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Change in Subgrade Soil Strength on Introduction of Waste Rubber

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ABSTRACT
Tyre recycling, or rubber recycling, is the process of recycling waste tyres that are no longer suitable for use on vehicles due to wear or irreparable damage. These tyres are a problematic source of waste, due to the large volume produced, the durability of the tyres, and the components in the tyre that are ecologically problematic. Because they are highly durable and non-biodegradable, they can consume valued space in landfills the objective of present work is to review the engineering properties of soil. The study pertains to find out the optimum moisture content and maximum dry density with different proportion of cut rubber tyre. The study included, to determine the California Bearing Ratio (CBR) value with different percentage of cut rubber tyre. Rubber Tyres was cut into 10mm to 20mm (Width) and 25mm to 45mm (Length). Added amount of rubber tyre had been varied in proportions of 5%, 7 %, 9% and 11 % so that the current study will help out in ascertaining the proper improvement of soil using rubber tyre.

KEYWORD: *rubber, pavement, subgrade,proctor test, CBR*

INTRODUCTION
1.1 GENRAL
Civil Engineering has been very kind to mankind since times immemorial and it is one of the ancient sciences. What not has Civil Engineering bestowed us with, from underground metros to sky high edifices, from clear and pristine water to drink to non reluctant and welcoming ambience, from airways to highways. The list of deeds never shortens, it goes on. As of well versed fact that an earthling is not a good Civil Engineer until and unless he or she is not a good environmentalist. And keeping and preserving this environmental aspect of Civil Engineering we had made an attempt to make our environment less hostile and non obnoxious. What drives Civil Engineering and makes it conforming? It is this rule and legacy of Civil Engineering to crave and hunt for better than better without making the resources less or more obsolete in future. We the group of Civil Engineers focused on the same idea and stuck to the legacy and essence of Civil Engineering. In this paper we have provided a series of engineering results regarding the improvement of sub grade soil by means of waste rubber tyres, which we are very sure, will provide the edge to the scholars in future.\

Followed by US, India is having the world's second largest road network. The larger the road network, the larger will be the automobile density of India. As Civil Engineers, our aim is to fulfil and to improve the components of roads not only from engineering point of view but from the view point of road user. The use of automobiles is increasing day by day due to the advancement of technology and sophisticated life style of the masses. As the number of vehicles is increasing so are the heaps of discarded rubber tyres or the waste of tyres increases. Today most tyres, especially those fitted to motor vehicles, are manufactured from synthetic rubber. In India, the waste tyres are classified as solid waste. Due to manufacturing of tyres with synthetic rubber, proper disposal of these waste tyres has become difficult. It is approximately estimated as 60% to 70% of waste tyres are disposed in improper way in various areas. As a result of this, there is a great damage to ecosystem like air pollution and aesthetic pollution. As discussed earlier environment is our responsibility and to avoid this damage by the improper disposal of worn out tyres, we can utilize these tyre wastes with technical development in different fields like using tyre wastes in construction of flexible pavements.

It is not only to decrease the pollution but also it is an effort to decrease the quantity of materials required in flexible pavements. In this investigation, we had put our efforts to make an effective use of waste tyres to stabilize the sub grade of highway pavement. Scrap tyre generations is always on the increasing trend everywhere in the world. Majority of them end up in the already congested landfill or becoming mosquito breeding places. Worst when they are burned. Our aim is to study the appropriateness of shredded rubber tyres for its use in pavement engineering. As stated earlier one of the main issues associated with the management of scrap tyres has been their proper disposal. So in this project work, an effort has been made to make use of these waste tyres in sub grade of the flexible pavement. In civil engineering applications, usually tyres are used in a shred form referred to as “tyre chips” or “tyre threads” These chips are between 12 and 50 mm in size or threads passing through 4.75 mm IS Sieve and with steel belting removed in processing. Approximately 12 million scrap tyres in 1995 and 15 million in 1996 have been used for civil engineering applications including leach ate collection systems, landfill cover, artificial reefs, and clean fill for road embankment, road bed support and similar projects (Liu et al., 2000). Using tyre shreds for civil engineering application has several advantages due to their unique characteristics. One of most important properties is that tyre shreds are a lightweight material. It is relatively inexpensive compared to other light fill materials. Tyre shreds induce low horizontal stresses since they are lightweight and have relatively high shear strength. However tyre shreds have not been tried extensively for using it in sub grade and sub base layers of the pavement. In this project an attempt has been made to discover its possible use in these layers. Now, talking about Srinagar-Banihal highway which is the only connecting link to the subcontinent and is still under construction for almost 20 years now. There are many low lying areas like Awantipora stretch or Panthachowk- Nowgam area where the construction of highway is still going on. Also worthy to mention there is no such area for deposition of solid wastes like tyre waste. What we do there is simply dispose the wastes on the banks of Jhelum which not only pollutes the water body but affects the surrounding environment drastically. The tyre waste can be utilized in the construction of road there as the use had shows positive results. Also by using that waste aesthetic dimensions of vicinity can be saved not only this many quantity of soil can be effectively saved. The soil here is often weak and has no enough stability in heavy loading. The purpose of our project was to use the waste rubber tyre and its effect on subgrade strength. The objective was achieved in due time of two months. And now we had generalized the facts about the strength and other parameters of the particular soil (which we was used in our study) on introduction of tyre waste.

