BEHAVIOR OF GEOGRID REINFORCED SOIL – RUBBER WASTE MIX AS PAVEMENT COMPONENT

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ABSTRACT

Scrap tire generations is always on the increasing trend all over the world and because of improper disposal of such waste results in environmental problems such as congestion in landfill occupying lager volume and the problem is worst when they are burnt. An attempt is made in this paper to study the performance of rubber tire chips waste (TCW) for beneficial improvement of problematic subgrade soil and also to enhance the elastic recoverable strain that a subgrade undergo under repetitive traffic loads using geogrid reinforcement. Static and repetitive load tests were conducted on soil and rubber waste in four different layer forms as well intermixed combination. Rubber chips of 30 - 45 mm are used. It is found that upon placing TCW in layer form, the thickness of rubber waste and placement location of waste layer influence the load carrying capacity and also very much to the elastic and plastic deformation of soil – rubber waste system. Geogrid reinforced TCW sandwiched between soil layers is found to have a better performance in terms of load carrying capacity and enhanced elastic recovery compared with either waste layer under laid by soil or soil under laid by waste.**
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Keywords: Tire chips waste, geogrid, elastic recovery

INTRODUCTION

The development of societies and use of various vehicles have caused extensive usage of rubber producing proportional quantities of wastes. About more than 300 millions of scrap tires have been disposed in huge piles across the world every day. According to estimates, one scrap tire per person per year is produced. In highly industrialized countries used tires constitute around 1 - 2% of total municipal solid waste. Major portion of the scrap tires is left in empty lots as illegal tire dumps which cause a serious fire hazard, a breeding ground for mosquitoes and an unpleasant sight. Rubber does not easily decompose, as a result economically feasible and environmentally sound scrap tire disposal system must be found. This situation has produced an acute need for finding new and beneficial ways to recycle and reuse large volumes of scrap tires. Salgado et al (1999) investigated the stress - strain relationship and the strength of tire chips and its mixture. Tire chips and shreds showed linear deviation stress - axial strain relationship and volume - change relationship except at the low confining stress. Rubber - sand contracted initially and then dilated as that of sand but its range of strains is found wider for contraction and much lesser for dilatancy.

Shalaby and Khan (2001) conducted a case study on recycling of shredded tires as a road base in Manitoba. It includes monitoring of road and environmental conditions during construction and service. They observed deflection of the tire road embankment is 15 to 25 mm, under 21000 Kg dual - tandem axle load. Also, an average rebound of 11 mm and a permanent deformation of 7 mm were recorded after two passes. Consoli et al (2002) carried out unconfined compression tests, splitting tensile tests and saturated drained triaxial compression tests to evaluate the benefit of utilizing randomly distributed polyethylene terephthalate fiber, obtained from recycling waste plastic bottles to improve the engineering behavior of uniform fine sand. The results showed that the polyethylene terephthalate fiber reinforcement improved the peak and ultimate strength of soil, however initial stiffness was not significantly changed. Youwai et al (2004) carried out analysis on the interaction between tire chips - sand mixture and the hexagonal wire reinforcement. Further strength characteristics were also investigated by pullout and direct shear tests. It was found both parameters increase with increased sand content. Zornberg et al (2004) carried out experiments in large scale triaxial apparatus on tire shreds. They found that the axial strain at failure was found to increase with increasing tire shred content.

Cetina et al (2006) investigated the geotechnical properties of pure fine and coarse grained tire - chips and their mixtures (10, 20, 30, 40 and 50%). Their results indicated that the mixtures up to 20% coarse grained and 30% fine grained tire - chips can be used above ground water tables where low weight, low permeability and high strength are needed in fills such as highway embankments, bridge abutments and behind retaining structures especially built on weak foundation soils with low bearing capacity and high settlement problems. Yoona et al (2006) evaluated the feasibility of using tire shred –sand mixtures as a fill material in embankment construction. They indicated that mixtures of tire shreds and sand are viable materials for embankment construction. Anh and Valdes (2007) conducted experiment to examine the time - dependent mechanical response of specimens composed of sand and granulated tire rubber, loaded in one - dimensional compression. The results indicated that sand–rubber creep is significant and may be reasonably estimated with the use of an available soil creep model. The swelling of granulated tire rubber due to oil absorption reveals the potential for its use as a stabilizing engineering material. Ozkul and Baykal (2007) evaluated the drained and undrained shear strength of mixtures of clay and tire buffing. Their results showed that the peak strength of the composite is comparable to or greater than that of the clay alone when tested at confining stresses below 200 – 300 kPa and the ductility, toughness and resistance to tensile cracking are also improved.

EXPERIMENTAL PROGRAMME

Natural Soil and Geogrid

Table 1 Properties of soil

Properties	Values
Gravel, %	0
Sand, %	18
Silt, %	42
Clay, %	40
Specific Gravity	2.65
Liquid Limit, %	57
Plastic Limit, %	21
Plasticity Index, %	36
Shrink Limit, %	12
Free Swell Index, %	55
Max. Dry Density, kN/m^3	17.6
Optimum Moisture Content, %	18.4
Plasticity Classification	CH
Swell Classification	High

In order to evaluate the possibilities of large scale utilization of rubbre wastes for the stabilization of problematic soils, natural soil was collected from Chennai, Tamil Nadu, India at a depth of 1.5 m. Soil sample was air dried at room temperature and sieved through appropriate sieve size before subjected to laboratory tests. The index properties of soil are shown in Table 1. Table 2 shows the properties of geogrid used in this investigation.

