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SUITABILITY OF WASTE TYRE RUBBER STABILIZED RED SOIL AS SUBGRADE MATERIAL

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ABSTRACT

Soil stabilization means alternation of soil properties to meet the specified engineering requirements. Lime and cement was commonly used as stabilizer for altering the properties of soil. Earth reinforcements was commonly done using metal strips, geotextiles, geogrids, geosynthetics, etc., from the recent study it is observed that solid waste materials such as waste tyre rubber is utilized forthe intended purpose with or without lime and cement. Now a days it is necessary to utilize the waste effectively with technical development in each field. The old abonded tyres from road vehicles are stockpiled throughout the country. This leads to various environmental problems which include air pollution associated with open burning of tires, harmful contaminants and aesthetic pollution. There are non-biodegradable and the waste tyre rubber has become a problem of disposal. This project is intended to utilize the feasibility of waste tyre rubber has stabilizing material for soil in pavements. The waste tyre rubber is mixed with soil in various percentages and carried out different tests results by forming normal and rubber stabilized soil and calculate various properties that may strengthen road pavement by achieving it economically. This not only minimizes the pollution occurred due to waste tyre, but also the use of conventional aggregate which is available in exhaustible quantity.

I. INTRODUCTION

Red soils are prominent in north coastal districts of Andhra Pradesh. These exhibit high strengths in dry condition and collapse on wetting. Several kilometers of road networking under highways, village roads have been running through these soils. Flexible pavements are the prominent type of road networking in these areas. The designers are using the CBR method (soaked) for the design of the pavement thickness and quality of component layers.

In recent decades, the worldwide growth of the automobile industry and the increasing use of cars as the main means of transport have tremendously boosted tire production. This has generated massive stockpiles of used tires. Extensive research projects were carried out on how to use used tires in different applications. CBR test is a strength test which is influenced by gradation, consistency, density, moisture content, etc., are required to perform the test. Especially most of the red soils in this area are sandy soils, in these soils of samples for testing of CBR may give true representation of the strength of against penetration. In this an attempt is made to study red soils with inclusion of tyre waste to improve these soils with respect to strength in terms of shear parameters, CBR and other parameters with respect to saturated condition.

II. REVIEW OF LITERATURE

H.K. Gupta et al (2021) Shredded rubber tyre having sizes ranges from 5mm to 10mm (Width), 10mm to 15mm (Length) and a couple of to 3mm in thickness and therefore the steel belting was removed are used extensively. Added amount of rubber tyre varied in proportions of 4%, 6%, 8% and 10% as well as 2% and 4% of cement. Use of shredded rubber tyres in geotechnical engineering for enhancing the soil properties has received great attention within its recent times. It presents the investigation of behaviour of pavement subgrade soil stabilized with shredded rubber tyre chips with addition of cement. It is seen that the CBR as well as UCS is increasing till 5% after that it is decreasing continuously. So we can use 5% of Rubber tyre chips.

Sumanjali Parimi et al (2018) Shredded rubber pieces having a size of 10 to 15 mm length, 2mm thickness are collected from scrap tyres. The rubber percentage was taken as 2, 4, 6, 8 and10% for the five trails. The 2% of the shredded rubber is required for Red soil to improve the California bearing ratio of 2 times to suit as subgrade material and 4 % of Shredded rubber is required for Red soil to improve CBR value 4 times to meet the higher load requirements. Stabilized Red soil with an amount of 2% and 4 % shredded rubber can be used effectively for the subgrade material of the pavement.

III. OBJECTIVES

1. To determine the index and engineering properties of red soil.

2. To study the effect of Tyre waste (0%, 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5%, 5%) as the additive to red soil on compaction, CBR, Shear strength and Seepage

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Characteristics.

3. To assess the compatibility/suitability of industrial wastes taken up for study, basedon the results of laboratory analysis for their use in construction activities as sub- grade component, fill material etc.

IV. METHODOLOGY

The red soil mixed with various dosages of tyre waste of 0%, 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5%, 5%. The samples was prepared as per dosages and tested for index properties, compaction, CBR, Shear strength and Seepage Characteristics to analyze the test results. Based the test results the conclusions was drawn below mentioned results and discussions.

V. RESULTS AND DISCUSSIONS

This paper consists of the performance of Red soil and waste tyre mixes as geotechnical materials like sub-grade and fill material in construction of roads.

Red Soil -I:

Red soil collected from surampalem, Andhra Pradesh The collected soil was dried and subjected to various geotechnical characterizations such as gradation, compaction, strength etc. and the test results are shown in table-1 and it is represent as SC.

Table.1 Geotechnical properties of Red Soil-I

Property	Values
Grain Size Distribution	
Gravel (%)	0
Sand (%)	80
Fines (%)	20
a) Silt (%)	12
b) clay (%)	8
Consistency Limits	
Liquid limit (%)	30
Plastic limit (%)	20
Plasticity Index(I_P)	10
IS Classification	SC
Specific Gravity	2.67
Compaction characteristics	

Optimum moisture content (%)	11
Maximum Dry density(g/cc)	1.80
Shear Parameters	
Cohesion-c(t/m^2)	1.80
Angle of shearing resistance (Ø)	28^o
California Bearing Ratio % (Soaked)	5

Red soil – II:

Red soil collected from G.vemavaram, Andhra Pradesh The collected soil was dried and subjected to various geotechnical characterizations such as gradation, compaction, strength etc. and the test results are shown in table 2 and it is representing as SP.

