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Strength characteristics of soil partially replaced with waste paper sludge ash and scrap tyre rubber

Engineering

KEYWORDS: WPSA, scrap tyre rubber, optimum moisture content, maximum dry density, unconfined compressive strength, cbr ratio

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ABSTRACT

This paper investigates strength characteristics of soil replaced partially with waste paper sludge ash (WPSA) and scrap tyre rubber. WPSA is a waste material obtained during combustion of paper sludge at the paper recycling industries and scrap tyre rubber have been used as a stabilizer for various civil engineering applications. In this present study the main objective is to know how much the combination of WPSA and scrap tyre rubber can be utilized for the improvement of strength properties of soil. The second objective is to find the variation of optimum moisture content and maximum dry density with increase in percentage replacement of WPSA and scrap tyre rubber. The third objective is to find the optimum concentration of WPSA and scrap tyre rubber based on the ucc test results and CBR ratio test. This study involves the determination of optimum concentration of WPSA and scrap tyre rubber by replacing the soil with different percentages and conducting the unconfined compression test and CBR Ratio test for each percentage. WPSA is used in 3, 6, 9 and 12% and scrap rubber in 4, 8, 12 and 16%. It is found that at 6% replacement of soil by WPSA the ucc value and cbr ratio got maximum result. Similarly at 8% of scrap tyre rubber these tests were shown maximum results and combination of WPSA and scrap tyre rubber have increased the unconfined compressive strength and CBR ratio than that of raw soil. This study shows WPSA and scrap tyre rubber can be used as stabilizers for improving the properties of soil.

I. INTRODUCTION

Soil stabilization can be used for the improvement of weak soil. The use of waste materials for soil stabilization has greater advantages since it reduce the disposal problems as well. Waste tyres are being generated and dumped causing an increasing threat to the environment. Rubber waste is chemically inert with all types of soils and are also a cheap alternative to expensive chemical stabilizers to manufacture and difficult for the application as stabilizer. By utilizing rubber wastes, the adverse impact on environment can also be reduced. These are abundantly available in nearby tyre repair workshops for free of cost. Like scrap tyre, waste paper sludge ash is also an industrial waste from paper recycling industries. Waste paper sludge ash (WPSA) is obtained from the combustion of wastepaper sludge in paper recycling factories. It is produced in large quantities and develops a major economic problem and creates environmental pollution.

In the present investigation attempt is made to analyze strength behavior of soil on replacement of scrap rubber tyre and waste paper sludge ash. By utilizing these waste materials adverse effects on the environment can also be reduced. The re-use of waste materials is a primitive step in creating a sustainable future, and due to increasing waste disposal cost, the re-use of waste and recycled materials is increasing worldwide and becoming more popular in civil engineering.

II. OBJECTIVES OF THE STUDY

The main objectives of the study include the following:

1. To find the performance of waste paper sludge ash as stabilizing agent and to find the effect of addition of scrap tyre on the behavior of soil.

2. To analyse plasticity characteristics, compaction characteristics and strength properties of soil based on the results obtained.

3. Analysis and interpretation of results.

III. SCOPE OF THE WORK

The scope of the work done is as follows

- To stabilize the soil with waste material
- To make the work less expensive
- To reduce accumulation of waste

IV.LITERATURE REVIEW

- **P. M. S. Bujulu, a. R. Sorta, g. Priol & a. J. Emdal (2010)- Potential of wastepaper sludge ash to replace cement in deep stabilization of quick clay-Sciencedirect**

Stabilization of quick clay using diffrent proportion of lime and paper sludge was conducted in this paper. Four mix types of different proportions were tested. The study has highlighted the possibility of re-using wastepaper sludge ash as a binder in stabilization of soft and problematic soils, thus saving on the cost of cement, disposal expenses, sparing land for other beneficial uses and reducing environmental pollution.

The tests have also shown that increasing the dose rate in lime-WSA mixtures from 100kg/m^3 to 150 kg/m^3 has negative effects to the mechanical properties of the mixtures.