Table 2 Properties of geogrid

Description	Values
Type	Netlon (121)
Aperture Size, mm	8 x 6
Mesh Thickness, mm	3
Weight, g/m^2	725
Tensile Strength, KN/m	7.68
Extension at Maximum Load, %	20.2
Extension at Peak Load, %	3.2
Load at 10% Extension, kN/m	6.8

Rubber Waste

As per ASTM D 6270, the particles less than about 12 mm in size, termed granulated or ground rubber, particles from 12 mm to 50 mm in size are grouped as tyre chips and particles greater than 50 mm (50 to 305 mm) are grouped with tyre shreds obtained by shredding on waste rubber tyres.

Tire buffing, by products of tire retread process are selected for conducting lab tests in the present investigation (as shown in Fig. 2). The particle size distribution of tire buffing, as obtained from the retreading industry, is shown in Fig. 1. As the sample size ratio approaches six, the effects of sample size become negligible (Head 1982; Indraratna et al 1993; Marachi et al 1972), the maximum particle size of the shredded rubber tires used in the tests is limited to 45 mm. In addition, the particle size and shape of the shredded rubber tire material selected to use is relatively uniform to eliminate any anisotropic and internal reinforcing effects on conditions in the mixed material. The physical properties of tire chips waste (TCW) are summarized in Table 3.

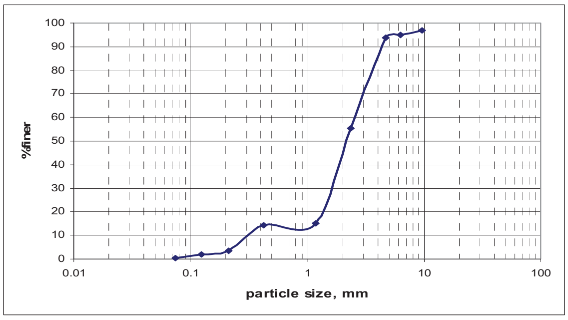


Fig. 1 Gradation curve of tire buffing used

Geogrid (GG)

Tire Chips Waste (TCW)

Fig. 2 View of geogrid and tire chips waste

Table 3 Properties of Tire Chips Waste (TCW)

Properties	Values
Particle Size, mm	30 to 45
Thickness, mm	7
Minimum Density, kN/m^3	4.32
Maximum Density, kN/m^3	6.38
Cohesion Intercept, kN/m^2	9.5
Friction Angle, Degrees	26

Static and Repeated Load Test in Model Tank

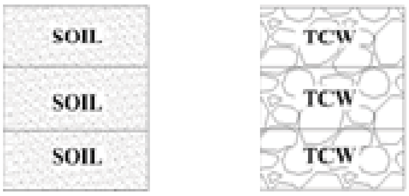
Both static and repeated load tests were conducted in two modes on soil with tire chips waste independently in a circular model tank of diameter 153 mm and depth of 180 mm. Tire chips wastes (TCW) were placed in layer form in different position as seen in Fig 3 and tested. This is to understand the ideal placement of rubber waste for the enhancement of recoverable elastic strain and reducing plastic strain in case of pavement subgrade.

In the case of repeated load test, repetitive load was applied on the soil - rubber waste mix atleast for 4 to 5 cycles of load until the slope of load - deformation curve became constant. The total load applied was corresponding to 20% deformation. After reaching the safe selected stress, the sample was allowed to rebound completely before applying the next loading cycle. The values of total, elastic and plastic strain were noted and the variation of static strain are analysed.

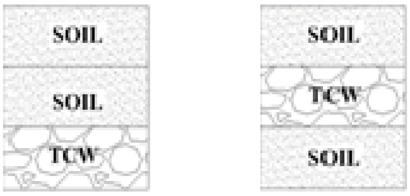
RESULTS AND DISCUSSIONS

Static Load - Deformation Behaviour of Soil + TCW with and without Geogrid

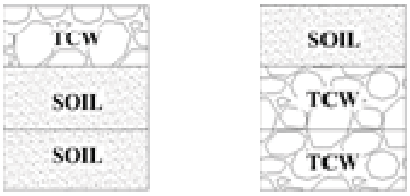
Figures 4 and 5 show the load - deformation curve of soil and crumbed rubber waste alone. The load - deformation curve for soil alone is a typical stress - strain curve and shows a significant peak load of 8.45 kN for a deformation of 30.08% of the height of the sample and that of tire chips waste alone have a shape of concave upwards and did not show any peak failure load and in fact beyond 20% strain there is a steep increase in the load caring capacity till to the maximum of 30% strain level. Rubber waste being pure elastic material and undergoes enormous deformation almost close to 70% of its thickness and hence it did not show any considerable resistance against the load. Earlier Bosscher et al (1997), Tatlisoz et al (1997 a) and Drescher (1999) also observed similar stress - strain curve for rubber waste alone.



(a) Soil alone (b)TCW alone

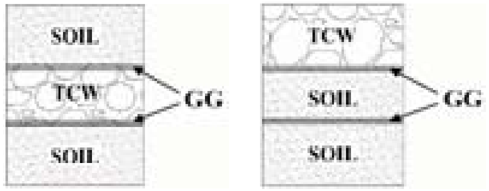


(c) Soil + Soil + TCW (d) Soil + TCW + Soil

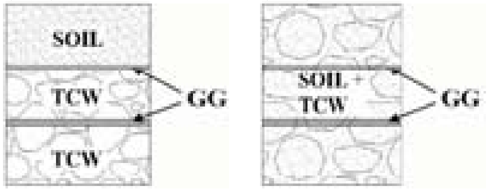


(e) TCW + Soil + Soil (f) Soil + TCW + TCW

(g) Soil + TCW (Intermix) (h) Soil (GG) + Soil (GG) + TCW



(i)Soil (GG) + TCW (GG) + Soil (j) TCW (GG) + Soil (GG) + Soil



(k) Soil (GG) + TCW (GG) + TCW (l) Soil-TCW(GG) (Intermix)

Fig. 3 Various combinations of soil + TCW used for load tests.