Table.2 : Geotechnical properties of Red Soil - II

Property	Values
Grain Size Distribution	
Gravel (%)	0
Sand (%)	96
Fines (%)	4
a) Silt (%)	4
b) Clay (%)	0
Consistency Limits	
Liquid limit (%)	NP
Plastic limit (%)	NP
Plasticity Index(I_P)	NP
IS Classification	SP
Specific Gravity	2.66
Compaction characteristics	
Optimum moisture content (%)	7.0
Maximum Dry density(g/cc)	1.70
Shear Parameters	
Cohesion-c(t/m^2)	1.80
Angle of shearing resistance (Ø)	32^o
California Bearing Ratio % (Soaked)	8.0

Tyre Waste:

Ground granulated waste tyre was collected from retreading service pvt.ltd, Kakinada, Andhra Pradesh. The collected tyre waste was dried and subjected for various tests.

Interaction between Red Soils and Waste Tyre(%)

To study the interaction between red soils and waste tyre in terms of various geotechnical characterization various percentages of waste tyre such as 0.5 - 5% for added by dryweight of red soils and the above mentioned tests were conducted such as consistency characteristics as per IS 2720-part-5-1985, compaction characteristics as per IS2720-part-8- 1983, permeability characteristics as per IS 2720-part-17-1986, shear strength characteristics as per IS 2720-part-13-1986 and CBR characteristics as per IS 2720-part-16-1987 and the results are shown in below tables & figures.

A. Type – I soil (SC)

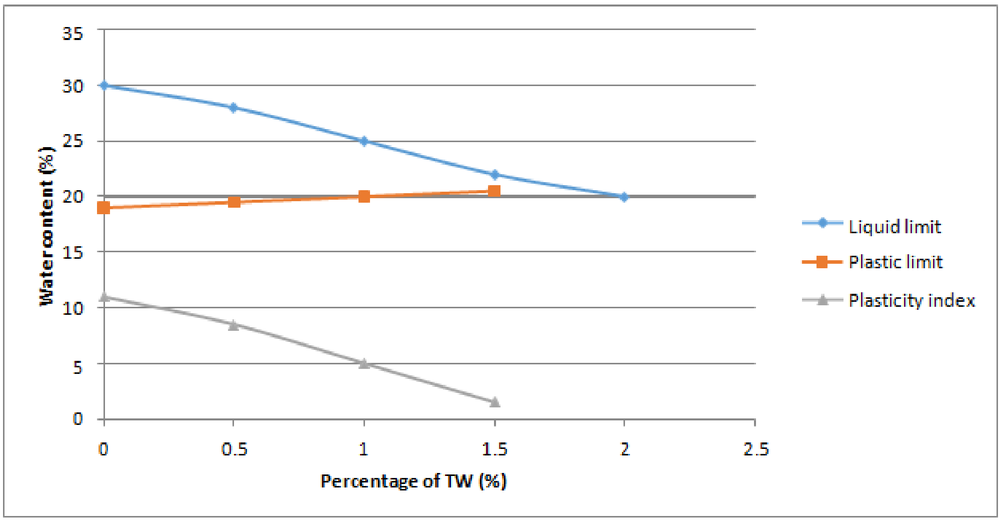
To study the effect of tyre waste on red soil various percentages of tyre waste i.e., 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5%, 5% were added to the red soil thoroughly mixed and the test results mentioned below tables and graphs.

a. Consistency characteristics of Red soil (SC) with tyre waste (%):

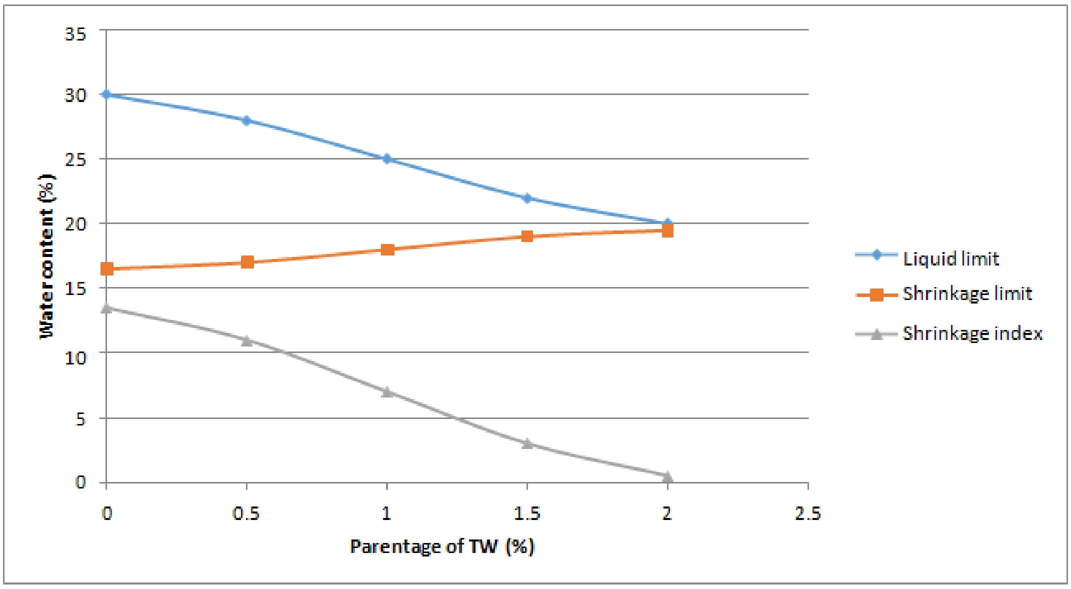
To study the effect of tyre waste on red soil for consistency limits such as liquid limit, plastic limit, shrinkage limit and allied indices like plasticity index, shrinkage index etc., as per IS 2720 and the results are shown in below.