LITERATURE REVIEW

Tatlisoz, Benson and **Edil (1997)** decrypted soil-tyre chip mixtures are unique fill materials with high compressibility and ductility. Soil-tyre chip mixtures also have unique mechanical properties that are primarily governed by the tyre chip content, not by soil type. **Zornberg, Costa** and **Vollenweider (2000)** conducted a field investigation to assess the mechanical behavior of an experimental embankment fill built with tyre shred sand cohesive soil. Immediately after construction, the embankment was submitted to heavy truck traffic and settlements were monitored for over two years. The results indicate that the embankment sections built with tyre shreds and cohesive soil showed satisfactory long term performances during traffic exposure. **Tatlisoz, Edil** and **Benson (2001)** assessed the shear strength and geosynthetic interaction of tyre chip and soil-tyre chip backfills that may be used for geosynthetic reinforced walls and embankments and concluded that soil-tyre chip mixtures have significantly higher shear strength than the soil used in the mixture. **Hassona, Hassan, Marei**and**Hashem, (2005)** based on their tests involving triaxialtest and CBR test on shred tyre reinforced soil, concluded that the presence of shredded waste tyres in sand improves the stress-strain properties for all different sizes and contents of shreds waste tyre over that pure sand. The maximum deviator stress of randomly reinforced sand occurs at a higher axial strain compared to sand alone. CBR values increases with the increase of shreds tyre content up to 3 percent content. After this content the increasing of CBR value decreases with the increase of shreds tyre content in both soaked and un soaked specimens.

So we see various studies had been carried out to know about the effect of rubber waste in different materials. Now taking the study of it to further advancement **we** studied and investigated about the changing parameters of the subgrade taken from area by introduction of rubber waste. Also, Geotechnical properties of soils such as consistency limits, compaction parameters, strength, permeability, swelling potential, swelling pressure, consolidation characteristics, etc are affected by the incorporation of waste rubber tires. The values of liquid limit and plastic limit of clayey soil have been observed to decrease with increase in shredded tyre waste. The reduction in Atterberg's limits is attributable to decrease in clay content. However, Srivastava and Shetal reported increase in shrinkage limit and decrease in shrinkage ratio with an increase in the percentage of tyre waste incorporated with clayey soil. Sarvade and Shetal also observed a decrease in the liquid limit, plastic limit and an increase in shrinkage limit with the addition of crumb rubber in the problematic clayey soil.

The compaction parameters of the rubberized clayey soil are affected by the content and type of the waste tire. The maximum dry density (MDD) of clayey soil has been observed to decrease with increase in waste rubber tire content. Al-Tabbaa and Aravinthan and Singh and Vinot reported that the optimum moisture content (OMC) of the clayey soil roughly remains the same with the inclusion of waste shredded tires and tire chips. Contrary to this, a decrease in OMC with an increase in waste rubber content in clayey soil was reported in other studies Lekan and Ojo reported that MDD of soil stabilized with tyre ash systematically decrease whereas the OMC increases with an increase in tyre ash content. The decrease in the MDD was attributed to the low specific gravity of tyre ash and porosity of tyre ash was ascribed the reason behind the increase in the OMC. Cabalar reported that a reduction in the maximum dry unit weight of lime stabilized clay on inclusion of tyre buffing whereas increase in the lime content higher the OMC of the mixtures citing two possible reasons (i) high water absorption capacity of lime particles and (ii) water used for hydration process. Srivastava reported a lower MDD of the black cotton soil incorporated with coarser size (4.75 mm- 2.00 mm) shredded tyre waste as compared to MDD of black cotton soil incorporated with finer size (2.00 mm- 0.075 mm) shredded tyre waste.

It has been shown that the voids of the mixture were filled by silica fume, which resulted in the decrease in MDD and the change of the gradation resulted in the increase in OMC. The inclusion of waste rubber tire affects the California Bearing Ratio (CBR) value of the clayey soil. Hambirao and Rakaraddi and Otoko and Pedro reported more than 5% additions of shredded rubber tyre chips and fibers in clayey soil reduce the CBR value. CBR values of rubberized cemented clayey soil having the optimum dose of 5% were found more than the non-rubberized cemented clayey soil. Cabalar et al. carried out an experimental investigation on the CBR value of clay stabilized with tyre buffing and lime. The addition of tyre buffing markedly reduces the CBR value of clay and lime stabilized clay. Subramanian and Jeyapriya [20] observed 6% improvement in the CBR value of clay by the addition of 7.5% waste tyre pieces (ranged between 20-25mm).