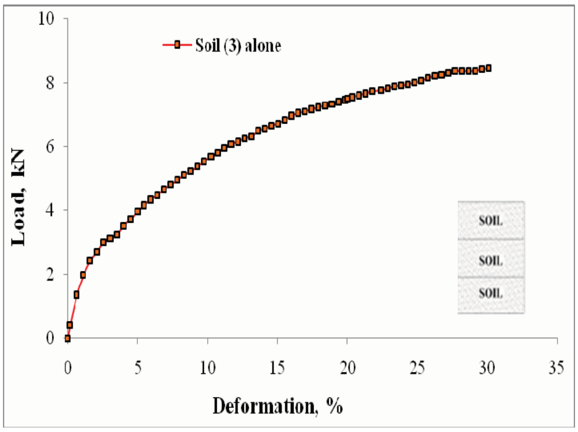


Fig. 4 Load - deformation curve of soil alone

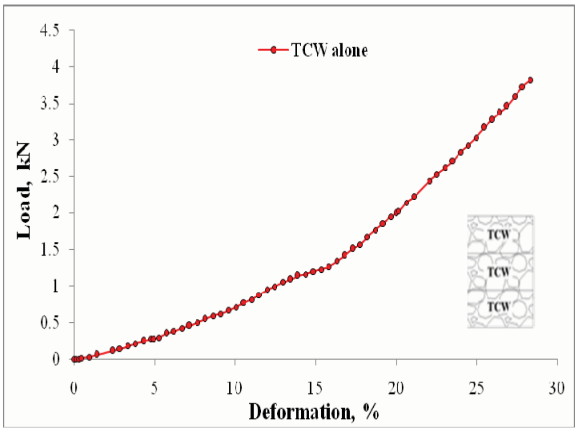


Fig. 5 Load - deformation curve of tyre chips waste alone

Figure 6 refers the load - deformation curve of soil + TCW + soil in three equal layers. Up to 2.5% deformation, soil + TCW + soil layer's behaviour is very close to behaviour of soil itself, because the load is initially taken by soil and beyond which the curve started slowley increasing and there is a considerable difference exists between soil alone and soil + TCW + soil layer combination. The peak load however observed corresponding to 20% deformation is 3.89 kN. Comparing soil + soil + TCW layers with soil + TCW + soil layers it may give an opinion that the first one better than the later. But on closer analysis of the curve, it may be observed that the load carrying capacity started increasing at larger strain level for the case of soil + TCW + soil layer than the other. In the beginning of the test, the load whatever applied is solely taken by the top two layers of soil and only after its full resistance, it transfers the load to the underlying TCW layer and because of which the soil + soil + TCW combination showed higher resistance at smaller strain level (<5%). On the other side, the load gets easily dispersed on to the TCW layer which is sandwiched between two soil layers.

Figure 7 refers the effect of intermixing of soil and TCW. Except for less than 2% strain level, the load - deformation pattern almost matches very well with the soil itself. The peak load corresponding to 20% deformation is found to be 6.77 kN which is much higher than any of the four cases. This may be because the soil and TCW are together sharing the load unlike the other four cases where the load sharing mechanism is more of independent. Figure 10 shows the view of soil + TCW mix after completion of load test.

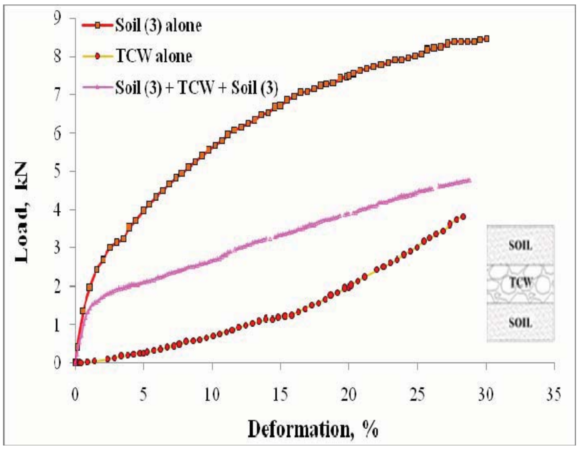


Fig. 6 Load - deformation curve of soil + TCW + soil layer

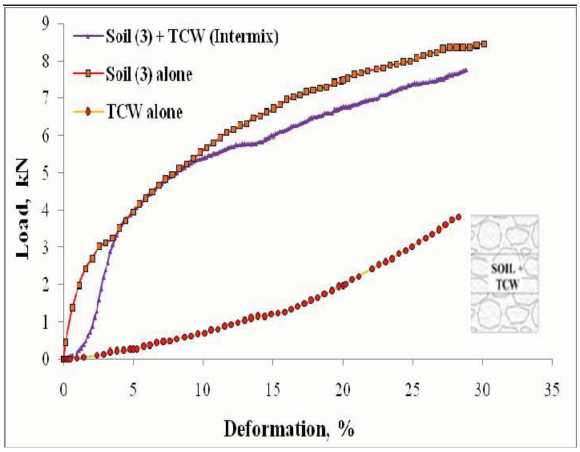


Fig. 7 Load - deformation curve of soil + TCW intermixed Form

Figure 8 compares the load - deformation characteristics of four different combinations of soil + TCW layers along with inter mixed soil + TCW materials. The behaviour of soil and TCW are also shown in the graph. Load - deformation of soil alone and TCW alone are the two extremes and other combinations very much lie well within the same irrespective of deformation level. Among all the combinations, soil + TCW + soil layer, soil + soil + TCW layer and soil + TCW intermix are seemed to have similar behaviour compared to other layer combinations, especially when deformation is less than 5%. In fact, the load carrying capacity is calculated both at 5% and 20% deformation level and compared as shown in table 4. At 5%

deformation, the peak load for soil + soil + TCW and soil + TCW intermix is 4.03 kN and 4 kN respectively and whereas for 20% deformation, soil + soil + TCW resulted in 4.43 kN and soil + TCW intermix gained a peak of 6.77 kN.