- **Chee-ming chan (2011)- Strength and stiffness of a cement-stabilised lateritic soil with granulated rubber addition-ICE proceedings**

The test was conducted on lateritic soil. Ordinary Portland cement was used as the binder, with rubber chips or rubber shreds added as filler materials. The reduced density of the stabilised material is due to the much lower unit weight of the rubber components. Small dosages of cement allow a shorter curing period to attain the desired strengths, and should be taken into account for economical as well as sustainability considerations. Excessive rubber dosage should be avoided to prevent the development of weak planes along large agglomerates of soil–cement–rubber within the stabilised material. This is evidenced by the markedly reduced strength and and stiffness moduli with high rubber content, where the increased ductility appeared to overshadow the cementation effect.

- **R. Ayothiraman, Ablish kumar meena (2011)- Improvement of subgrade soil with shredded waste tyre chips-proceedings of Indian geotechnical conference**

This paper aims at studying the suitability of shredded tyres for its use in pavement engineering, i.e. to stabilize the subgrade of the pavements. It discusses about CBR value of soil-tyre mixture and the results are presented. The shredded tyre material used is of size 10 x 20 mm. The shreds had a thickness ranging from 2 to 3 mm and don't contain any steel wire or nylon fibres. From the experiment they found

that dry density reduces with increase of % tyre waste, however, there is no significant change in OMC. Tyre waste material mixed with soil showed improvement in CBR value with its addition up to 2% and there onwards decreased with further increase in tyre content in unsoaked/soaked condition. Hence the optimum value of waste tyre content is 2% in unsoaked and soaked conditions.

- **Binod tiwari1, Beena ajmera, Suzanne moubayed, Alexander lemmon, and Kelby styler (2012)- Soil modification with shredded rubber tires-ASCE, Geo congress.**

In order to evaluate the effect on the compaction characteristics of the soil to be modified with shredded rubber tires, several different types of soils were prepared in the laboratory. The types of soils tested include (a) a poorly graded sand prepared from Ottawa sand, (b) a well graded sand prepared from concrete aggregate, (c) a silty sand (d) a poorly graded sand with silt both prepared by mixing silt in construction sand, and (e) a fat clay.

Optimum moisture contents and maximum dry unit weights were obtained for different amounts of shredded rubber tires, in particular, 10%, 20% and 30%, in different types of soil. The shredded rubber tires used in this study were obtained from Home Depot and were coarser than 2.75 mm. The test results showed that 10% mixture of tire aggregate with soil showed a consistent increase in dry unit weight compared to the soil without any tire aggregates, irrespective of the type of soils used. On the other hand, 20% mixture yielded lowest amount of optimum moisture content

- **Norazlan khalid, Mazidah mukri, Faizah kamarudin (2012)- Clay soil stabilized using waste paper sludge ash (wpsa) mixtures**

This paper present the results of an experimental study on the clay soil stabilized using Waste Paper Sludge Ash (WPSA). The aim of this study is to investigate and to

show the potential use of waste paper sludge ash.(WPSA) as an additive to stabilize a clay soil. This an experimental studies to determine the concentration of WPSA as an additive, the development of compressive strength and the CBR value. A laboratory was conducted on soil sample of slightly sandy CLAY of high plasticity soil stabilized using WPSA. This paper focuses on the development of compressive strength (qu) of clay stabilized with WPSA at 0, 14 and 28 days of curing periods and the CBR value for soaked and unsoaked condition. Based on the experimental results on this study, they concluded that The suitable optimum percentage of WPSA was determined about 10% to stabilize the sandy CLAY of high plasticity soils at the compressive strength about 737kPa. The addition of 10% WPSA were increased the unconfined compressive strength of the clay soil until 28 days and this strength will get higher might be beyond to 28 days. The addition of 10% WPSA were increased the CBR value about 1.5 times compared to control sample for unsoaked condition and 3.6 times compared to control sample for soaked condition

- **Amit srivastava, Shikha pandey & Jeeshant rana (2014) - Use of shredded tyre waste in improving the geotechnical properties of expansive black cotton soil, Taylor and francis ISSN: 1748-6025- 1748-6033**

In this paper geotechnical properties of black cotton soil on addition of shredded tyre were analysed. Shredded tyre waste of two different categories, such as, (i) passing 2.0–0.075 mm retained (fine), and, (ii) passing 4.75–2.0 mm retained (coarse) were used. Different tests, such as, Atterber's limit, Proctor test, unconfined compressive strength (UCS) tests, swelling pressure and consolidation tests were performed to characterise the black cotton soil–shredded tyre mix. From the It is observed that 30–50%addition of shredded tyre waste in expansive black cotton soil considerably reduces the volume change potential of the black cotton soil. It is noted that addition of 30–50% shredded tyre waste reduces the shear strength of the soil as observed from the UCS tests. Addition of shredded tyre waste in black cotton soil reduced the swelling and shrinkage characteristics. From the combined observation of compaction tests and UCS test results, they observed that addition of 5% shredded tyre waste in black cotton soil will provide a mix having a lighter weight and marginally improved shear strength.