Very few studies have been reported in the literature on the swelling potential and swelling pressure of clay- tire mixtures. Cokca and Yilmaz observed decrease in the swelling pressure of fly ash-bentonite-rubber mixture with an increase in the rubber content and decrease in bentonite content. Kalkan had made the similar observation for clayey soil modified with rubber fibers and silica fume. The creation of drainage path for the dissipation of pore pressure and restraining of swelling pressure generated during the application of load on the sample by the rubber fibers was identified as the reason behind this. Srivastava reported a lower swelling pressure of black cotton soil with coarse size shredded tyre waste as compared to swelling pressure of black cotton soil with fine size shredded tyre waste. Many experimental studies have been cited in the literature on the utilization of waste rubber tires for improving the geotechnical properties of clayey soil. In this context, compaction parameters and California Bearing Ratio are evaluated for subgrade soil with crumb rubber content 0%, 5.0%, 7.5% and 10% respectively. The proposed composite could be used for construction of roads having low traffic intensity, lightweight backfill behind retaining wall, etc. and based on the results of various tests done on the both subgrade with and without tyre waste a strict conclusion is made out. The load carrying capacity of the subgrade being investigated was found out to be satisfactory. This report has the whole process how we dealt with our idea and what and how the tests were performed.

MATERIAL USED

SOIL

A soil sample of necessary strength and various other parameters is to be collected from the under constructed Srinagar-Jammu highway near Nowgam area of Srinagar city. On investigating about the soil sample it came to our knowledge that it has some sand content in it as well. Rest parameters were concluded after the start of our project work.

TYRE WASTE

Small pieces of waste tyre scrapped from light motor vehicles will be used in this study. Waste tyre pieces will be cut into square and rectangular shapes preferably passing IS 25mm sieve and retained on IS 20mm sieve. Then further assessment will be done after the start of project work.

MATERIAL TESTING

Sieve Analysis Result

[As per IS 2720, Part 4]

Subgrade sample from Nowgam borrow area.

IS Sieve (mm)	Wt. Retained (g)	Cumulative Wt. Retained (g)	Cumulative Percentage Retained (%)	Cumulative Percentage Retained	Remarks
100					Gravel
75					Gravel
19					Gravel
4.75	-	-	-	100	Gravel
2.00	12.55	12.55	2.51	97.49	Sand
0.425	21.85	34.40	6.68	93.32	Sand
0.075	33.40	67.80	13.56	86.44	Sand
Pan					Silt & Clay

Description of particle		Sieve size (mm)	Percentage (%)
Gravel	Coarse	75 – 20	0
	Fine	20 – 4.75	
Sand	Coarse	4.75 – 2.00	13.56
	Medium	2.00 – 0.425	
	Fine	0.425 – 0.075	
Silt &Clay		Passing through 0.0075	86.44

Table1 the percentage of Sand in the soil sample was found to be equal to 13.56 and Silt and clay content was 86.44

FREE SWELL INDEX RESULT

[As per IS 2720, Part 40]

Subgrade sample from Nowgam borrow area.

S. No.	Sample level in water (Vw) ml	Sample level in kerosene (Vk)ml	Free Swell in Water (Vw-Vk) ml	FSI 100x (Vw-Vk) / Vk (%)	Average FSI (%)
1	12.5	11	1.5	13.64	13.64

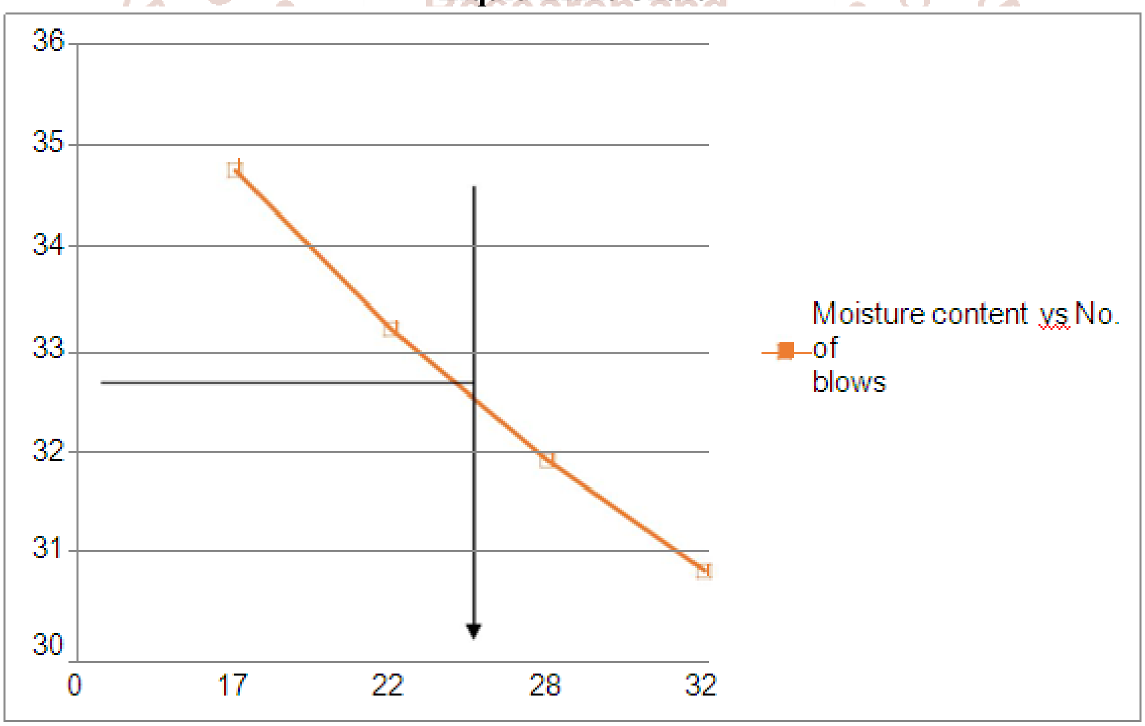
Test Sample passed through 425 micron sieve.
The sample was oven dried before commencing of test.
10gm sample was taken.
This is the result of FSI of the soil subgrade sample.
The FSI of the tested sample was taken out to be 13.64%. It is much lesser to 50%.