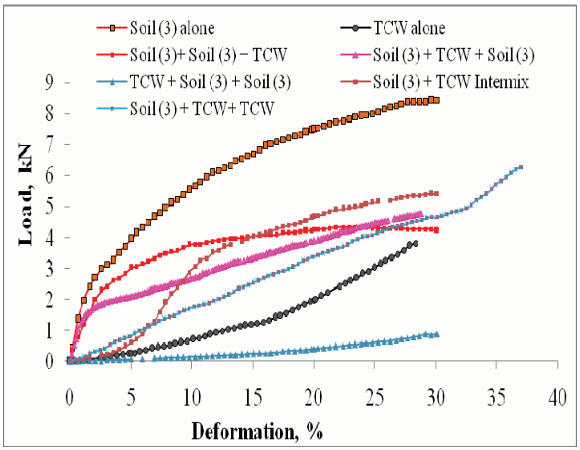


Fig. 8 Load - deformation curve of soil and TCW of layer and intermixed Form

Effect of Geogrid Reinforcement

In case of geogrid reinforced tyre chips waste sand - wiched between soil layers (figure 9) resulted in a maximum load of 4.45 kN, which is 14.39% higher than the unreinforced case.

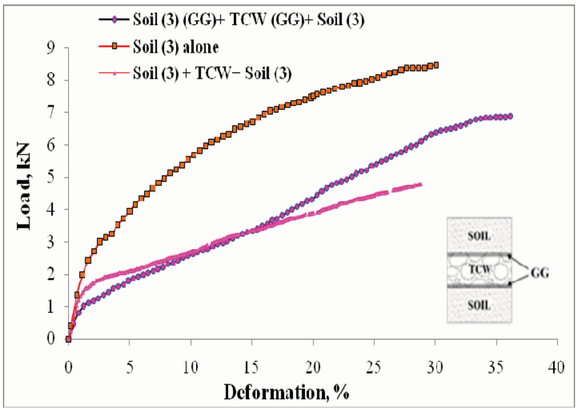


Fig. 9 Load - deformation curve of soil + TCW + soil layer with geogrid

In case of reinforced soil + TCW (GG) mix (Fig. 10), the peak load observed is 7.91 kN and unreinforced case is 6.77 kN with a % difference of 16.84. These results only imply that providing reinforcement could not alter the load carrying capacity substantially unlike the case of soil (GG) + soil (GG) + TCW layer combinations.Further, figure 16 shows a comparison of reinforced soil + TCW mix and same case of unreinforced one. In soil + TCW intermix case, the load carrying capacity is 6.77 kN for a deformation of 20%, but at the same deformation the load carrying capacity of soil with geogrid reinforcement increases to 7.91 kN. This additional strength and less deformation may be entirely due to the tensile strength of geogrid reinforcement. Table 4 gives the details of peak load corresponding to 5% and 20% deformations.

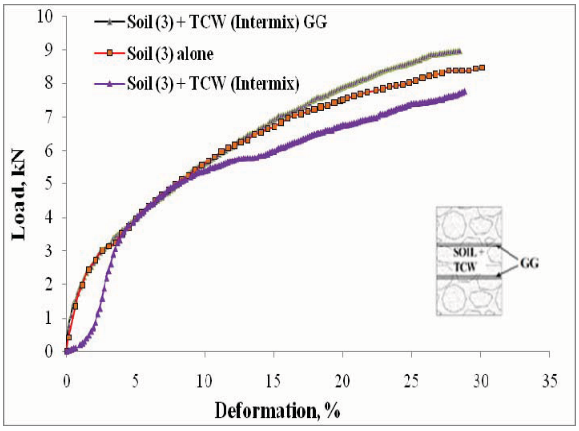


Fig. 10 Load - deformation curve of soil + TCW inter mix with geogrid

From Fig. 11, it can be observed that in all the cases, with the presence of geogrid reinforcement, the peak load corresponding to any deformation increases. The load carrying capacity increased from 4.43 kN to 6.52 kN for deformation of 20% in soil (GG) + soil (GG) + TCW case. In case of soil (GG) + TCW (GG) + soil, the load carrying capacity changes from 3.89 kN to 4.45 kN with a % increase of 14.39 and in TCW (GG) + soil (GG) + soil, the load carrying capacity changes from 3.53 kN to 3.91 kN with a % increase of 10.76. It is also found that, the geogrid reinforced soil (GG) + TCW (GG) + soil and soil (GG) + soil (GG) + TCW (GG) are giving a promising results and the stiffness of geogrid is very much pronounced. Provision of geogrid could not effectively act as reinforcement even when it is placed in layers for the cases of TCW (GG) + soil + soil and soil + TCW + TCW. Both at 5% and 20% deformation, the load carrying capacity of reinforced soil + TCW layer always higher compared with unreinforced soil + TCW layer (Table 4).

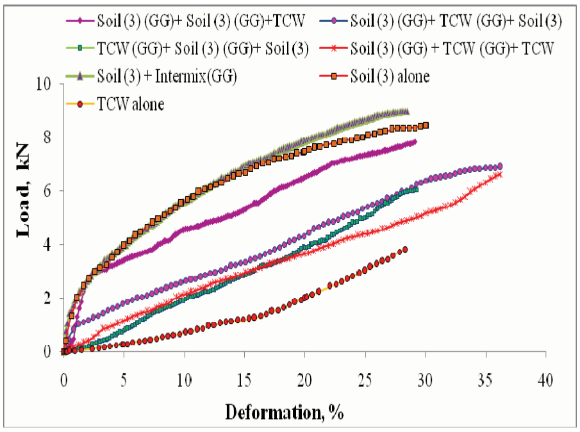


Fig. 11 Load - deformation curve of soil + TCW layer and intermixed form with geogrid