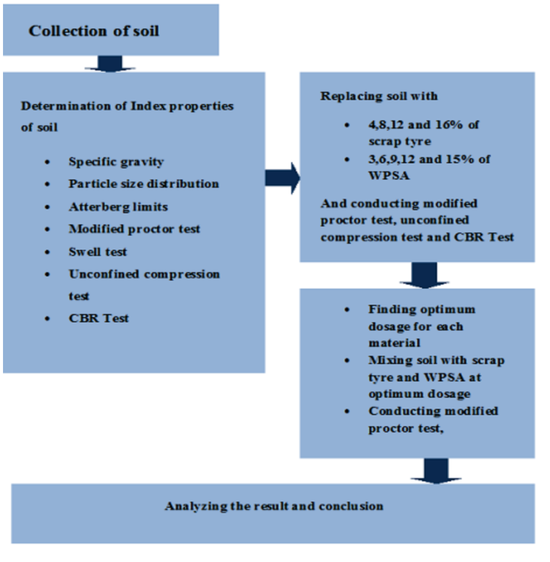
- **Ghatge sandeep hambirao,Dr.P.G.Rakaraddi (2014) - Soil stabilization using waste shredded rubber tyre chips- - IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)**

The tests were conducted on black cotton soil and sheddi soil. Ordinary Portland cement is used as the binding agent. The shredded tyre material used is of size 10mm to 25 mm in length. The shreds have a thickness ranging from 2 to 3 mm and they don't contain any steel wire or nylon fibres.

Unconfined Compressive Strength Tests and California bearing ratio tests are conducted for black cotton soil and shedi soil with 2% and 4% cement with the varying rubber percentage i.e 0%,5%,10% and 15%.for 2%cement, maximum unconfined compressive strength at the rubber content of 5% and curing period of 14 days for black cotton soil is 74 kPa where as for shedi soil it is 201kPa. This indicates that the increase in the curing period leads to an increase the unconfined compressive strength at an optimum mix of 5% shredded rubber. This indicates that there is an increase in the stiffness of the stabilized soil is not only due to the hydration of cement with time but optimum rubber content. that there is an increase in the bearing capacity of the stabilized soil due to the hydration of cement with time and optimum rubber content

V. METHODOLOGY

Methodology of the present study is shown below



II. MATERIAL USED FOR EXPERIMENT

The various materials used are scrap rubber tyre and waste paper sludge ash.

6.1 Scrap tyre rubber

Scrap tyre rubber is a waste material available from tyre retreading industries. These are chemically inert with all type of soils and are also a cheap alternative to expensive chemical stabilizers. The scrap

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tyre was collected from tyre retreading shops at kannur.

Fig.1: Scrap rubber tyre

6.2 Waste paper sludge ash

It is a waste product from the combustion of waste paper sludge in paper recycling factories. It is produced in large quantities in paper recycling industries during deinking process. The WPSA used were collected from Hindustan Newsprint limited, Kottayam.

6.3 Soil

The soil used for present study was collected from Madambam, kannur at a depth of about 50cm. The soil was oven dried for 24 hours at a temperature of about 105-110^{0}c and stored in air tight bags.

The index properties of the soil were determined and test results were obtained as follows.

Table 1: index properties of soil

NAME OF TEST	TEST RESULT
Specific gravity	2.54
Particle size distribution	D10 = 0.15mm D30 = 0.63mm D60 = 1.7mm Cu = 11.33%
Atterberg limits Plastic limit Liquid limit Shrinkage limit	32% 58% 24%
Free swell	12.5%
Modified proctor test OMC Dry density	21% 1.585g/cc