Result of Atterbergs Limits
[As per IS 2720, Part 5]
Subgrade sample from Nowgam borrow area.

Description	Liquid Limit				Plastic Limit	
Serial No.	1	2	3	4	1	2
Container No.	1	2	3	4	5	6
Empty wt of container (w1) gm	20.31	20.37	22.61	25.22	21.75	23.29
Wt of container plus wet sample (w2) gm	42.83	43.26	45.88	50.40	25.33	27.51
Wt of container plus dry sample (w3) gm	37.02	37.50	40.27	44.47	24.67	26.74
Wt of moisture (w4= w2- w3) gm	5.81	5.76	5.61	5.93	0.66	0.77
Wt of dry material (w5= w3-w1) gm	16.71	17.13	17.66	19.25	2.92	3.45
Moisture Content W=100x w4/w5 %	34.77	33.63	31.77	30.81	22.60	22.32
No. of blows	17	22	28	32	Average	22.46

To know:
The plastic index is calculated as the difference between its Liquid Limit & Plastic Limit.
In case of sandy soil the PL should be determined first. When PL cannot be determined, the PI should be reported as Non-Plastic
When the plastic limit is equal to or greater than the liquid limit, the PI shall be reported as zero.

Liquid Limit Chart



The graph above is drawn between numbers of blows on X-axis to the moisture content on Y-axis. The blue arrow is drawn at the 25 no. of blows.

The Liquid Limit was calculated from the graph and was equal to 32.56%. The Plastic Limit calculated was 22.46%. The sample was having the Plastic Index of 10.10.

RESULT OF MODIFIED PROCTOR TEST

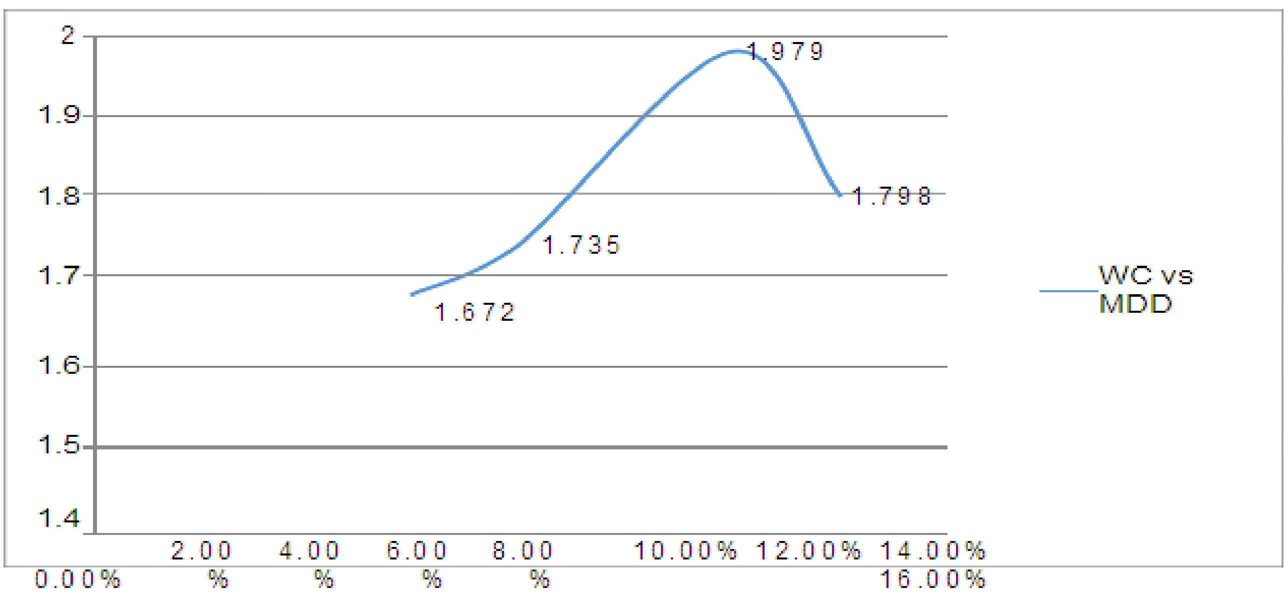
[As per IS 2720, Part-8]

Subgrade sample from Nowgam borrow area.