Table 4 Comparison of peak load at 5% and 20% deformation for soil + TCW with and without geogrid

Description	Peak Load in kN			
	at Deformation of 5%		at Deformation of 20%	
	Without Geogrid	With Geogric	without Geogrid	With Geogrid
Soil alone	3.9	-	7.5	-
TCW alone	0.28	-	1.99	-
Soil + Soil + TCW	4.03	3.42	4.43	6.52
Soil + TCW + Soil	2.1	1.86	3.89	4.45
TCW + Soil + Soil	0.24	0.81	3.53	3.91
Soil + TCW + TCW	0.9	1.23	3.43	3.70
Soil + TCW Inter Mix	3.88	4.0	6.77	7.91

Repeated Load – Deformation Behaviour of Soil + TCW with and without Geogrid

It is well known that unlike sandy soil, the clay soil undergoes permanent plastic deformation because of consolidation. The permanent unrecoverable strain is largely responsible for poor performance of pavement and early damage of pavement before its design life. In order to understand the effect of TCW on soil in layer form and completely mixed condition, static repeated load test were conducted for different number of cycles (maximum of five cycles) and the behaviour elastic and plastic strain values are discussed in this section.

The static stress under which repeated load test conducted was 326 kN/m^2 for soil and 86.5 kN/m^2 for tire chips waste, which is approximately 80% of the peak load corresponding to the deformation of 20%. In the first cycle, the soil alone showed (Fig. 4) a plastic strain of 14.4% and TCW alone showed 3.8% strain and consecutive number of cycles, the soil alone responded a recovering strain level of 0.5 to 2% of its total strain till the end of the cycles and whereas for TCW alone (Fig. 12), the recovery is the same as in the first case (100% recovery) and in the process of total accumulated strain for soil alone is more than 19.2% and for TCW, it is hardly 4.8% only.

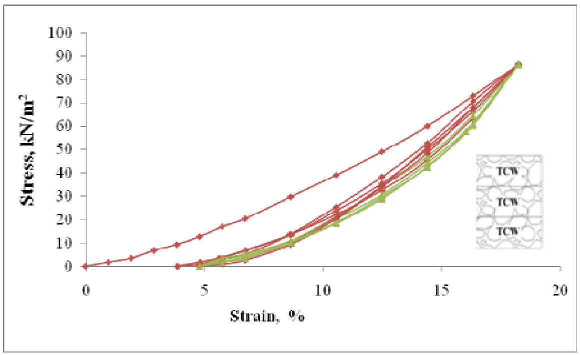


Fig. 12 Stress - strain curve of TCW alone under repeated load

Figures 13 and 14 show the stress - strain characteristics, under repeated load condition, for soil + soil + TCW layer and soil + TCW + soil layer respectively. While elastic recovery is low for soil + soil + TCW layers and the same is relatively high for soil + TCW + soil layers. The unrecovered plastic strain is 5.76% to 8.88% for soil + TCW + soil combination, where as it is 7% to 11.4% for soil + soil + TCW. This may be due to the fact that only after the compression of soil layer the load is transferred to the underlying TCW layer.

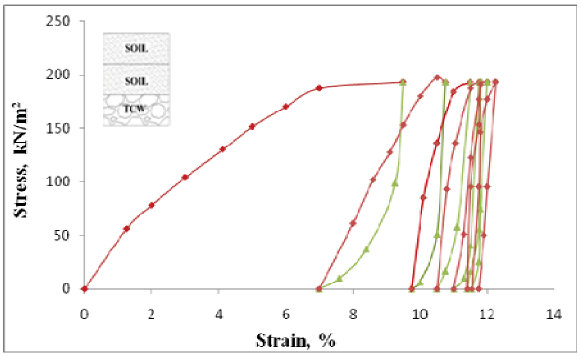


Fig. 13 Stress - strain curve of soil + soil + TCW layer under repeated load

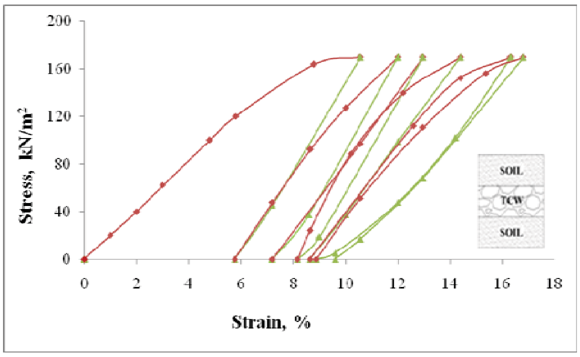


Fig. 14 Stress - strain curve of soil + TCW + soil layer under repeated load

From the above discussion on both reinforced and unreinforced cases of soil + TCW + soil (or) soil + soil + TCW, it is seen that the load transfer mechanism is different for TCW + soil + soil and soil + soil + TCW layers. This reason stated for the lesser peak load for TCW on the top of the soil supports the findings of unrecoverable strain as seen in Figs. 13 and 14. Figures 15 and 16 show the repeated stress - strain characteristics for TCW + soil + soil layer and soil + TCW + TCW layers. While total strain is ranging from 16.66% to 21.3% for five numbers of cycles, for TCW + soil + soil, the same is varying between 15.44% to 17.88% for soil + TCW + TCW layers. However, the recoverable elastic strain is between 5% to 6% for TCW + soil + soil and the same is 7% to 8% for soil + TCW + TCW.

Figure 17 shows the repeated load test on soil + TCW intermix. Similar to the previous case, the total strain is between 9.72% to 13.85% and recoverable elastic strain did not show the expected value. It is varying between 0.5% to 0.8% only. Even though soil + TCW mix provided a better strength equal to that of soil compared with other soil + TCW layer combinations, the recoverable elastic strain is high for soil + TCW layer. This may be because the operating stress and corresponding deformation level is low for the TCW to undergo its fullest compression in turn to regain its original size, as is happening with the individual layer system.