II. EXPERIMENTAL METHODS TO FIND OPTIMUM DOSAGE FOR EACH MATERIAL

7.1 Testing of soil for modified proctor test

Modified proctor test is called heavy compaction test. For doing the test about 3000g of ovendried soil passing 20mm IS sieve is taken. This soil is replaced with 4,8,12 and 16%of tyre and 3, 6, 9, 12 and 15% of WPSA.. For each percentage compaction test is performed by varying the water content. The weight of hammer is 4.9kg and the drop 450mm.The soil mass is compacted in 5 layers each layer tamped 25 times

Table2: Variation of optimum moisture content and max.dry density with % increase in WPSA

% of WPSA	Max. dry density (g/cc)	Optimum moisture content (%)
0	1.585	21
3	1.536	22.5
6	1.497	23.55
9	1.435	24.1
12	1.385	27.1

The table shows variation of optimum moisture co ntent and maximum dry density with percentage replacement of WPSA. The OMC increases with increase in percentage of WPSA and the max.d ry density gradually decreases.

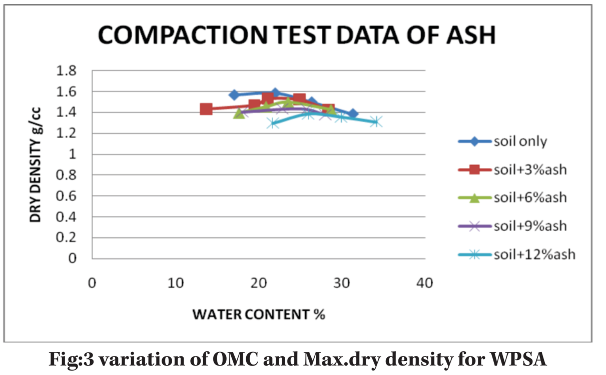

Fig:3 variation of OMC and Max.dry density for WPSA

The table given below shows variation of optimum moisture content and maximum dry density for various percentage of scrap tyre.

Table 4: Variation of optimum moisture content and max.dry density with % increase in scrap tyre

% of Scrap tyre	Max. dry density (g/cc)	Optimum moisture content (%)
0	1.585	21
4	1.502	21.84
8	1.453	22.1
12	1.41	22.95
16	1.295	25.1

The OMC increases with increase in percentage of scrap tyre and there is a corresponding decrease in maximum dry density.

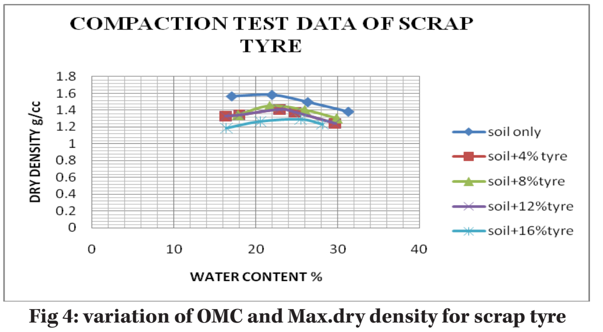

Fig 4: variation of OMC and Max.dry density for scrap tyre

7.2 Preparation of specimens for unconfined compression test
About 150g of oven dried soil passing through 425μ sieve is replaced with 4, 8, 12 and 16% of scrap tyre and 3, 6, 9 and 12% of WPSA. The optimum moisture content and maximum dry density for each mix is determined using modified proctor test. The mixture is thoroughly mixed with optimum amount of water and filled in the mould. For each mix 4 specimens were prepared. Specimen of diameter 35mm and height 70mm is made. The specimen is cured for 0 and 7 days using wet gunny bags.

7.3 Testing of specimen for unconfined compression test
The unconfined compression test is conducted as per IS 2720 part X, 1991. The specimen is placed in the loading platform. Bottom plate of loading device is adjusted so as to make contact with the specimen. Loading is done at a rate such that axial strain is 0.5 to 2 percent/min. The specimen is loaded until shear failure. Finally unconfined compressive strength is determined based on failure load and corrected area.

7.4 Results of unconfined compression test
Unconfined compression test was conducted on soil replaced with 4, 8, 12and 16% of scrap tyre and 3, 6, 9, 12 and 15% of WPSA. The results were noted and compared.

The graphs given below show the variation of unconfined compressive strength for various percentages of WPSA.

