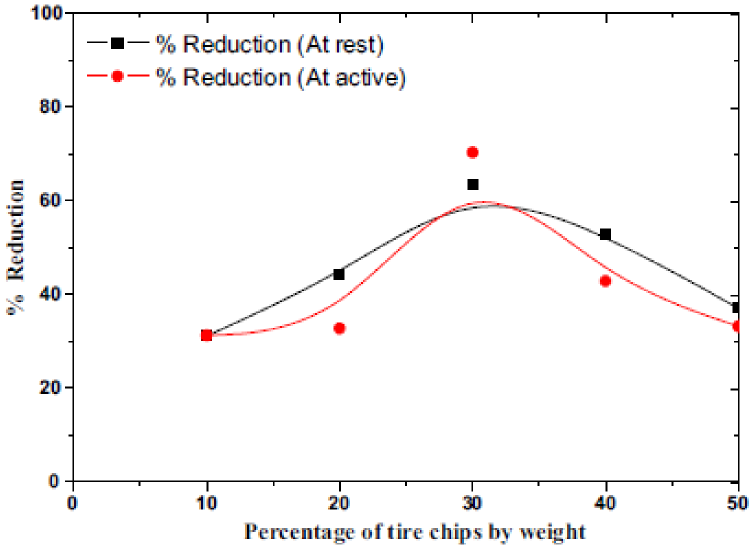
V. LITERATURE REVIEW

A. S. Bali Reddy and A. Murli Krishna (2015) [1]

used recycled tyre shreds in sand-tyre chips (STC) mixtures for rigid retaining wall application as a backfill material. They obtained data with different STC mixtures on 600 mm high rigid retaining model which is constructed in a Perspex container. STC mixtures were prepared with different tyre chips mixtures proportions such as 10, 20, 30, 40, and 50%. Static surcharge load up-to 10KPa was applied using concrete blocks. The results were obtained in the form of wall displacement (Fig. No. 3) and reduced lateral earth pressure (Fig. No.4), they found that displacement and lateral earth pressure are reduced to about 50-60% by using STC mixtures.



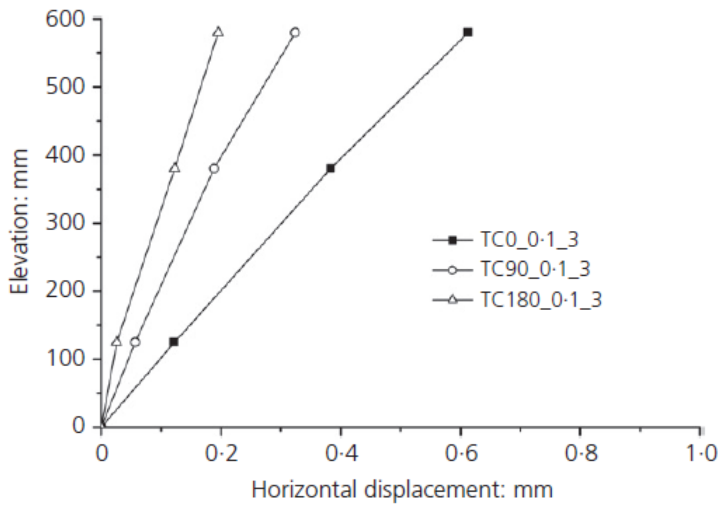
(Fig No.3 Displacement profile with different STC mixtures)



(Fig No.4 Lateral Earth Pressure Profile with different STC mixtures)