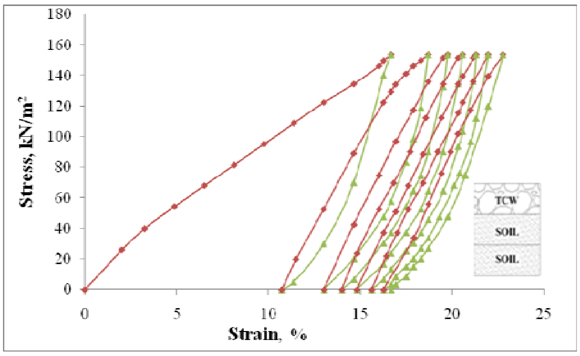


Fig. 15 Stress - strain curve of TCW + soil + soil layer under repeated load

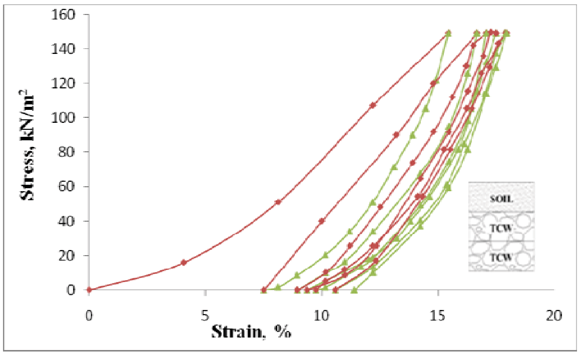


Fig. 16 Stress - strain curve of soil + TCW + TCW layer under repeated load

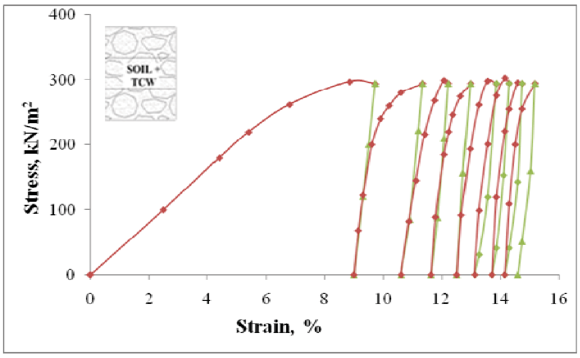


Fig. 17 Stress - strain curve of soil + TCW intermixed form under repeated load

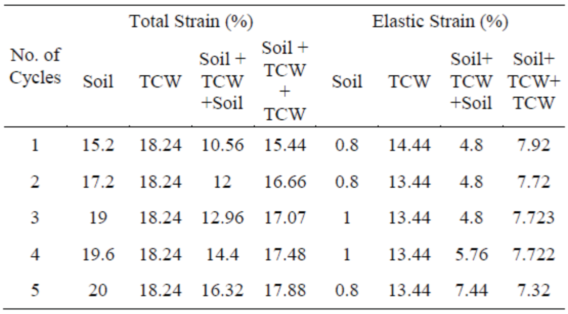
Tables 5 and 6 show the comparison of total strain and recoverable elastic strain for varying number of cycles, for soil and TCW layer. In different combinations while soil alone is having the total strain of 20% and elastic strain of 0.8%, the TCW has yielded total strain of 18.24% and elastic strain of 13.44%. The total strain in all the four combinations of layers is varying from 9% to 21% (maximum is for TCW + soil + soil layer) and the elastic strain is the least for soil + soil + TCW layer and soil + TCW mix (0.4% to 0.74%). Corresponding to fifth cycle, the same is between 7.4% to 5.7% for soil + TCW + soil and TCW + soil + soil combinations (table 5). From the variation of recoverable strain, it may be inferred that considering the load carrying capacity and as well as the enhancement of recoverable elastic strain, the order of preference of layer may be soil + TCW + soil > soil + TCW + TCW > soil + TCW intermixing.

It can also be observed from the table 5 and 6 that introducing 33% of rubber waste to soil results in more recovery of elastic strain which is comparable to that of pure rubber waste chips. For example, considering fifth cycle, the elastic strain of soil alone is 4% of its total strain and when introducing 66% of tyre chips waste, it increases to 40.94% of the total strain. But the elastic strain of pure rubber waste is arrived as 73.68% of its total strain and hence introduction of 33% rubber waste content is more effective when considering both load carrying capacity and rebound nature.

Table 5 Comparison of total and elastic strain of 33% of TCW in soil in layer and intermixed form

Combination of Soil - TCW	No. of Cycles	Total Strain (%)	Elastic Strain (%)
Soil + Soil + TCW	1	9.5	2.5
	2	10.75	1
	3	11.5	1
	4	11.75	0.75
	5	11.8	0.4
TCW + Soil + Soil	1	16.66	5.93
	2	18.69	5.7
	3	19.75	5.77
	4	20.56	5.77
	5	21.3	5.69
Soil + TCW Inter mixed	1	9.72	0.74
	2	11.34	0.74
	3	12.23	0.59
	4	12.96	0.44
	5	13.85	0.74

Table 6 Variation of total and elastic strain of soil - TCW combinations



No. of Cycles	Total Strain (%)				Elastic Strain (%)			
	Soil	TCW	Soil + TCW +Soil	Soil + TCW + TCW	Soil	TCW	Soil+ TCW +Soil	Soil+ TCW+ TCW
1	15.2	18.24	10.56	15.44	0.8	14.44	4.8	7.92
2	17.2	18.24	12	16.66	0.8	13.44	4.8	7.72
3	19	18.24	12.96	17.07	1	13.44	4.8	7.723
4	19.6	18.24	14.4	17.48	1	13.44	5.76	7.722
5	20	18.24	16.32	17.88	0.8	13.44	7.44	7.32

Effect of Geogrid Reinforcement

Figures 18 to 22 show the results of a typical repeated loading test on soil + soil + TCW, soil + TCW + soil, TCW + soil + soil, soil + TCW + TCW, soil + TCW inter mix with geogrid and results are presented subjected to stress of 283 kN/m^2, 187 kN/m^2, 169 kN/m^2, 157 kN/m^2 and 343 kN/m^2 respectively. All the four stress - strain curves behave as same as to that of without geogrid except that there is an increase in static strain in all cycles of loading because the applied stress was more than that of mix alone. Referring table 7 and 8, it can also be observed that the presence of geogrid showed moderate to high influence in change of elastic or accumulated strain (when considering as % of static strain). The change in the static strain with and without geogrid reinforcement for the soil - rubber mix is shown in figure 23.