B	Mould No. 1		Wt. Of Mould = 4019gm			Volume of Mould (V) = 1000cc	
C	Trail No.		1	2	3	4	5
D	Wt of wet sample plus mould	gm	5614	5831	5934	6252	6067
E	Wt of wet sample	gm	1595	1812	1915	2233	2058
F	Wet density ofsample	gm/cc	1.595	1.812	1.915	2.233	2.058
G	Container No.	No.	5	6	7	8	9
H	Wt of empty container	gm	114.10	120.16	106.78	121.18	116.97
J	Wt of wet sample plus Container	gm	220.32	231.94	222.88	242.42	243.24
K	Wt of dry sample plus container	gm	214.12	223.79	211.99	228.66	227.30
L	Wt of water	gm	6.20	8.65	10.89	13.76	15.94
M	Wt of dry sample	gm	100.02	103.13	105.21	107.48	110.33
N	Water Content (100x L/M)	%	6.20	8.39	10.35	12.80	14.45
P	Dry Density	gm/cc	1.502	1.672	1.735	1.979	1.798

After the calculations with the help of graph between Moisture content and Dry density the Optimal Moisture Content known. The OMC is the water content at which we get maximum dry density of soil. And it is one of the chief parameter of soil which is very important in various engineering works.

Maximum Dry Density Graph



The graph is plotted between water content on the X-axis and the Dry density on the Y-axis. The point at which the dry density is maximum, we will have the OMC of the sample at the same point on X-axis.

The OMC of the sample was calculated to be 12.80% and the MDD was 1.979 gm/cc. This test was performed under the supervision of Er. Suhail. To know:

Weight of Rammer is 4.89 kg
Number of blows are 25
Number of layers are 5
MDD is 1.979gm/cc
OMC is 12.80%

Result of CBR

[As per IS 2720, Part 16]

Subgrade sample from Nowgam borrow area. Without inclusion of any waste rubber.

S. No.	Description	Mould No. 42		Mould No. 45		Mould No. 47	
A	No. of Layers	5		5		5	
B	No. of blows per layer	56		56		56	
C	Condition of sample while soaking	Before	After	Before	After	Before	After
D	Wt. of mould (gm)	7750		7830		7772	
E	Wt. of wet sample plus mould (gm)	12450	12471	12625	12651	12582	12604
F	Wt. of wet sample (gm)	4700	4721	4795	4821	4810	4832
G	Volume of mould (cc)	2250	2250	2250	2250	2250	2250
H	Wet density (gm/cc)	2.08	2.10	2.13	2.14	2.14	2.15

The table above the various schematic calculations and values of the different parameters while conducting the CBR. There are various values of the CBR moulds which were casted. The values are of before soaking and after soaking. This will be followed by load penetration table on the next page.