Table.3 : Consistency characteristics of Red soil (SC) + Tyre waste (%)

Tyre waste (%)	Consistency Limits				
	WL	WP	WS	IP	IS
0	30	19.0	16.5	11.0	13.5
0.5	28	19.5	17.0	8.50	11.0
1.0	25	20.0	18.0	5.00	7.00
1.5	22	20.5	19.0	1.50	3.00
2.0	20	NP	19.5	NP	0.50
2.5	NP	NP	NP	NP	NP
3.0	NP	NP	NP	NP	NP
3.5	NP	NP	NP	NP	NP
4.0	NP	NP	NP	NP	NP
4.5	NP	NP	NP	NP	NP
5.0	NP	NP	NP	NP	NP



Graph.1 :Variation of Liquid limit, Plastic limit and Plasticity index with Tyre waste (%)



Graph.2 : Variation of Liquid limit, Shrinkage limit and Shrinkage indexwith Tyre waste (%)

Increasing the percentage of TW decreases liquid limit values, increases plastic limit and shrinkage limit values. Increasing the percentage of TW decreases plasticity index and shrinkage index values. At 2% WT the soil become non-plastic. Decrease in liquid limit values are due to replacement of clay particles by TW particles resulting decrease of net negative charge, diffused double layer between clay particles. Increase in plastic is due to decrease in repulsion between clay particles due to flocculation, further increases particles contact to contact, therefore increases shearing resistance at particle level. Increase in

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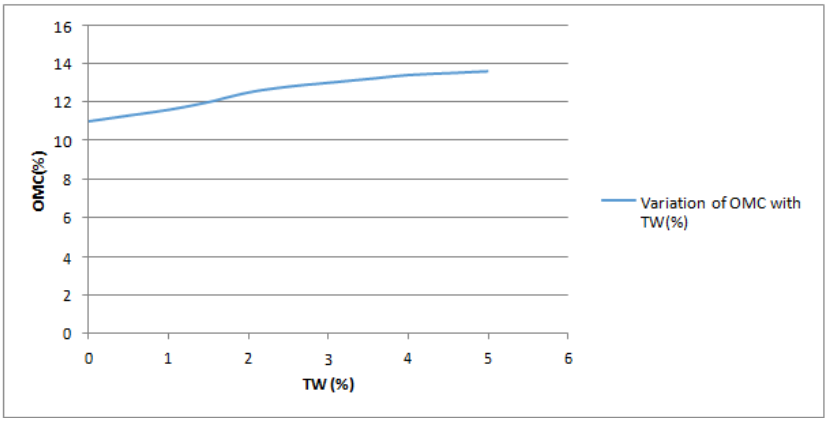
shrinkage limit values shows that addition of TW increases the tolerability against shrinkage and the net volumetric shrinkage is less due to increase of moisture content. Decrease of plasticity index and shrinkage index shows the decrease of plasticity characteristics and shrinkage characteristics respectively.

b. Compaction characteristics of Red soil (SC) with tyre waste (%):

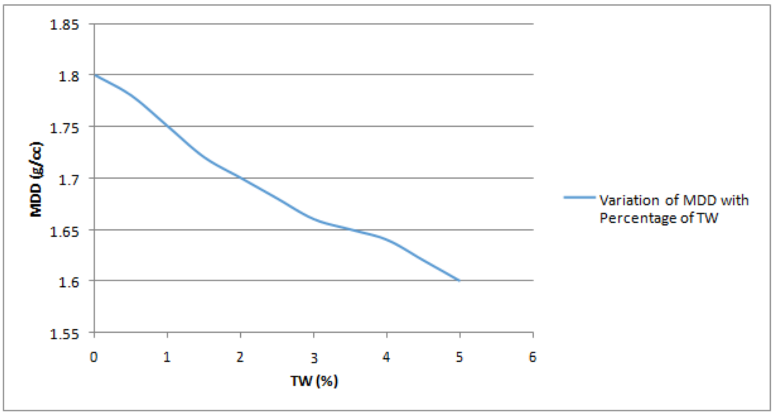
To study the effect of tyre waste on red soil for compaction characteristics of dry weights and modified proctor test was performed as per IS 2720-part 8-1983 and the results are shown in below.

Table.4: Compaction characteristics of Red Soil (SC) + Tyre waste (%)

Tyre waste (%)	OMC (%)	MDD (g/cc)
0	11	1.8
0.5	11.3	1.78
1.0	11.6	1.75
1.5	12.0	1.72
2.0	12.5	1.7
2.5	12.8	1.68
30	13.0	1.66
3.5	13.2	1.65
4.0	13.4	1.64
4.5	13.5	1.62
5.0	13.6	1.6



Graph.3 : Variation of OMC with percentage of TW



Graph.4: Variation of MDD with percentage of TW

From the test results it is identified that increasing the percentage of TW increases optimum moisture content values and decreases maximum dry density values. Increase in OMC values are due to adherence of soil particles on to the tire surface and the matrix turn in to flocculated structures. Decrease in maximum drydensity values are due to replacement of soil particles by tire waste particles which are light weight material and the unit weight of tire waste particles is less than that of soil particles.

c. CBR characteristics of Red soil (SC) with Tyre waste (%):

To know the CBR characteristics of Red soil with TW (%), samples are prepared at their OMC & MDD values and soaked for 4 days and CBR test was conducted as per IS 2720 and the results are shown in below.

