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Rubber Waste Utilization In The Improvement Of Problematic Clays

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Abstract

To overcome the difficulties experienced with problematic soils in geotechnical applications and to reuse wastes effectively, an attempt was made in this investigation to explore the possibilities of utilizing rubber waste in the improvement of problematic soils. Problematic clay of high swelling and high compressible nature, rubber waste and a waste from discarded tires are selected and various tests conducted. The results that on addition of rubber waste to soil decreases its maximum dry density drastically and does not show a proportionate decrease in optimum moisture content. It decreases its UCC strength and initial tangent modulus and increases its axial strain at failure slightly up to addition of 20% rubber waste and drastically upon more than 20% wastes. The cohesion observed from the direct shear test decreases linearly but the angle of internal friction increases slightly upon addition of 10% rubber waste and thereafter remains constant up to 30% rubber wastes. The coefficient of consolidation decreased for soil + 10% rubber waste and thereafter it remained more or less constant and whereas the slope of the unloading curve increased with increasing percentage of rubber waste and also with decrement of applied pressure. Based on the analysis of results, it is recommended that rubber wastes can be used to increase the elastic properties of any problematic soil and so that it is suitable for geotechnical engineering areas such as highway embankments, pavements and oil storage tanks, bunkers and silos, etc., where the foundation soil is subjected to often loading-unloading cycles.

1. Introduction

The occurrence of problematic soils like black cotton soils are associated with low strength, high compressibility, high swelling potential and hence they are not suitable for geotechnical engineering applications. Rapid urbanization and industrialization in our country results in large production of many wastes and cannot generally be deposited in landfills since they require large spaces. In the present investigation it is proposed to study the effect of rubber waste on the engineering characteristics of problematic soil of high compressible clay. Rubber waste, a waste which is emanating from used /discarded tires is proposed to be used

In order to utilize the rubber waste for the improvement of problematic soils, it is proposed to obtain shear strength, compressibility, stress-strain characteristics from laboratory tests and to obtain load deformation characteristics and and response under repeated load from model tests for problematic soils mixed with varying percentage of rubber waste.

Plate 1 Rubber waste

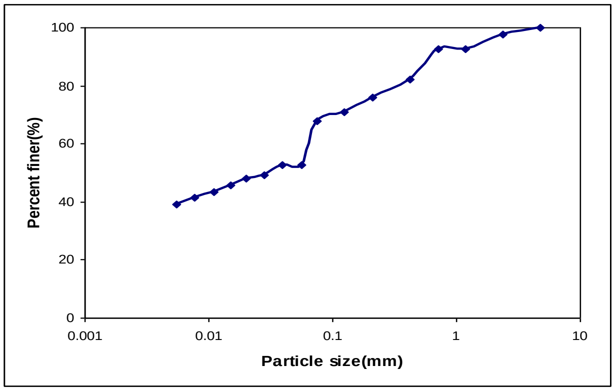

Fig.1 Particle size distribution of Natural clay used in the present study

Table 1. Physical properties of rubber waste used in lab tests

Properties	Values
Particle size	4.75 to 1.18 mm
Specific gravity	0.98
Water Absorption	5.5 %
Minimum density	474 kg/m^3
Maximum density	543 kg/m^3
Cohesion Intercept	5.47 KN/m^2
Friction Angle	23 degrees

2. Effect of Rubber on Load Deformation Characteristics

Load deformation behaviour of soils is essential to find out its strength and deformation characteristics in turn its suitability in various engineering applications. it is observed that the addition of rubber waste to soil decreased its shear strength and increased its strain at failure. Hence to know its suitability to use in high strain loading areas, it is essential to conduct repeated load test, for which peak load of soil rubber waste mixtures should be known. Hence load test was conducted on soil and rubber waste alone. and results are presented.