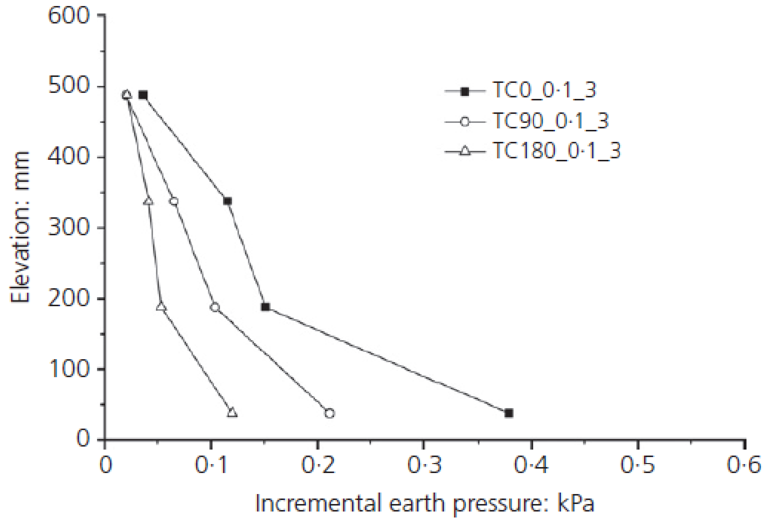
B. S. Bali Reddy and A. Murli Krishna (2017) [2]

investigates the performance of retaining wall models using recycled tyre chips as compressible inclusions under dynamic loading through shaking table tests. Scrap tyre derived tyre chips of 10 mm * 10 mm size and about 200 mm length have been used. It has been observed that horizontal displacement and incremental lateral earth pressure response of the retaining wall models becomes reduced with the inclusion of tyre chips. Reduction of these parameters also provides reduction in material cost and construction cost. Fig. No.5 shows that the displacement significantly decreases with the increasing compressible inclusion thickness of 0, 90, 180% at the end of 20 cycles of dynamic motion (a=0.1g and f=3 Hz). The maximum horizontal displacement of wall models with compressible inclusions is reduced by 60-75%.



(Fig. No.5 Effect of compressible inclusion on wall displacement for 0.1g_3Hz)

Fig. No.6 shows that incremental of lateral earth pressure along the height of wall with different STC inclusions at the end of 20 cycles of dynamic motion (a=0.1g and f=3 Hz). They found that incremental earth pressure is reduced by around 68-83% compared with the control tests.

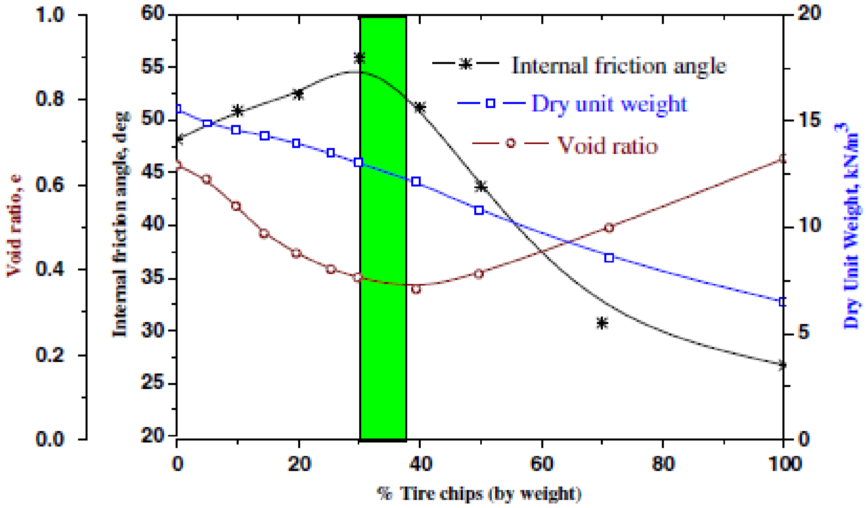


(Fig. No.6 Effect of compressible inclusion on incremental earth pressure for 0.1g_3Hz)

Similar mechanism were also discussed in the case of the effectiveness of EPS geo-foam as a compressible inclusion (Bathurst et al. 2007, Dave and Dasaka 2012, Horvath 1997).

C. S Bali Reddy et al. (2015) [3]

evaluate the optimum mixing ratio of sand-tyre-chips (STC) mixtures based on void ratio and shear strength properties. Tyre chips of 20 mm * 10 mm size are adopted. The volume of voids and weight-volume relations were determined from the dry unit weight and specific gravity values obtained for various mixtures. The results shows that the addition of tyre chips upto 40% by weight decreases the void ratio by 43% and shear-strength properties like angle of internal friction values are increased by 30% with STC. Fig. No.7 shows that internal friction angle value is high where the void ratio is less. It also shows that the optimum mixing ratio range is 30-40% by weight.