Table 5: Strength Characteristics of Red Soil (SC) + TW (%):

Tyre waste (%)	CBR (%)

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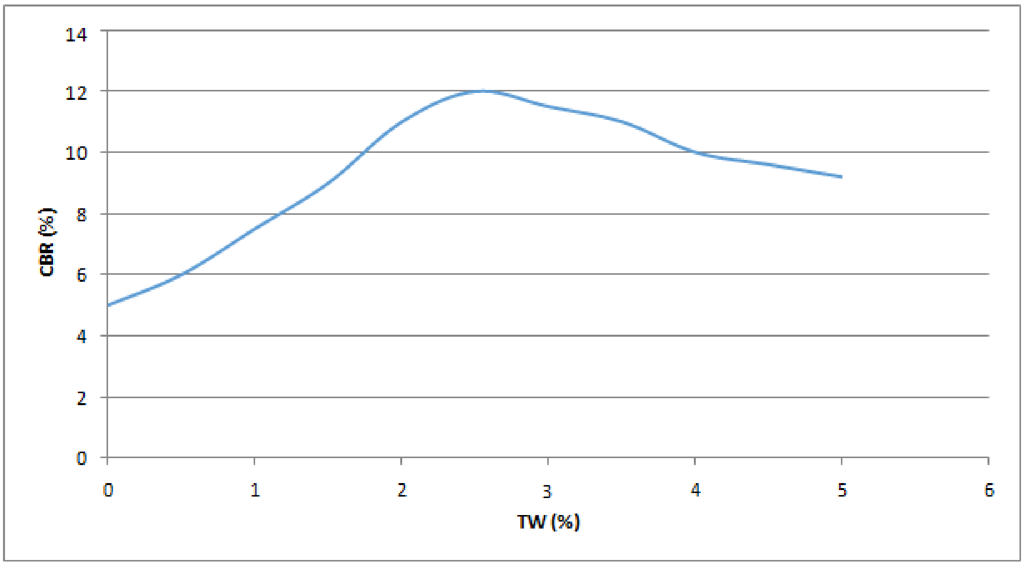
0	5.0
0.5	6.0
1.0	7.5
1.5	9.0
2.0	11.0
2.5	12.0
3.0	11.5
3.5	11.0
4.0	10.0
4.5	9.6
5.0	9.2



Graph.5: Variation of CBR (%) with percentage of TW

From the test results it is identified that increasing the percentage of TW increases CBR values up to 2.5% and then decreases. A combination of Red soil with TW helps to develop more shear resistance against penetration. This phenomenon is rapid up to 2.5% and then steadily decreasing due to segregation of particles. But at all percentages of TW, the combined soil-TW matrix attained high CBR values which are greater than the individual soil mass.

d. Shear strength characteristics of Red soil (SC) with TW (%):

To know the shear strength of Red soil (SC) with TW can be explained in terms of shear parameters(C & Ø) by performing tests at various drainage condition i.e., un-consolidated

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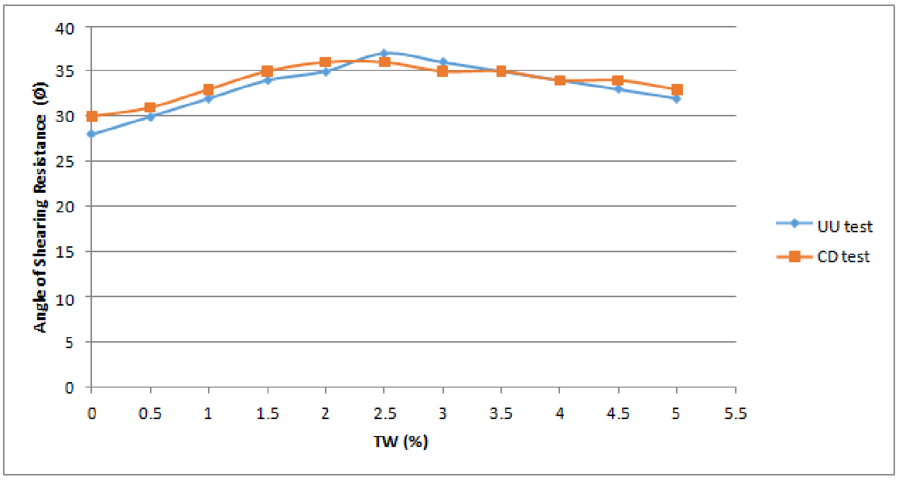
un-drained test (UU) and Consolidated drained test (CD) by direct shear apparatus. The tests were conducted as per IS 2720 part 13-1986 and the results are shown in below.

Table 6: Shear parameters of Red Soil (SC) + TW (%):

TW (%)	Unconsolidated Un-drained (UU)		Consolidated drained (CD)	
	Cohesion (C)	Angle of internal friction(φ)	Cohesion (C')	Angle of internal friction(φ')
0	1.8	28	0.5	30
0.5	1.5	30	0.3	31
1.0	1.3	32	0.1	33
1.5	1.0	34	0.0	35
2.0	0.5	35	0.0	36
2.5	0.2	37	0.0	36
3.0	0.0	36	0.0	35
3.5	0.0	35	0.0	35
4.0	0.0	34	0.0	34
4.5	0.0	33	0.0	34
5.0	0.0	32	0.0	33



Graph.6: Variation of Angle of Shearing resistance (φ) with percentage of TW

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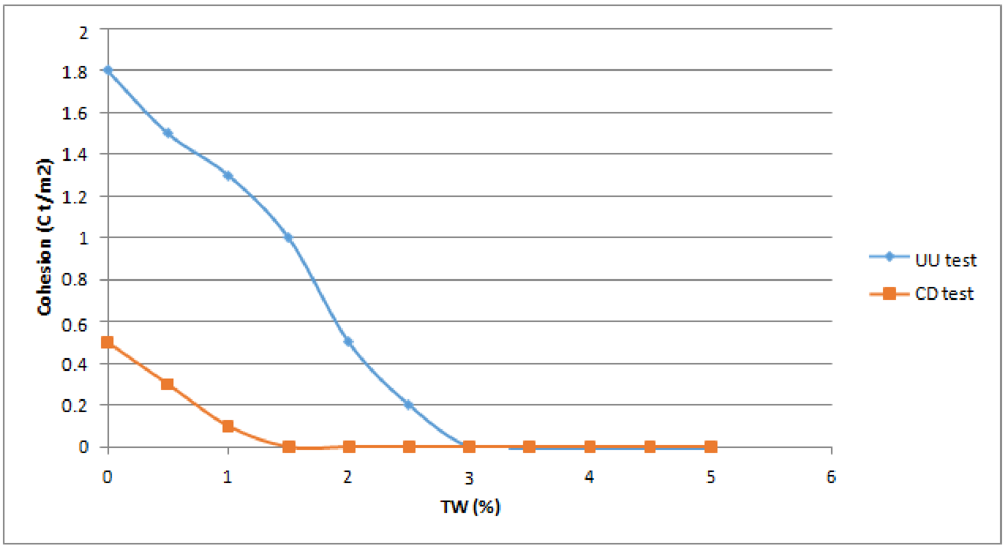