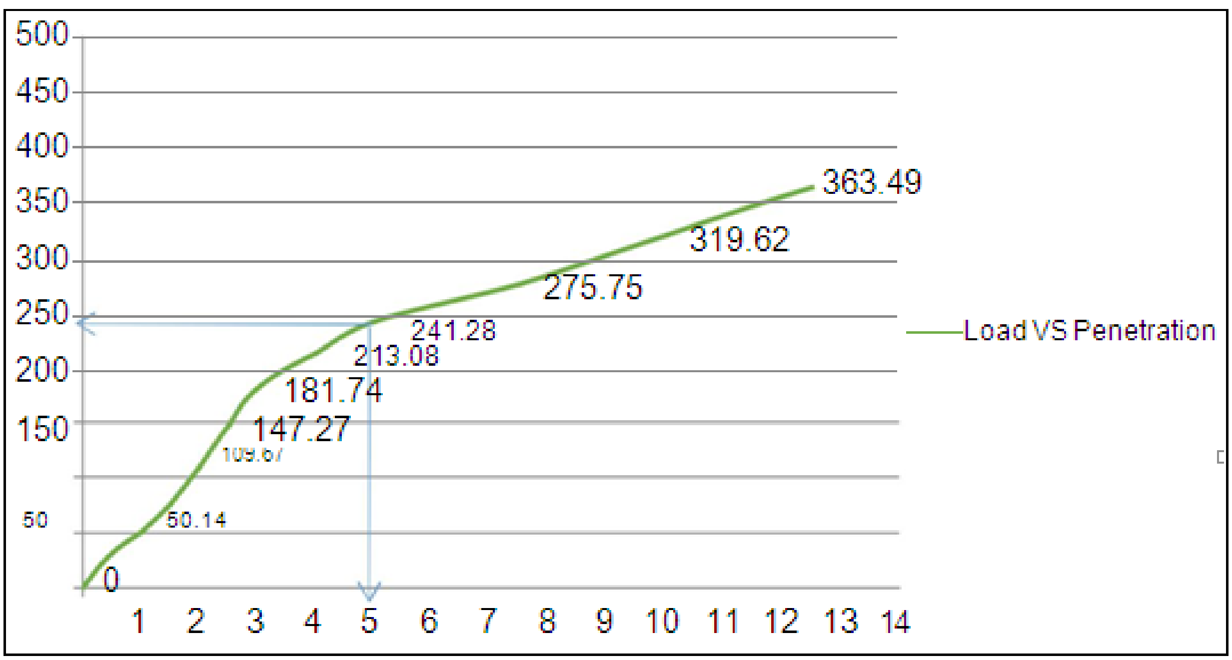
Load Penetration Data

General Information	Penetration (mm)	Proving Ring Reading	Load (kg)	Proving Ring Reading	Load (kg)	Proving Ring Reading	Load (kg)
Dynamic Compaction	0.0	0	0	0	0	0	0
	0.5	5	31.34	6	37.60	8	50.14
Period of Soaking 4 days	1.0	8	50.14	10	62.67	11	68.94
	1.5	12	75.20	16	100.27	17.5	109.67
Wt. Of Surcharge 5kg	2.0	17.5	109.67	18	112.81	19.5	122.21
	2.5	23.5	147.27	24	150.41	24.5	153.54
Proving Ring No. And Capacity 14, 30KN	3.0	29	181.74	32.5	203.68	33	206.81
	4.0	34	213.08	36	225.61	38.5	241.28
Proving Ring Load factor: 6.267	5.0	38.5	241.28	40.5	253.81	42	263.21
	7.5	44	275.75	45	282.02	47	294.55
	10.0	51	319.62	53	332.15	58	363.49
	12.5	58	363.49	61	382.29	72	441.22
CBR at 2.5 mm (%)		10.75		10.98		11.21	
CBR at 5 mm (%)		11.74		12.35		12.81	
CBR Reported (%)				12.30			

The CBR value after every calculation was found to be 12.30% at 5mmpenetration of the plunger over the specimen without waste rubber in it. Following by the load penetration data a graph is made between the Penetration of plunger in (mm) on the X- axis and the load in (kg) on the Y- axis and the results are drawn. The load corresponding to 2.5 mm penetration and 5 mm penetration is marked. The more the CBR value of soil the more strength it has got and it means lesser thickness of the layer is required in the highway pavement.

CBR value is one of the chief parameter of soil in Highway Engineering and it determines the overall economy of the project as well. The more the CBR value the less material needs to me used and viceversa. As already discussed our aim is to enhance the CBR value of the soil by means of rubber waste and with how much percentage that got increased or decreased (if) will be discussed and illustrated in the next segments of this report. as this test denotes a measure of resistance to penetration of soil of plunger under controlled test conditions. The CBR test may be conducted in a laboratory generally on re-moulded specimens; the test may also be conducted on undisturbed specimens. The laboratory procedure should be strictly adhered if high degree of reproducibility is desired. Procedure for field determination of CBR value of soil in-place or in-situ has also been developed and standardised by different agencies including BIS. The basic principle in CBR test is by causing a cylindrical plunger of 50mm diameter to penetrate into the specimen of soil or pavement component material at a rate of 1.25 mm per minute. The loads required for 2.5mm and 5.0mm penetration of the plunger into the soil tested are recorded. The CBR value of the material tested is expressed as a percentage of a standard load value in a standard material. The standard load values have been established based on a large number of tests on soil at respective penetration levels of 2.5mm and 5.0mm. These standard load values already discussed are used to calculate the CBR value of the soil. This report contains all the relevant graphical representation of the different CBR graphs. As this is the important and prime parameter in Highway Engineering so there is the emphasis on CBR studies. In final and concluding CBR test over the waste rubber mix of soil there we will give graphical representation on the different values of CBR at different proportions of rubber waste present in it. That will help in understanding general design and fashion of the variation of CBR values with the different percentage of rubber waste.

Load VS Penetration Graph



Results:

CBR at 2.5 mm penetration	10.98
CBR at 5 mm penetration	12.30
Correcected CBR at 2.5 mm penetration	-
Correcected CBR at 5 mm penetration	-
CBR reported as (%)	12.30

CBR values at 2.5 mm penetration was found to be 10.98. And the CBR value at 5mm penetration was found to be 12.30. This whole test was completed almost in 5 days and 3 moulds were tested upon to get the above results. The arrow on graph above shows the load of 249 kg on Y-Axis at 5mm penetration on X- Axis

Full Summary of Sample

Sample from Borrow Area Nowgam			
Description	**Unit**	**IS Code**	**Result**
Gravel	%	IS 2720- Part 4	-
Sand	%	IS 2720- Part 4	13.56
Silt & Clay	%	IS 2720- Part 4	86.44
FSI	%	IS 2720- Part 40	13.64
LL	%	IS 2720- Part 5	32.56
PL	%	IS 2720- Part 5	22.46
PI	-	IS 2720- Part 5	10.10
MDD	g/cc	IS 2720- Part 8	1.979
OMC	%	IS 2720- Part 8	12.80
CBR	%	IS 2720- Part 16	12.30

Waste Rubber

Rubber as we know belong to the family of polymers and is non biodegradable that means it has tendency to appear in the environment for a larger time if after its wear and tear its disposal is not managed properly. The rubber waste used in this study was crumb waste derived from tyres or light motor vehicles. It was shredded so that it can pass through 4.75mm IS sieve. The uniformity was such that it can get easily with the soil under investigation. The waste tyres were in abundance everywhere and our source was the Bus Stand of Batamaloo, area of Srinagar. The rubber was investigated if any uneven matter is present it or not that may have changed the results. So the rubber was thoroughly investigated as well. And definite amounts were used in the soils for the study and behavioral change of soil sample under consideration already.

Definite amount of rubber to be used in the study was also estimated and then having the material required and knowing what tests to be done laboratory investigations were started in a very discrete way for getting the results. Worthy to mention the rubber used was free from any dirt or any foreign matter. If any kind of matter was present in the waste rubber it was washed under the jet of stream then was dried by keeping it out for sunlight then the waste rubber was taken into use. And in the following segment we will Be discussing the laboratory investigations with sample and rubber and the results we got.