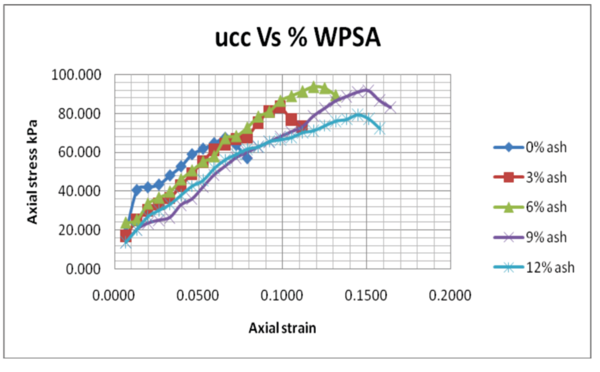

Fig 5: variation of unconfined compressive strength with WPSA

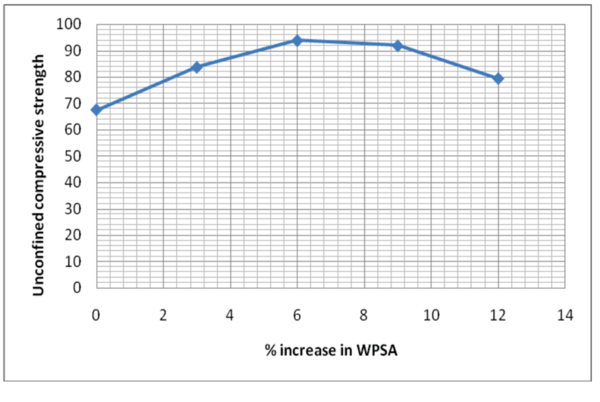

Fig 6: variation of un confined compressive strength with WPSA

From the graphs it is clear that unconfined compressive strength increase with increase in percentage up to 6% replacement of WPSA after that the value gradually decreases. The maximum value is obtained as 93.91kPa for 6% WPSA.

The graphs plotted below shows variation of unconfined compressive strength of specimen after 7 days curing.

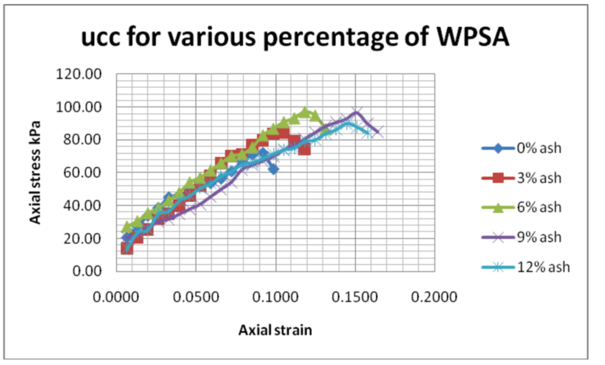

Fig 7: variation of unconfined compressive strength with WPSA

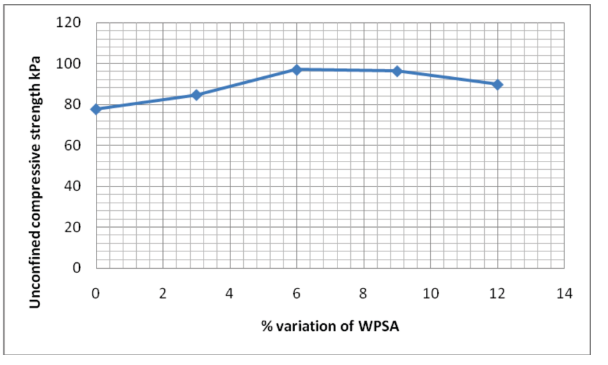

Fig 8: variation of un confined compressive strength with WPSA

Curing of specimen is done with wet gunny bags and it shows increase in unconfined compressive strength than 0 days curing and maximum value obtained as 97.007kPa for 6% replacement of WPSA. The table given below shows comparison of ucc value obtained for 0 and 7 days curing.