Graph.7: Variation of Cohesion (C) with percentage of TW

From the test results it is identified that cohesion values are rapidly decreasing in UU test whereas slowly decreasing in CD test. It is also identified that Angle of shearing resistance (Ø) values are steadily increasing up to 2.5% and then decreasing. Angle of shearingresistance (Ø) values are higher in case of CD test and the shear strength turn in to frictional component. In all the mixes Ø values in CD is more than in UU test. More interlocking is taking place due to inclusion of TW particles.

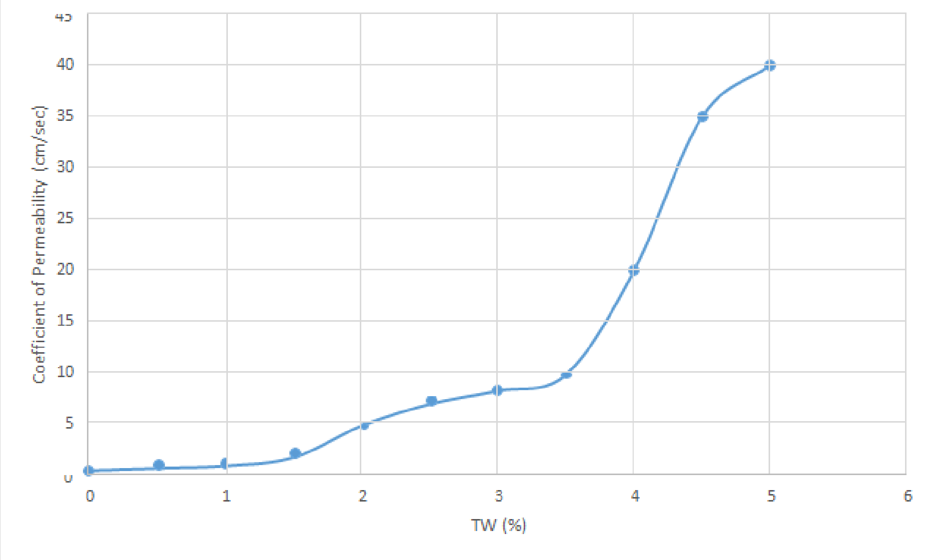
e. Seepage Characteristics of Red Soil (SC) with TW (%):

To know the seepage characteristics of Red soil (SC) with TW, sample are prepared at their OMC and MDD values and falling permeability test was performed on these soil samples and the results are shown in below.

Table 7: Seepage characteristics of Red soil (SC) with TW (%):

TW (%)	Coefficient of Permeability-K (x 10^{-5}cm/sec)
0	0.43
0.5	0.65
1.0	0.89
1.5	1.70
2.0	4.80
2.5	6.90
3.0	8.20
3.5	9.80
4.0	20.0

4.5	35.0
5.0	40.0



Graph.8 : Variation of Coefficient of Permeability with percentage TW

From the test results it is identified that increasing the percentage of TW increases coefficient of permeability values. Flocculation of particles leads to agglomeration which increases the pore size, finally more seepage characteristics are identified. This behavioris rapid with respect to dosage of TW.

B. Type – II soil (SP):

To study the effect of tyre waste on red soil various percentages of tyre waste i.e., 0.5%, 1%, 1.5%, 2%, 2.5%, 3%, 3.5%, 4%, 4.5%, 5% were added to the red soil thoroughly mixed and the test results mentioned below tables and graphs.

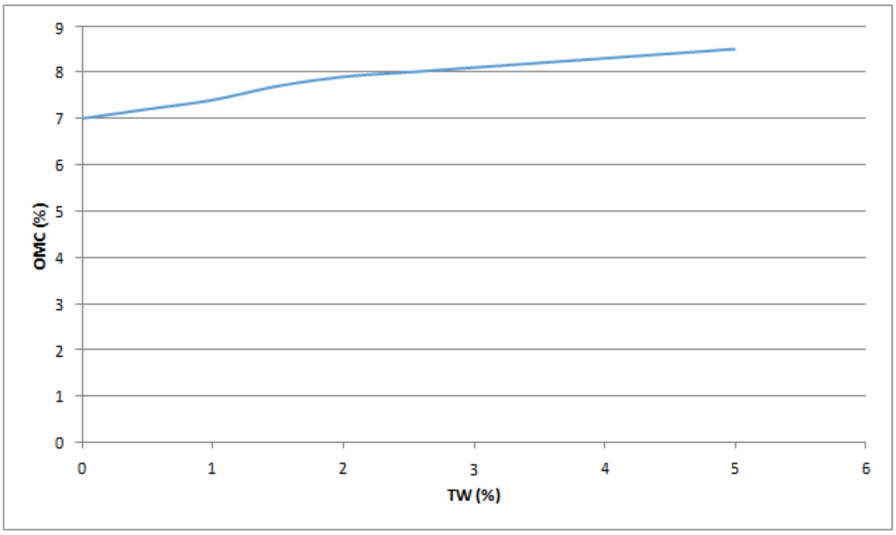
a. Compaction characteristics of Red soil (SP) with tyre waste (%):

To study the effect of tyre waste on red soil for compaction characteristics of dry weights and modified proctor test was performed as per IS 2720-part 8-1983 and the results are shown in below.