LABORATORY INVESTIGATION

Inclusion of Waste Rubber in Sub grade Sample

As discussed earlier the tyre waste was introduced in the soil sample in the different proportions and the cases were studied accordingly. We aimed to calculate the particular amount of rubber waste proportion that will enhance the CBR value very effectively. So starting from the 5% by weight of the sample then 7.5% and then we concluded our study at 10% and framed the results.

PARAMETERS AT 5% TYRE WASTE

Modified Proctor Test

As stated earlier in this report that modified proctor test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density. This laboratory tests generally consist of compacting soil at known moisture content into a cylindrical mold of standard dimensions using a comp active effort of controlled magnitude. The soil is usually compacted into the mold to a certain amount of equal layers, each receiving a number of blows from a standard weighted hammer at a specified height. This process is then repeated for various moisture contents and the dry densities are determined for each. The graphical relationship of the dry density to moisture content is then plotted to establish the compaction curve. The maximum dry density is finally obtained from the peak point of the compaction curve and its corresponding moisture content, also known as the optimal moisture content. As this test is required to get the heavy compaction we observed this that while conducting this test there was a slight difference in the reaction of the hammer used for blowing. Also the quantity of soil that was to put in the mould was required less than the quantity without rubber. As the two materials were not composite there was an appreciable chance of having voids still after compaction. So it is required while compacting this soil mix of waste tyre rubber that there is proper compaction. Starting from 6% of water content we kept adding the water to the sample under consideration unless the point was reached when there was decrease in the weight of the mould containing wet soil sample having 5% of waste rubber in it. After every set of test sample was taken from the compacted mould to get the water content after 24 hours keeping that in the oven. It was seen that the compacted soil sample got its weight decreased only after 4 sets which was the set indication that the sample had attained MDD rubber waste. Thus this was the first appreciable change we observed after inclusion of the waste mix. All 4 sets of samples were taken in the oven and after 24 hours were taken out to know the weight of the dry samples which were in the oven for 24 hours at almost 104 degree Celsius. It was seen that the sample after drying was somehow different than that of the sample without rubber waste in it.

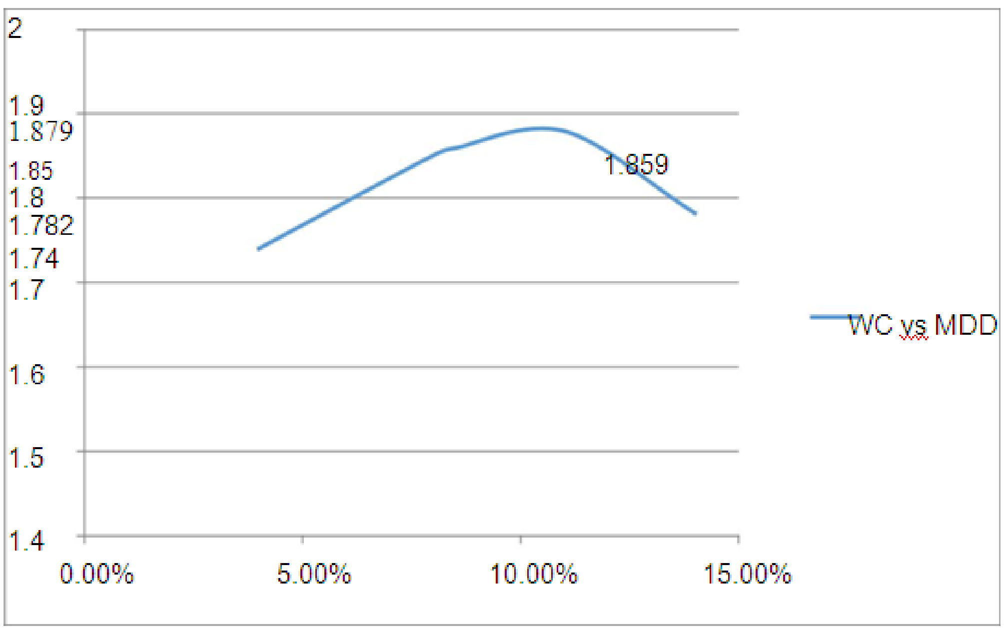
RESULT OF MODIFIED PROCTOR TEST

[As per IS 2720, Part-8]

Subgrade sample from Nowgam borrow area. Inclusion of 5% waste Rubber.

B	Mould No. 2		Wt. Of Mould = 4080gm			Volume of Mould (V) = 1000cc	
C	Trail No.		1	2	3	4	5
D	Wt of wet sample plus mould	gm	5950	6095	6135	6176	6127
E	Wt of wet sample	gm	1870	2015	2055	2096	2047
F	Wet density of sample	gm/cc	1.870	2.015	2.055	2.096	2.047
G	Container No.	No.	30	31	32	33	34
H	Wt of empty container	gm	24.5	24.7	24.00	25.00	25.00
J	Wt of wet sample plus container	gm	180.00	219.00	219.74	186.80	167.66
K	Wt of dry sample plus container	gm	169.30	202.60	201.14	170.00	149.60
L	Wt of water	gm	10.70	16.40	18.60	16.80	18.50
M	Wt of dry sample	gm	144.80	177.90	177.14	145.00	124.16
N	Water Content (100x L/M)	%	7.30	9.20	10.50	11.50	14.90
P	Dry Density	gm/cc	1.74	1.85	1.859	1.879	1.782

Maximum Dry Density Graph



The graph is plotted between water content on the X-axis and the Dry density on the Y-axis. The point at which the dry density is maximum, we will have the OMC of the sample at the same point on X-axis.