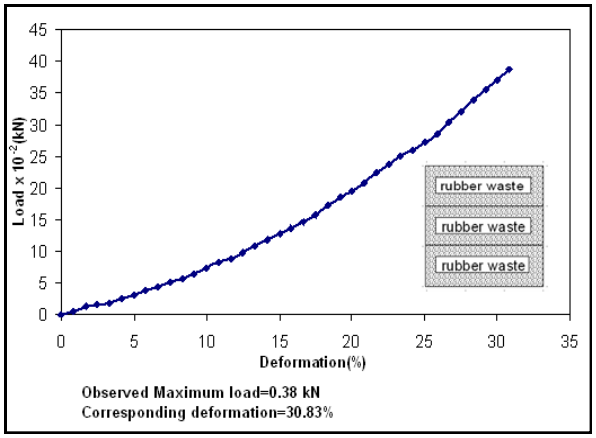

Fig.2 (a) Load deformation curve of rubber waste

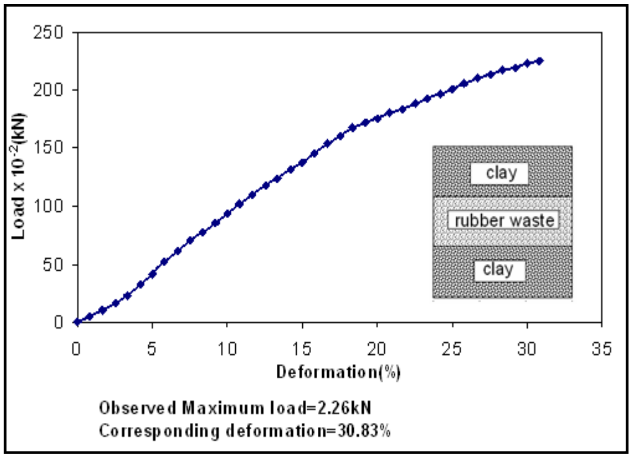

Fig.2(b) Load deformation curve of 1/3 clay layer + 1/3 rubber waste layer + 1/3 clay layer

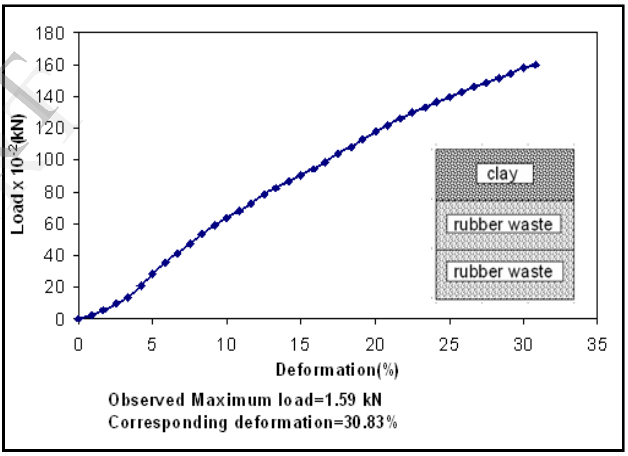

Fig. 2(c) Load deformation curve of 1/3 clay layer + 2/3 rubber waste layer

From the above figures it can be observed that in all the cases, the peak load and corresponding deformation increases. In case of soil alone, the load carrying capacity changes from 4.83 kN to 6.01 kN with a percentage increase of 24.4% and for rubber waste alone, the load carrying capacity changes from 0.17 kN to 0.38 kN with a percentage increase of 100%. In case of 1/3rd clay layer + 1/3rd rubber waste layer + 1/3rd clay layer, the load carrying capacity changes from 1.63 kN to 2.26 kN with a percentage increase of 38.6% and in 1/3rd clay layer + 2/3rd rubber waste layer, the load carrying capacity changes from 1.10 kN to 1.59 kN with a percentage increase of 44.5%.

It is obvious that with increase in percentage of rubber waste, in increasing the load carrying capacity of the **mixture is high.**

3. Effect of Rubber on Response of Soil Under Repeated Load

Most of the geotechnical engineering construction which includes embankment, land reclamation, filling up low lying areas, land fill construction etc., require proper compaction of soil generally achieved corresponding to maximum dry density with relative compaction of 90% and above. Embankments (both railway and highway), foundation below oil storage tanks, bunkers and silos etc., are subjected to often repetitive loading. The behaviour of soil especially fine grained soil under static loading is totally different from repetitive loading. Because of permanent plastic deformation of clayey soil, they are not suitable as such in the above application areas especially in situations like repeated load combined with very large strain is happened to occur over the soil below the foundation. In such cases geotechnical engineer is forced to look for an alternative material whose behaviour under repeated loading and large strain will be better. In order to address these issues, repeated loading and unloading tests were performed on constrained samples of soil and rubber waste alone and combination like 1/3rd clay layer + 1/3rd rubber waste layer + 1/3rd clay layer, 1/3rd clay layer + 2/3rd rubber waste layer and results were discussed below.