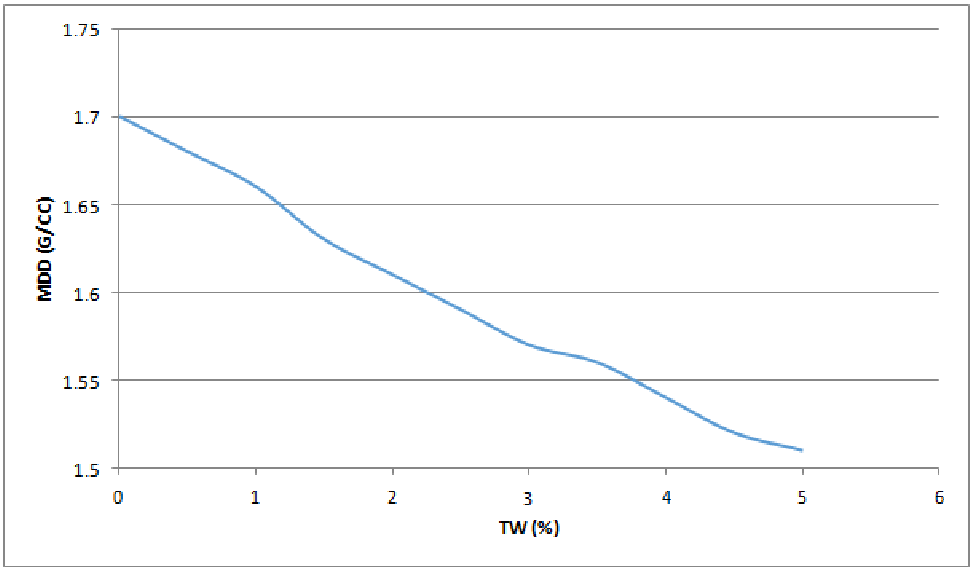
Table.8 : Compaction Characteristics of Red Soil (SP) with TW (%):

TW (%)	Compaction characteristics	
	OMC(%)	MDD (g/cc)

0	7.0	1.70
0.5	7.2	1.68
1.0	7.4	1.66
1.5	7.7	1.63
2.0	7.9	1.61
2.5	8.0	1.59
3.0	8.1	1.57
3.5	8.2	1.56
4.0	8.3	1.54
4.5	8.4	1.52
5.0	8.5	1.51



Graph.9: Variation of OMC with percentage of TW



Graph.10: Variation of MDD with percentage of TW

From the test results it is identified that increasing the percentage of TWincreases optimum moisture content values and decreases maximum dry density values Increase in OMC values are due to adherence of soil particles on to the tire surface and the matrix turn in to flocculated structures. Decrease in maximum dry density values are due to replacement of soil particular by tire waste particles are light weight material and the unit weight of tire waste particles is less than that of soil particles. Comparing with the results of Red soil with plasticity characteristics, the rate of decrease with respect to OMC&MDD values are less due to low specific surface of sand particles and non-availability of silt and clay particles.

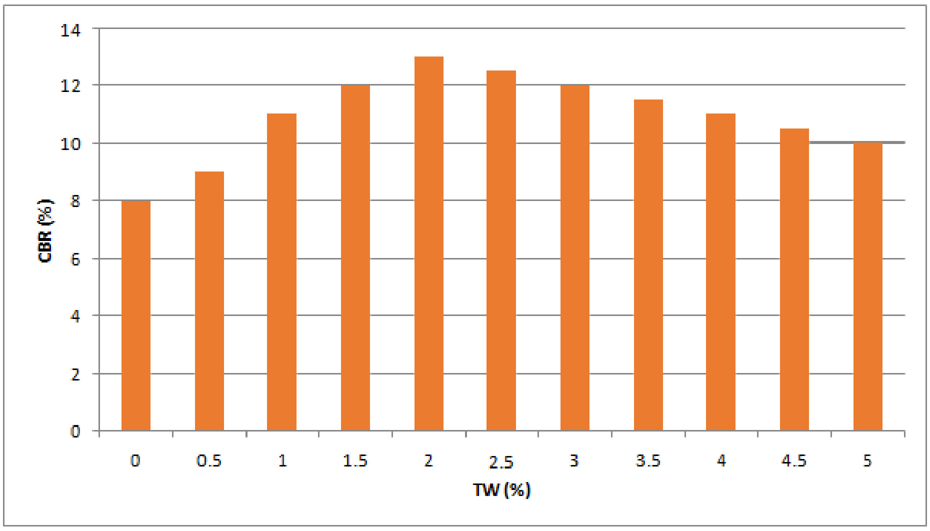
b. CBR characteristics of Red soil (SP) with Tyre waste (%):

To know the CBR characteristics of Red soil with TW (%), samples are prepared at their OMC & MDD values and soaked for 4 days and CBR test was conducted as per IS 2720 and the results are shown in below.