From Figs. 18 to 22 and Tables 7 and 8, it is observed that the % increase of recoverable strain in reinforced soil + TCW layer is higher compared to unreinforced case. Comparing static load bahaviour with repeated load, even though soil + TCW + soil and soil + TCW inter mix did not show so much of recoverable strain, but considering the overall behaviour, this two combinations is expected to behave much better than other two combinations especially at larger number of cycles of loading.

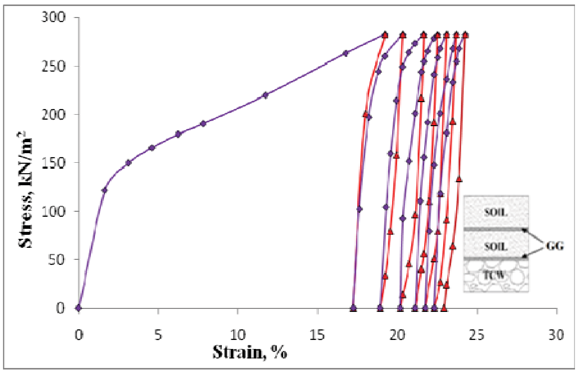


Fig. 18 Stress - strain curve of soil + soil + TCW layer with geogrid under repeated load

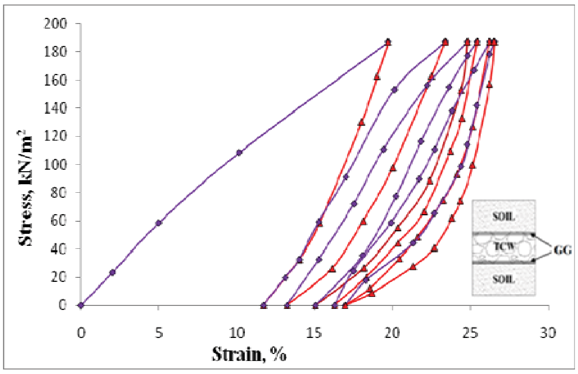


Fig. 19 Stress - strain curve of soil + TCW + soil layer with geogrid under repeated load

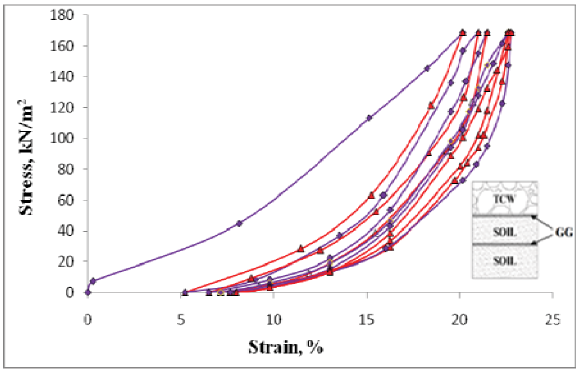


Fig. 20 Stress - strain curve of TCW + soil + soil layer with geogrid under repeated load

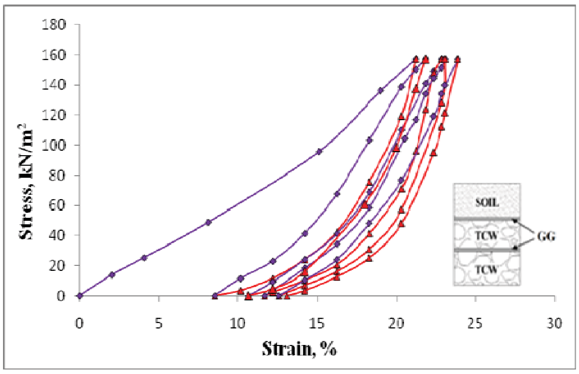


Fig. 21 Stress - strain curve of soil + TCW + TCW layer with geogrid under repeated load

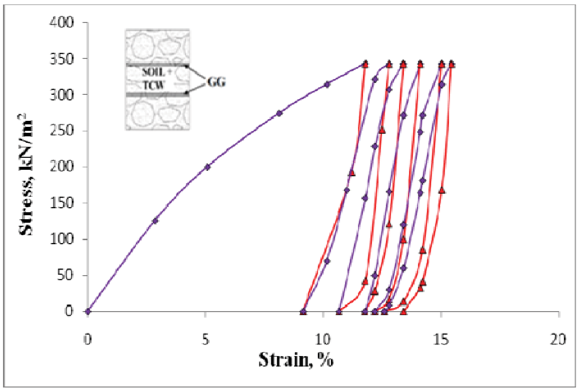


Fig. 22 Stress - strain curve of soil + TCW intermixed form with geogrid under repeated load

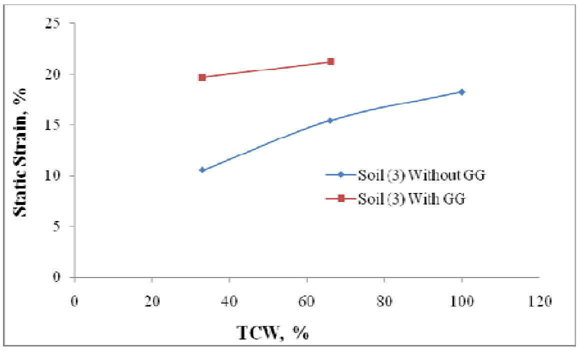


Fig. 23 Effect of TCW on the static strain of soil with and without geogrid

Figure 23 shows the effect of TCW on the static strain with and without geogrid reinforcement. The static strain becomes almost unaffected for geogrid reinforced rubber tyre waste and the same increases up to 66% TCW and thereafter remains constant.