3.1 Effect of rubber waste on response under repeated load

Figure 3(a) to (d) show the results of a typical repeated loading test for soil, rubber waste, 1/3rd clay layer + 1/3rd rubber waste layer + 1/3rd clay layer, 1/3rd clay layer + 2/3rd rubber waste layer which are subjected to stress of 197 kPa, 7.6 kPa, 70.9 kPa, and 48 kPa respectively. From the figure, it can be observed that the general shape of all the curves are similar and with increase in rubber waste content, the slope gets flattened due to increase in compression and rebound of rubber waste during loading and unloading respectively. For all soil-rubber waste mixtures, the largest strain occurred in the first loading cycle and subsequent cycles were smaller The same trend is observed in all other samples of varying percentage of rubber waste.

The strain obtained at the end of the first cycle of loading is called the “static strain” whereas the strain generated in subsequent cycles of loading is called the “cyclic strain” (Edil and Bosscher 1994). Static strains for the soil-rubber waste mixtures were shown in fig. 4. It was observed from the figure that the mixtures having higher rubber waste content undergo greater static strain (for soil, static strain is 9.504% and that in 1/3 soil + 2/3 rubber waste is 13.25%) and this was due to the reason that the compressibility is primarily governed by the rubber waste than soil mixtures. Although a significant portion of the static strain was not recoverable, some rebound occurred during unloading. In addition, subsequent loading cycles did not result in much additional permanent strain. In all cases, the variation is not more than 0.5-2%. The recoverable component of the cyclic strain depends on rubber waste content and was higher for greater rubber waste content (for soil the elastic strain is 1.778% and for 1/3 soil + 2/3 rubber waste, it is 8.17% in first loading cycle) and in subsequent cycles the elastic strain decreases due to increase of plastic strain.

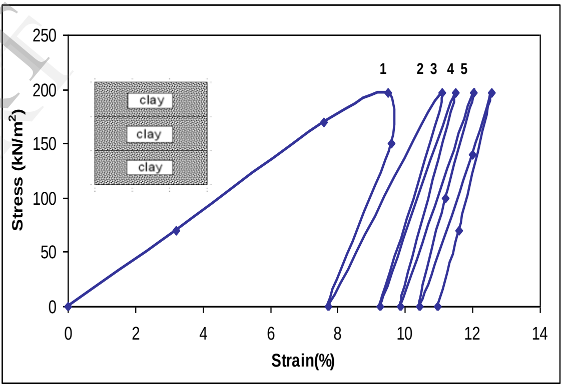

Fig. 3(a) Response of clay under repeated load

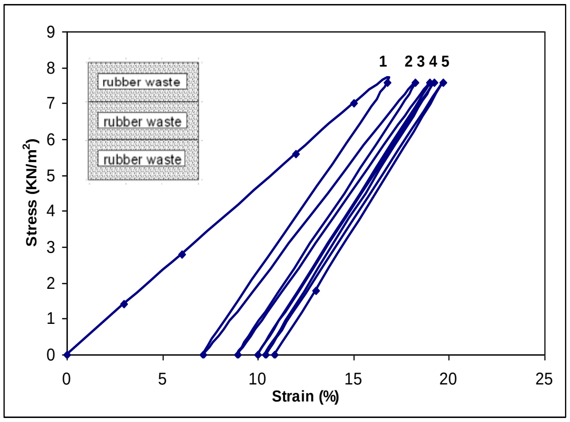

Fig.3 (b) Response of rubber waste alone under repeated load

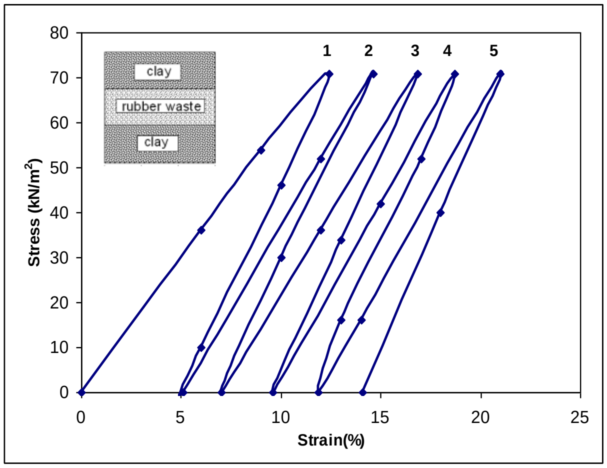

Fig.3(c) Response of 1/3 clay layer + 1/3 rubber waste layer + 1/3 clay layer under repeated load