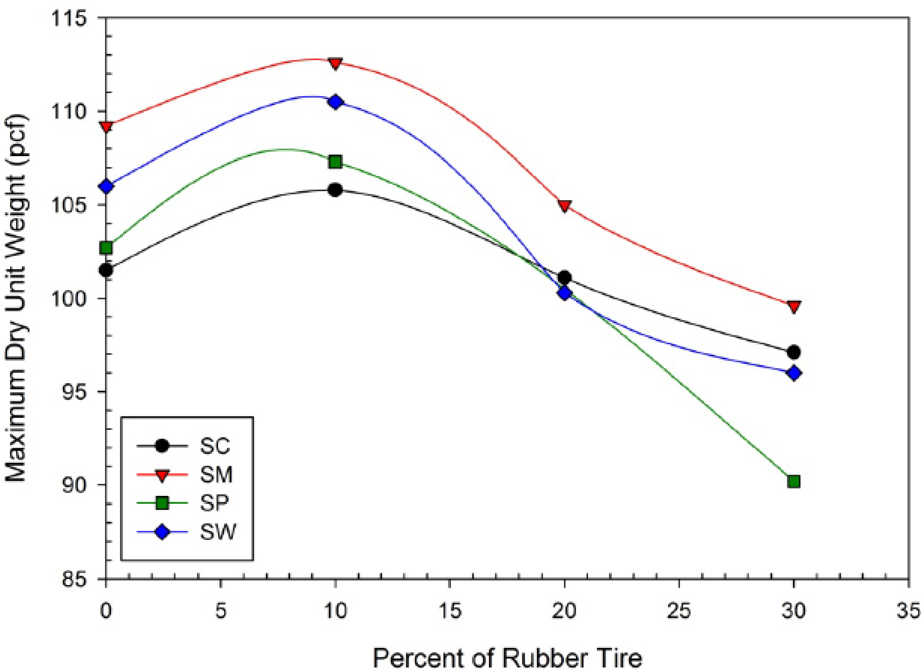


(Fig No.7 Internal friction angle, dry unit weight and void ratio profile with % TC)

The similar range was reported by Zornberg et al. (2004) and Tanchaisawat et al. (2010) for different tyres of sand-tyre-chips.

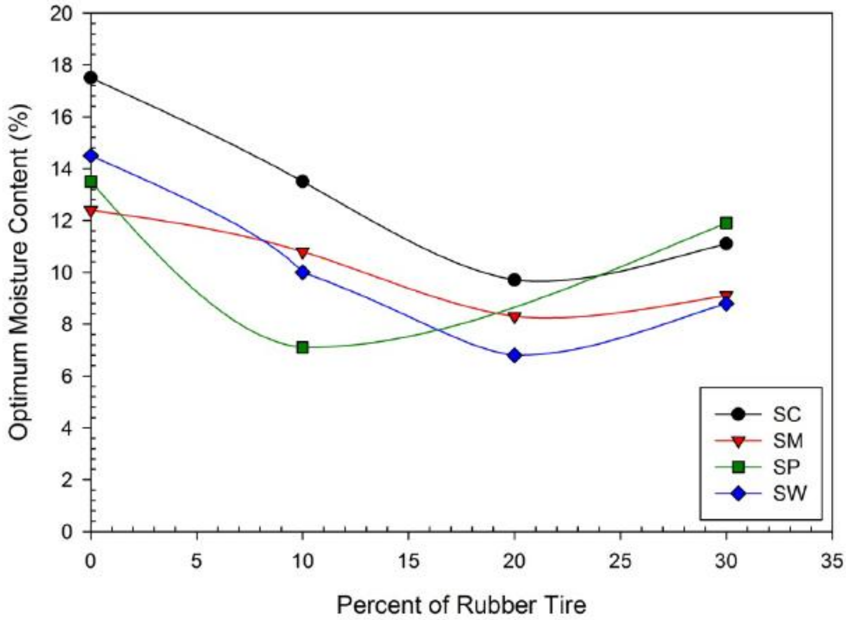
D. Binod Tiwari et al. (2012) [5]