The variation of accumulated strain (expressed as % of its total strain) with number of cycles is shown in Figs 24, 25 and 26. It can be understood from the figure that the plastic strain of soil decreases with increase in % of tyre chips waste and also introduction of 33% tyre chips waste reduces the plastic strain of soil by more than 80% and thereafter decrease in plastic strain is marginal. Hence introduction of 33% rubber waste content is more effective in both the cases with and without geogrid. Further comparing Tables 7 with 8, it may be observed that the provision of geogrid reinforcement improved the recoverable elastic strain considerably compared to unreinforced case. Thus it may be concluded that the geogrid reinforced soil + TCW either intermixed one and soil + TCW + soil layer form, can perform as a better material compared to soil itself.

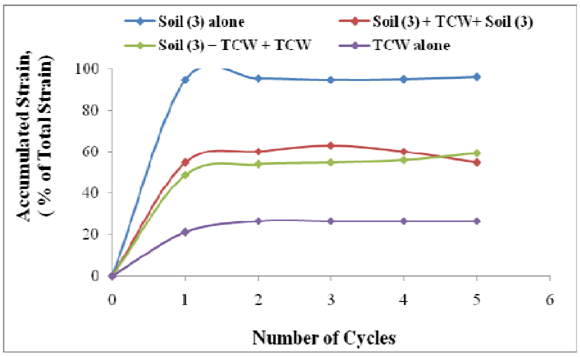


Fig. 24 Accumulated strain and number of cycles for soil + TCW layer combination without geogrid

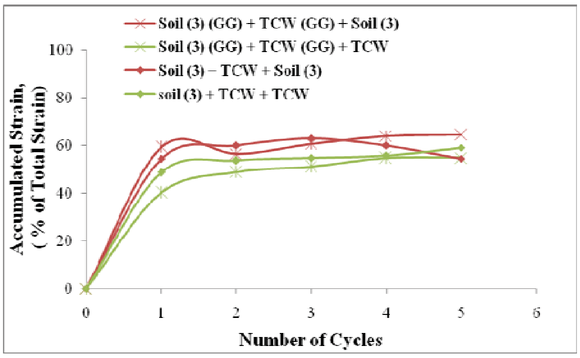


Fig. 25 Accumulated strain and number of cycles for soil + TCW layer combination with and without geogrid

Figure 24 shows the accumulated strain with number of cycles for 1/3 TCW, 2/3 TCW, TCW and soil. The % of accumulated strain decreases with increasing % of TCW in soil and vice-versa. This is an advantage of using TCW in soil, because the elastic recovery is important when a better performance of soil as a foundation material especially in case where cyclic load is expected. Figure 25 presents the effect of geogrid reinforcement on accumulated strain. The geogrid reinforcement reduces the accumulated strain which is advantage over the performance.

Table 7 Comparison of total and elastic strain of TCW in soil in layer and intermixed form

Case	No. of Cycles	Total Strain (%)	Elastic Strain (%)
Soil (GG) + Soil (GG) + TCW	1	19.245	2.034
	2	20.34	1.408
	3	21.67	1.486
	4	22.53	1.408
	5	23.078	1.3299
TCW (GG) + Soil (GG) + Soil	1	20.16	14.96
	2	20.97	14.47
	3	21.46	14.31
	4	22.59	14.95
	5	22.59	14.62
Soil (GG) + TCW (GG) + TCW (GG)	1	21.23	12.7
	2	21.84	11.17
	3	22.86	11.18
	4	23.06	10.46
	5	23.88	10.77
Soil + TCW Intermixed (GG)	1	11.79	2.65
	2	12.8	2.13
	3	13.4	1.61
	4	14.1	1.93
	5	15.04	2.45

Table 8 Variation of total and elastic strain for soil - TCW combinations with geogrid

No. of Cycles	Total Strain (%)		Elastic Strain (%)	
	Soil + TCW + Soil	Soil + TCW + TCW	Soil + TCW + Soil	Soil + TCW + TCW
1	19.71	21.23	8.03	12.7
2	23.368	21.84	10.16	11.18
3	24.79	22.86	9.754	11.18
4	25.4	23.06	9.144	10.46
5	26.2	23.88	9.25	10.77

CONCLUSIONS

From the static and repeated load tests conducted on soil with tire chips waste in layer form with and without geogrid reinforcement, the following conclusions may be drawn

1. For different soil – rubber chips waste (TCW) layer combinations, the largest strain occurred always in the first cycle of loading and for the subsequent cycles of loading, the strains were hardly between 0.5% to 2% only.
2. Higher the rubber waste content in soil, higher was the total strain, however, the elastic recovery or elastic strain of soil – TCW increases with percentage of TCW. While the total strain for soil alone is 20% corresponding to fifth cycles of repeated loading, the same is 18.24% for TCW alone. But on the other hand, the elastic recovery is 0.8% for soil and 13.44% for TCW.
3. For geogrid reinforced soil + TCW + soil layer, the elastic strain is 25% higher than of unreinforced case. For soil + TCW intermix, the recoverable elastic strain is 2 to 2.5 times higher than that of unreinforced soil + TCW intermix. This implies that soil + TCW intermixed or soil + TCW + soil layer with geogrid would always behave as a good foundation material below the pavement under repeated load.

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