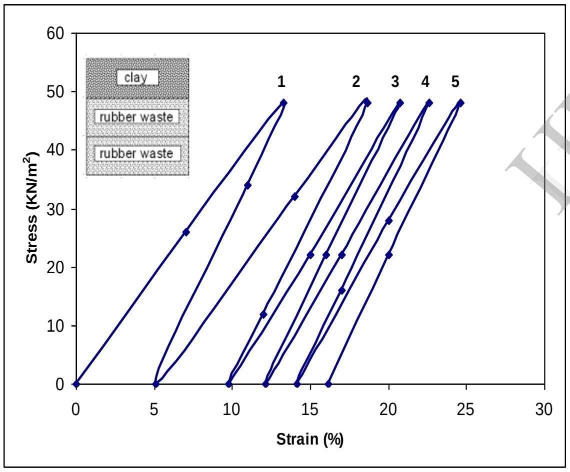

Fig. 3 (d) Response of 1/3 clay layer + 2/3 rubber layer under repeated load

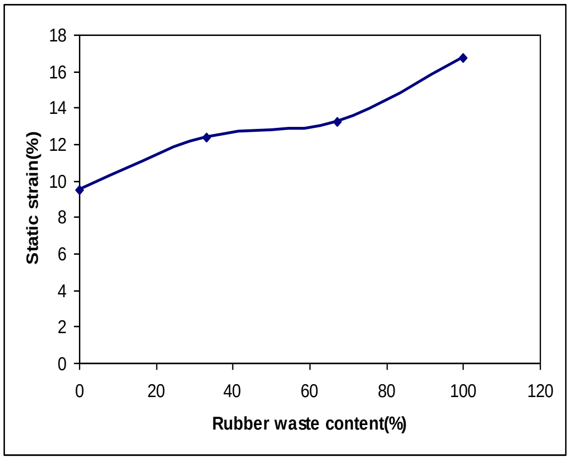

Fig. 4 Static strain for soil-rubber waste mixtures

Table 2(a) Variation of Total Strain with Number of cycles for soil-rubber waste mixtures

Number of cycles	Total Strain (%)			
	Soil	10% RW	30% RW	50% RW
0	0	0	0	0
1	9.504	12.425	13.25	16.785
2	11.091	14.647	18.627	18.225
3	11.494	16.87	20.765	18.987
4	12.044	18.733	22.585	19.241
5	12.573	20.976	24.596	19.664

Table 2(b) Variation of Elastic Strain with Number of cycles for soil-rubber waste mixtures

Number of cycles	Elastic Strain (%)			
	Soil	10% RW	30% RW	50% RW
0	0	0	0	0
1	1.778	7.345	8.17	9.673
2	1.82	7.662	8.848	9.293
3	1.63	7.26	8.616	8.996
4	1.63	7.26	8.424	8.827
5	1.63	6.88	8.425	8.827

It can also be observed from the table that even introducing 33% of rubber waste to soil results in more elastic strain relatively comparable to that of pure rubber waste. For example, considering fifth cycle, the elastic strain of soil increases from 13% to 32.8% of total strain and when introducing 67% of rubber waste, it increases to only 34.2% of the total strain. But the elastic strain of pure rubber waste is arrived as 44.9% of its total strain and hence introduction of 33% rubber waste content is more effective when considering both load carrying capacity and rebound nature.

CONCLUSION

From the compaction, UCC, direct shear and consolidation test conducted on selected problematic soil with increasing percentage of rubber wastes and from load and repeated load tests conducted on soil and rubber waste and the following general conclusions may be drawn.

It was noticed that although there was drastic decrease in $\gamma_{d\ max,}$ but there was no proportionate decrease in OMC. The decrease in density was due to low specific gravity of rubber waste and energy dissipation over the rubber waste rather than the effective energy on to the whole system of soil + rubber waste mixtures. The decrease in OMC is attributed to the presence of rubber waste which did not absorb moisture but the marginal decrease might be because of large volume of rubber waste material occupying the total volume of soil + rubber waste mixtures.