Table 5: ucc value for 0 and 7 days curing of WPSA

% of WPSA replaced	Ucc value for 0 days curing	Ucc value for 7 days curing
0	67.457	77.59
3	83.68	84.608
6	93.91	97.007
9	91.93	96.31
12	79.409	89.703

Scrap tyre rubber is also used to replace the soil by 4, 8, 12 and 16%. The specimens were tested after 0 and 7 days curing. The graphs plotted below shows the value of ucc cured for 0 days

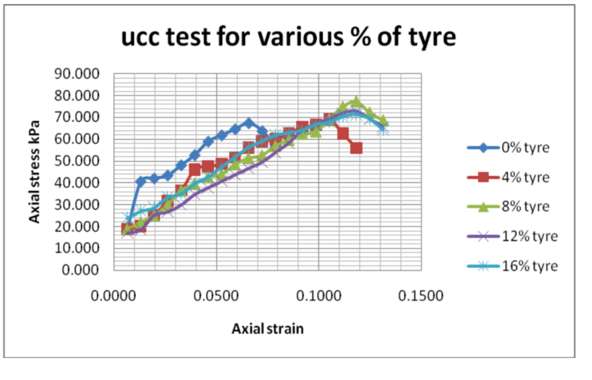

Fig 8: variation of unconfined compressive strength with scrap rubber tyre

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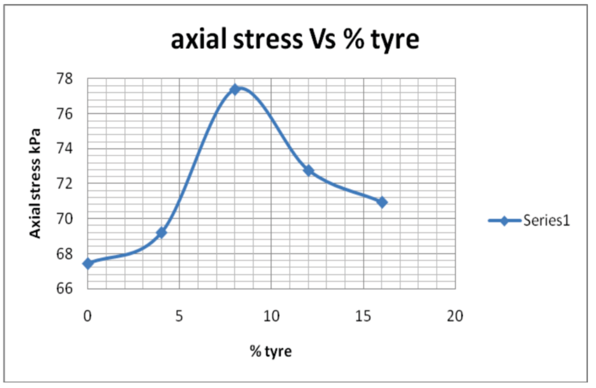

Fig 9: variation of un confined compressive strength with scrap rubber tyre

At 8% replacement of scrap tyre a maximum value of 77.37kPa was obtained. The following graphs shows ucc value for 7 days curing.

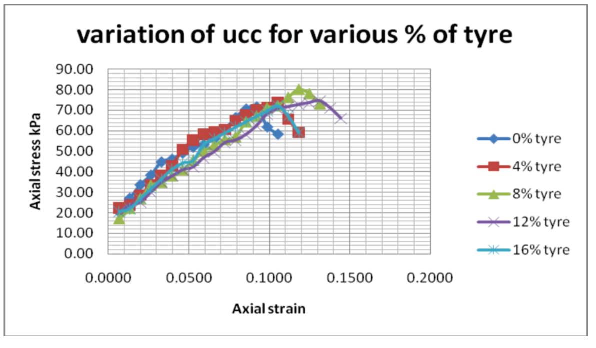

Fig 10: variation of unconfined compressive strength with scrap rubber tyre

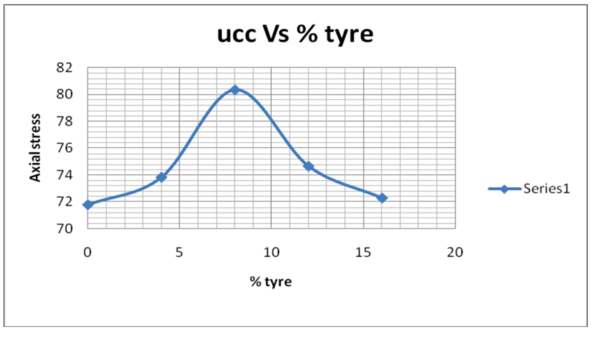

Fig 11: variation of un confined compressive strength with scrap rubber tyre

After 7 days curing maximum ucc value is obtained for 8% replacement of scrap tyre as 80.33kPa. Th table given below shows comparison of ucc value obtained for 0 and 7 days curing.

Table 6: ucc value for 0 and 7 days curing of scrap tyre

tyre %	Ucc value for 0 days curing	Ucc value for 7 days curing
0	67.457	71.8
4	69.22	73.84
8	77.37	80.33
12	72.76	74.66
16	70.95	72.3

7.4 Preparation of specimen for California bearing ratio test

In CBR test mould of internal diameter and height 175cm and collar of 50cm is used. From the maximum dry density obtained from modified proctor test, the mass of soil occupied in the mould is determined by multiplying the maximum dry density by volume of CBR mould. The portion of obtained mass of soil is replaced with different percentage of shredded tyre such as 4,8, 12 and 16% and with 3,6,9 and 12% of WPSA. This soil – stabilizer mix is mixed with optimum amount of water and filled in the mould completely in 5 layers. Unsoaked samples were made for the determination of cbr ratio.