Table.9: Strength Characteristics of Red Soil (SP) with TW (%):

TW (%)	CBR (%)
0	8.0
0.5	9.0
1.0	11.0

1.5	12.0
2.0	13.0
2.5	12.5
3.0	12.0
3.5	11.5
4.0	11.0
4.5	10.5
5.0	10.0



Graph.11: Variation of CBR with percentage of TW

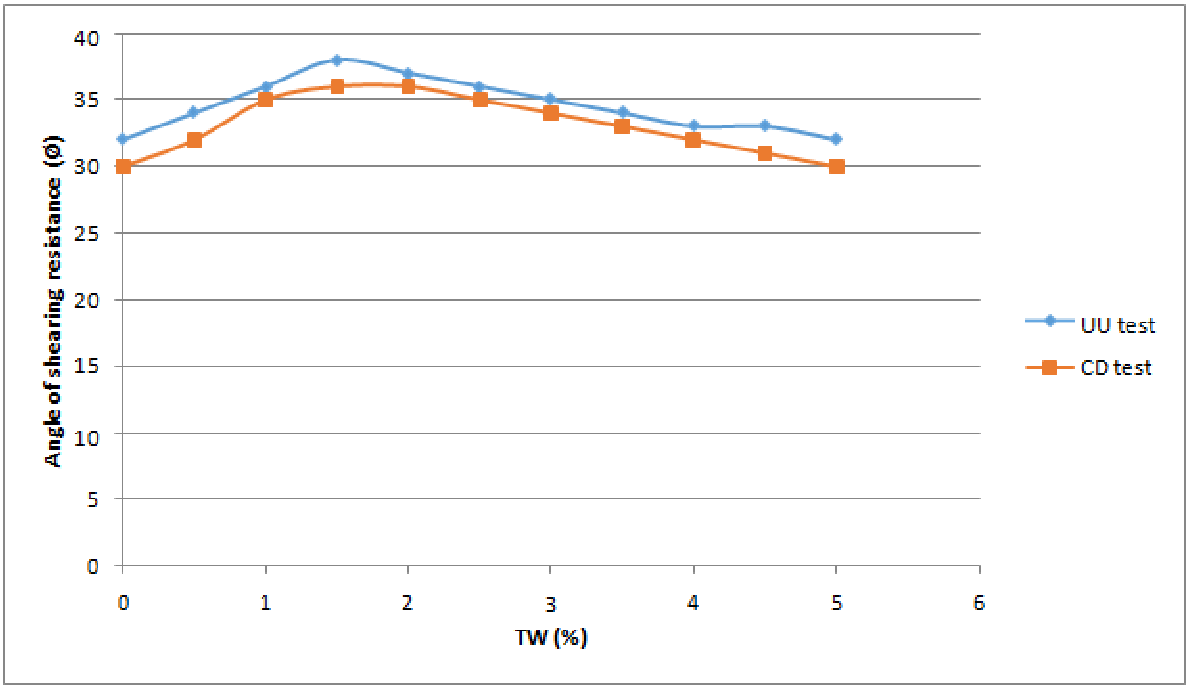
From the test results it is identified that increasing the percentage of TW increases CBR values up to 2.0% and then decreases. A combination of Red soil with TW helps to develop more shear resistance against penetration. This phenomenon is rapid up to 2.0% and then steadily decreasing due to segregation of particles. But at all percentages of TW, the combined soil-TW matrix attained high CBR values which are greater than the individual soil mass. Comparing with the CBR values of Red soils of plastic nature relatively Red sandy soils develop high CBR values due to porous nature and inherently frictional nature of sand particles helps to generate more shear resistance against penetration.

c. Shear strength characteristics of Red soil (SP) with TW (%):

To know the shear strength of Red soil (SC) with TW can be explained in terms of shear parameters(C & Ø) by performing tests at various drainage condition i.e., un-consolidated un-drained test (UU) and Consolidated drained test (CD) by direct shear apparatus. The tests were conducted as per IS 2720 part 13-1986 and the results are shown in below.

Table.10: Shear Parameters of Red Soil (SP) with TE (%)

TW (%)	Shear parameters	
	UU	CD
	Φ	Φ'
0	32	30
0.5	34	32
1.0	36	35
1.5	38	36
2.0	37	36
2.5	36	35
3.0	35	34
3.5	34	33
4.0	33	32
4.5	33	31
5.0	32	30



Graph.12: Variation of Angle of shearing resistance with percentage of TW

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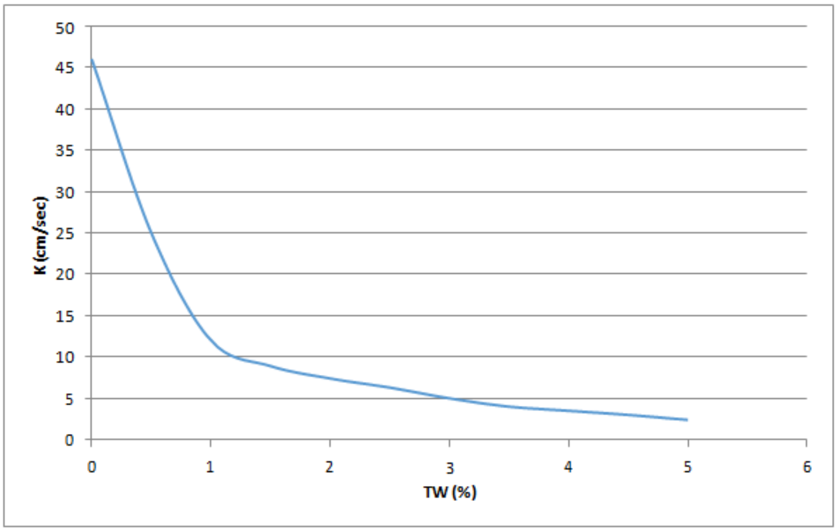
From the test results. It is identified that Angle of shearing resistance (Ø) values aresteadily increasing up to 1.5% and then decreasing. Angle of shearing resistance (Ø) values arehigher in case of UU test and the shear strength turn in to frictional component. In all the mixes Ø values in UU is more than in CD test. More interlocking is taking place due to inclusion of TW particles. Comparing with the shear strength results of Red soils of plastic nature Red soils of non-plastic nature achieved high frictional resistance in terms of high angle of shearing resistance in drained condition. Porous nature quick condition of pore water helped in achieving these values.

d. Seepage Characteristics of Red Soil (SP) with TW (%):

To know the seepage characteristics of Red soil (SC) with TW, sample are prepared at their OMC and MDD values and falling permeability test was performed on these soil samples and the results are shown in below.