In soil-rubber waste mixtures having rubber fibers up to 20% showed a slight decrease in strength than that of soil from 174.5 kN/m^2 for soil alone to 149.7 kN/m^2 for soil + 20% rubber waste, but on addition of 30% rubber waste to soil showed a huge decrease in its strength(92.7 kN/m^2), but an enhanced residual strength. The initial tangent modulus also decreased whereas the axial strain at failure increased with increasing percentage of rubber waste. This decrease in strength and initial tangent modulus and increase in axial strain at failure might be because of, on the addition of rubber waste, due to its reduced maximum dry density and poor bonding, soil-rubber waste mixtures behave like loose soil and hence require more deformation to mobilize their ultimate shear strength.

The shear strength of soil-rubber mixtures decreased whereas the strain at failure increased as that observed in UCC test. The cohesion value decreased linearly from 62 kN/m^2 to 56 kN/m^2 whereas the angle of internal friction increased slightly from 14° for soil to 15° for soil +10% rubber wastes and remains constant up to soil + 30 % rubber waste. The decrease in cohesion of soil-rubber mixtures might be due to increase in loss of bonding between cohesive soil and the rubber waste, and increase in ϕ might be due to reinforcement effect of rubber fibers and temporary compression upon application of the normal stresses.

Corroborating the results of UCC test and direct shear test, it is noticed that while undrained cohesion value drastically decreased in UCC test, the same is less affected in direct shear test. Further, the higher undrained cohesion value from UCC test indirectly contributed by 'Φ' value which could not be measured for UCC test. But from direct shear test, 'Φ' and 'c' could be measured independently; and hence the 'c' value was relatively less.

The load-deformation curve for soil alone was a typical stress strain curve and showed a significant peak load and have a shape of concave upwards and did not show a pronounced peak load and showed an increase in load with increasing deformation. Earlier studies also observed the same behavior for rubber waste alone and the reason for such behavior was not explained clearly. The other three combinations of layered mixtures (1/3 soil + 1/3 rubber waste + 1/3 soil, 2/3 soil + 1/3 rubber waste, 1/3 soil + 2/3 rubber waste)showed the combined behavior of soil and rubber waste depending on the percentage and position of soil and rubber waste. Though the percentage of rubber waste is same in third and fourth cases, the influence of rubber waste is more in the third case due to its presence in second layer in third case while rubber waste was placed in bottom most layer in fourth case and hence third case was considered in further analysis instead of considering both.

In all the cases, the general shape of the curve was similar and with increase in rubber waste content, the slope gets flattened due to increase in compression and rebound of rubber waste during loading and unloading respectively. For all soil-rubber waste mixtures, the largest strain occurred in the first loading cycle and subsequent cycles were smaller (for soil, the strain is 9.504% in the first loading cycle but only 0.5-2% variation in subsequent cycles). The mixtures having higher rubber waste content undergo greater static strain (for soil, static strain is 9.504% and that in 1/3 soil + 2/3 rubber waste is 13.25%) and this is due to the reason that the compressibility is primarily governed by the rubber waste than soil. Although a significant portion of the static strain was not recoverable, some rebound occurred during unloading. In addition, subsequent loading cycles did not result in much additional permanent strain. The recoverable component of the cyclic strain depends on rubber waste content and was higher for greater rubber waste content (for soil the elastic strain is 1.778% and for 1/3 soil + 2/3 rubber waste, it is 8.17% in first loading cycle). Introduction 33% of rubber waste to soil results in more elastic strain relatively comparable to that of pure rubber waste.

The Cv values of soil + rubber waste mixtures was observed to be less than virgin soil itself. In fact, the result expected was opposite to the result observed. The introduction of rubber waste would result in open fabric and permeability value will be normally higher. The reduction in Cv values might be because of the elastic compression of rubber waste material, especially for higher pressure increment, along with the compression of soil. If Cv values were to be determined at lesser pressure, it is postulated that Cv values might increase due to increasing percentage of rubber wastes.

The initial void ratio in all the cases varied from 0.52 to 0.47 for a density range of 16.39 kN/m^3 to 11.86 kN/m^3 and this might be due to increased volume of solids because of low specific gravity of rubber waste material. The static strain increased linearly with percentage of rubber waste from lower value of 12% to 22% corresponding to soil + 50% rubber waste because of excess elastic compression of rubberized materials compared to the compression of soil itself. For all the rubber waste mixtures in all cycles, the slope of the unloading curve was found to increase with increase in pressure decrement.

It is hence recommended that on addition of rubber to the soil, it may act as an ideal material for various geotechnical applications especially in cases where clays are subjected to static or repetitive loading combined with large strain.

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