modify the soil with shredded rubber tyres coarser than 2.75 mm were obtained from Home Depot. They used different types of soils SP, SW, SM, SC, SP-SM and CH based on the USCS system mixed with three proportions of shredded rubber tyres 10%, 20% and 30% of the soil mass by weight to obtain the reduction in the amount of water required for the compaction effort to maintain good maximum dry density with the help of Modified Proctor Test outlined by ASTM D 1557 as well as providing a solution for the disposal of used rubber tyres. This paper evaluates the effectiveness of shredded rubber tyres in compaction fills. Figure shows the relationship between the proportion of rubber tyre and maximum dry unit weight of four different types of soil and reported that the maximum dry unit weight increased with an increase in the amount of rubber tyre up to 10%.



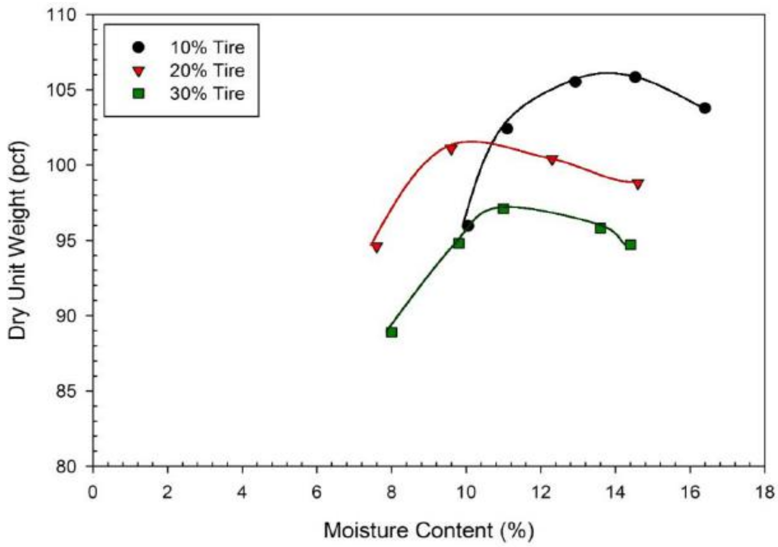
(Figure No.8 Change in Maximum Dry Unit Weight of soil with Different proportion of Rubber)

The optimum moisture content required to obtain the maximum unit weight for different combination of shredded rubber tyres with different types of soils is showed in figure. With the maximum unit weight, the optimum moisture content was found at 20% shredded rubber tyres by weight of soil. For poorly graded sand (SP), the results for the variation of OMC with different proportion of shredded rubber tyres in the soil mass were inconsistent.



(Figure No.10 Change in OMC of soil with Different proportion of Rubber)

Figure shows that Proctor Compaction Curve obtained by compacting clayey sand (SC) with different proportion of shredded rubber tyres. The investigation shows that 10% tyre aggregate to the soil can be recommended for use in compacted fills and backfill materials.



(Figure No. 11Proctor Compaction Curve for various mixtures of shredded tyres with clayey sand)

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VI. CONCLUSION

Performance of retaining under various loading conditions depends on the types of backfill soil however many lightweight fills material like geofoam, fly ash, waste tyre (in many forms) etc. are being extensively used as a backfill material. The primary advantages of using these lightweight materials are reduction in total lateral thrust on wall and lateral displacement of retaining wall. The tyre chips have high damping ratio and lesser elastic modulus due to which it reduces the dynamic earth pressure behind the retaining wall than sand alone. The permeability and shear strength of the tyre chips mixture are higher than that of sand alone due to which STC mixture provides higher factor of safety against sliding, overturning compared to sand as backfill under static loading condition as well as dynamic loading condition. So, tyre chips with sand as a backfill gives a significant role in performance of retaining wall under different loading situations.

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