Table.11: Seepage characteristics of Red Soil (SP) with TW (%):

TW (%)	Coefficient of permeabilityK (cm/sec)
0	$4.6x10^{-2}$
0.5	$2.5x10^{-2}$
1.0	$1.2x10^{-2}$
1.5	$8.9x10^{-3}$
2.0	$7.4x10^{-3}$
2.5	$6.3x10^{-3}$
3.0	$5.0x10^{-3}$
3.5	$4.0x10^{-3}$
4.0	$3.5x10^{-3}$
4.5	$3.0x10^{-3}$
5.0	$2.4x10^{-3}$



Graph.13: Variation of Coefficient of Permeability with percentage of TW

From the test results of Red soils of plastic nature it is identified that increasingthe percentage of TW decreases coefficient of permeability values. Flocculation of particles leads to agglomeration which increases the pore size, finally more seepage characteristics are identified. This behavior is rapid with respect to dosage of TW. In case of red soils of non-plastic nature (SP) it is identified that coefficient ofpermeability is decreasing with increase of TW helps in reducing the size of the pore by interlocking sand particles, through inclusion of TW in Red soils of non-plastic still in pervious conditions.

VI. CONCLUSIONS

By using this combination (Red Soil + Waste Tyre) we can reduce the natural Sub-Grade material, further optimum utilization of waste tyre residues will reduce the environment pollution. This kind of blending material, even embankment fill material also can be made as Sub-Grade material also saves time in Earth works. Taken two soil samples from two different locations, those are sample 1 from surampalem and sample 2 from G.Vemavaram.

Addition of TW to the red soil from 0.5% etc., After adding TW to notice the improve the soil properties. Inclusion of TW to the red soils the following conclusions are drawn.

- TW helps to reduce plasticity characteristics in SC soil at a dosage of 2.5%.
- TW improves seepage characteristics of SC soil from impervious to pervious.
- Red soil (SC) of plastic nature with TW achieved CBR values 12 at 2.5% of TW and Red soil (SP) of non-plastic nature achieved 13 at 1.5 % dosage. Non plastic soils

achieved high CBR values.

- Red soils of SC nature achieved "Ø" values 36^0 and whereas SP soil achieves 38^0 atthe dosage of 2.5% and 1.5% respectively.
- Natural Red soils SC & SP can be improved by adding TW can be used as fillmaterial and sub grade.

REFERENCES

1. H.K. Gupta, Mohit Choubey, "SOIL STABILIZATION USING WASTE SHREDDED RUBBER TYRE CHIPS WITH ADDITION OF CEMENT", 2021 IJCRT | Volume 9, Issue 9 September 2021 | ISSN: 2320-2882.
2. Sumanjali Parimi, Prof. P.V.V. Satyanarayana, "A STUDY ON SUITABILITY OF WASTE TYRE RUBBER STABILIZED RED SOIL AS SUBGRADE MATERIAL", International Journal of Emerging Trends in Engineering and Development Issue 8, Vol.6(Oct-Nov 2018).
3. Ahmed and Lovell (1993)-"Rubber soils as Light weight Geo materials", Transportation Research Record, 142 TRB, National research council, Washington DC, PP 61-70.
4. Ashkan GHolipoor Norozi, Siavash Kouravand, Mohammad Boveiri,(2015) ―A review of using the waste in soil stabilization‖ International Journal of Engineering Trends and Technology (IJETT) Vol. 21, No. 1, March 2015.
5. Ashok Raajiv.v.s, Augustine Maniraj Pandian (2015) "Experimental investigation on the effects of using soil as a replacement of sand in concrete"ICETSH-2015, page: 66-69.
6. Baleshwar sing and Valliapan Vinot (2011) " Influence of Waste tire chips on strength characteristics of soils" Journal of Civil Engineering and Architecture, USA, ISSN 1934-7359, Volume 5, N0.9
7. Bernal, A., Salgado, R. and Lovell, C.W., (1997), "Tire Shreds and Rubber-sand as Light weight Backfill Material", accepted for publication as a technical paper in the Journal of Geotechnical and Geo-environmental Engineering.
8. Prasad D.S.V and Prasada Raju G.V.R(2009) " Performance of Waste tyre Rubber on model flexible pavement" Vol. 4, No.6, ISSN 1819-6608 ARPN Journal of

Engineering and Applied Sciences.

9. Ravi kumar Sharma, Deen Bandhu, Rounak Maheswari and Sukhendra Kumar (2013) " Compaction and Subgrade characteristics of Clayey soil Blended with Beas sand and Waste Plastic strips " Indian Highways, Volume 41, Number 6, pp 43-49.
10. Ghatge Sandeep Hambirao, Dr.P.G. Rakaraddi (2014) "Soil stabilization using waste shredded rubber tyre chips" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, ISSN: 2320-334X, Volume 11, Issue 1 Ver. V, PP 20-27 www.iosrjournals.
11. IS 2720 : Part 13 : 1986 Methods of Test for Soils – Part 13 : Direct Shear test
12. IS 2720 : Part 16 : 1987 Methods of Test for Soil – Part 16 : Laboratory Determination of CBR
13. IS 2720 : Part 17 : 1986 Methods of Test for Soils – Part 17 : Laboratory Determination Permeability
14. IS 2720 : Part 4 :1985 Methods of Test for Soils – Part 4 : Grain size analysis
15. IS 2720 : Part 8 : 1983 Methods of Test for Soils – Part 8 : Determination of Water Content – Dry Density Relation Using Heavy Compaction
16. IS 2720:Part 3 : Sec 2: 1980 Test for Soils- Part III : Determination of Specific Gravity – Section 2 : Fine, Medium and Coarse Grained Soils.