7.5 Testing of specimen for California bearing ratio test

The California bearing ratio test conducted is in accordance with IS 2720 part XVI, 1987. The loading frame is with loading capacity of five tones provided with proving ring and a dial gauge reading to 0.01mm. Soil samples are placed on bottom plate of loading device the base plate. Annular surcharge weight equal intensity of base material and the pavement is placed. Load is applied at a strain rate of 1.25 mm/min.Penetration is measured by strain gauge. Load is recorded at the penetration of 0.0, 0.5, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10.0 and 12.5 mm. *CBR* value is expressed as a percentage of the actual load causing the penetrations of 2.5 mm or 5.0 mm to the standard loads.

The graph given below shows variation of cbr ratio for different percentage of WPSA

Fig 12: variation of cbr ratio with different percentage of WPSA

Cbr ratio of soil sample was obtained as 7.27%.At 6% of WPSA the cbr value obtained was 33.81%

The graph given below shows variation of cbr ratio for different percentage of scrap rubber tyre.

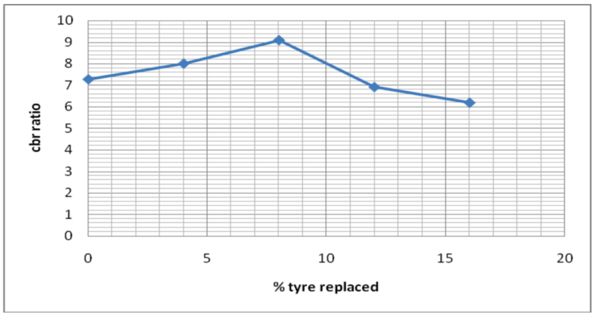

Fig 13: variation of cbr ratio with different percentage of scrap rubber tyre

A maximum value of 9.09% is obtained as cbr ratio at 8% scrap tyre replacement.

At 6% replacement of WPSA, the ucc value and cbr ratio obtained was maximum. Ucc value of 93.91kPa was obtained for 0 days curing and 97.007kPa was obtained for 7 days curing. Also cbr ratio was obtained as 33.81% for 6% WPSA replacement. So 6% of WPSA was taken as the optimum dosage.

Maximum value of ucc and cbr was obtained for 8% replacement of scrap tyre. 77.37kPa was obtained for 0 days curing of specimen and 80.33kPa for 7 days curing. The cbr ratio obtained was 9.09%. So 8% of scrap tyre was taken as the optimum dosage.

II.DETERMINATION OF STRENGTH CHARACTERISTICS OF SOIL AT OPTIMUM DOSAGE OF SCRAP TYRE AND WPSA

8.1 Testing of specimen for optimum moisture content and max.dry density

About 3kg of soil passing through 20mm IS sieve was taken and it is replaced with 6%by weight of soil by WPSA and 8% by weight of soil by scrap rubber tyre. This mixture is thoroughly mixed with different percentages of water and the OMC and max.dry density were determined. The graph plotted below shows OMC and max.dry density obtained during the test.

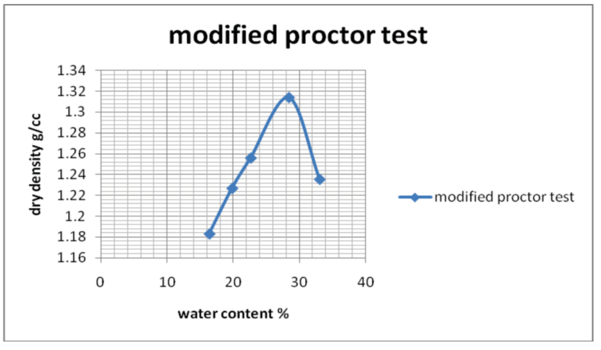

Fig 14: modified proctor test data at optimum dosage of scrap tyre and wpsa

The optimum moisture content was obtained as 28.41% and max.dry density as 1.31g/cc.

These values were taken for determining the unconfined compressive strength and cbr ratio.

8.2 Testing of specimen for unconfined compressive strength

About 150gm of oven dried soil passing 425μ sieve is replaced with 6% of WPSA by weight and 8% scrap tyre by weight. This dry mix is then mixed with optimum quantity of water and filled in the mould to make the specimen. These samples were cured for 0 and 7 days and tested in the apparatus.

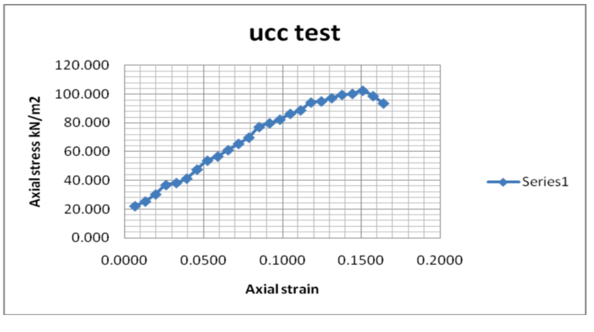

Fig 15: ucc test result for 0 days curing

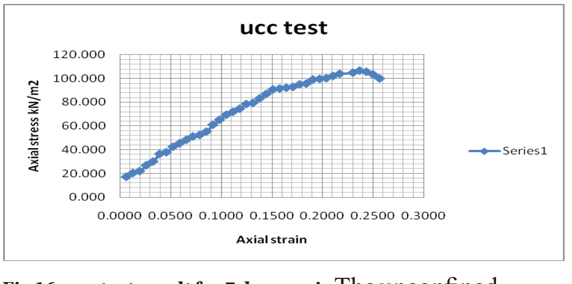

Fig 16: ucc test result for 7 days curin The unconfined compressive strength for 0 days curing was obtained as 102.47kPa and for 7 days curing was obtained as 106.302kPa which means curing time increases the strength of specimen.

8.3 Testing of specimen for CBR ratio test

From the max.dry density obtained from modified proctor test, the weight of soil required to occupy the cbr mould was determined. This amount of soil is replaced with 6% of WPSA and 8% of scrap tyre and mixed with optimum quantity of water and filled in the mould in 5 layers completely by applying 55 tamping for each layer. The graph given below shows the result of cbr ratio test.**g**

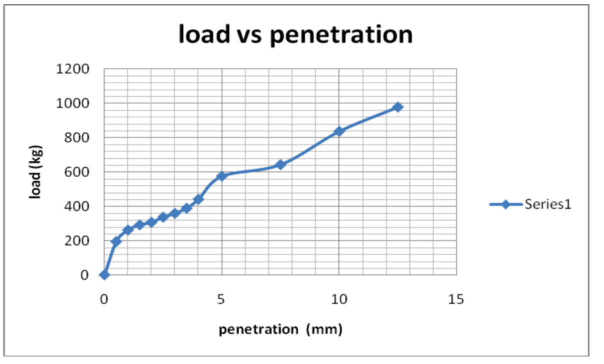

Fig 17: cbr ratio test result

The cbr ratio obtained for optimum dosage of WPSA and scrap rubber tyre is 27.99% for unsoaked sample.

IX. CONCLUSION

- The optimum moisture content increases with increase in percentage replacement of WPSA and scrap rubber tyre.
- The maximum dry density decreases with increase in percentage replacement of WPSA and scrap rubber tyre
- The optimum dosage of WPSA and scrap rubber tyre is 6% and 8% respectively.
- At 6% replacement of WPSA, the ucc value increase from 67.457kPa to 93.91kPa for 0 days curing and to 97.007kPa for 7 days curing which indicate that ucc value increases with increase in curing time.
- At 8% replacement of scrap tyre, the ucc value increase from 67.457kPa to 77.37kPa for 0 days curing and to 80.33kPa for 7 days curing which indicate that ucc value increases with increase in curing time.
- The ucc value at optimum dosage of 6% WPSA and 8% scrap tyre rubber is 102.147kPa for 0 days curing and 106.302kPa for 7 days curing which means the ucc value increases with increase in curing time.
- The CBR ratio at 6% WPSA was found to be 26.9% and at 8% scrap tyre was 9.09kPa whereas the CBR ratio for the raw soil was 7.27kPa.
- At the combination of 6% WPSA and 8% scrap tyre rubber the CBR ratio obtained as 27.99%
- The use of WPSA and scrap rubber tyre has increased the unconfined compressive strength and cbr ratio of the soil. There was increase in unconfined compressive strength of about 27%nand 74.03% in CBR ratio so that we can conclude that WPSA and scrap tyre rubber can be used as the stabilizers for the improvement of strength properties of the soil.

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