The OMC of the sample was calculated to be 11.50% and the MDD was 1.879 gm/cc. This test was performed under the supervision of Er. Suhail.

To know:
Weight of Rammer is 4.89 kg
Number of blows are 25
Number of layers are 5
MDD is 1.879gm/cc
OMC is 11.50%

The MDD graph resulted in the similar MDD parabolic curve as that of ordinary sample hence we conclude that at 5% rubber content the graph plotted between the water content and dry density will be same as of the ordinary soil sample without having any foreign material. So let us also see if the graphs change with variation of percentage in waste rubber content in next coming sections.

Result of CBR

[As per IS 2720, Part 16]

Subgrade sample from Nowgam borrow area. Inclusion of 5% of waste rubber.

S.NO.	Description	Mould No. 81		Mould No. 82		Mould No. 83	
A	No. of Layers	5		5		5	
B	No. of blows per layer	56		56		56	
C	Condition of sample while soaking	Before	After	Before	After	Before	After
D	Wt. of mould (gm)	7706		7755		7798	
E	Wt. of wet sample plus mould (gm)	12257	12276	12380	12408	12415	12438
F	Wt. of wet sample(gm)	4551	4570	4625	4653	4617	4640
G	Volume of mould(cc)	2250	2250	2250	2250	2250	2250
H	Wet density(gm/cc)	2.02	2.03	2.05	2.07	2.05	2.06

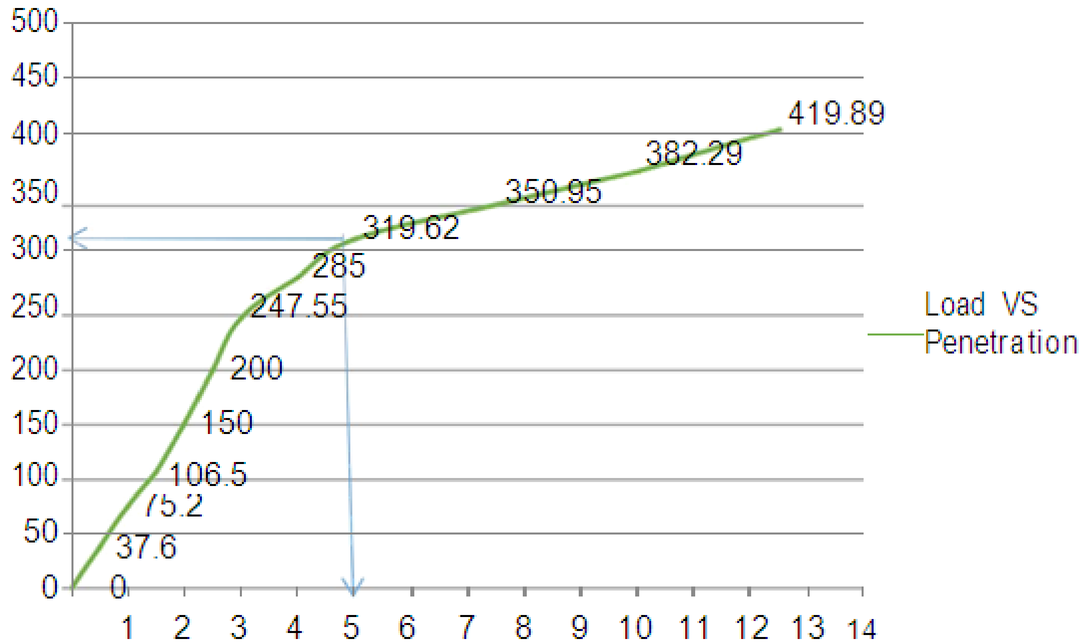
The table above the various schematic calculations and values of the different parameters while conducting the CBR. There are various values of the CBR moulds which were casted having the inclusion of waste rubber by 5%. There is also increase in the wet density of sample by appreciable amount by the presence of waste rubber reason being the good absorption characteristics of waste rubber. The values are of before soaking and after soaking. This will be followed by load penetration table on the next page.

LOAD PENETRATION DATA

General Information	Penetration (mm)	Proving Ring Reading	Load (kg)	Proving Ring Reading	Load (kg)	Proving Ring Reading	Load (kg)
Dynamic Compaction	0.0	0	0	0	0	0	0
	0.5	6	37.60	6	37.60	7	42.87
Period of Soaking 4days	1.0	11	68.94	12	75.20	13	81.47
	1.5	17	106.54	17	106.54	17.5	109.67
Wt. Of Surcharge 5kg	2.0	23	144.14	22	137.87	23	144.14
	2.5	29.5	184.88	32	200.54	34.5	216.21
Proving Ring No.and Capacity 14, 30KN	3.0	39	244.41	39.5	247.55	41	256.95
	4.0	42	263.21	44	275.75	47	294.55
Proving Ring Load factor: 6.267	5.0	48	300.82	51	319.62	53.5	335.28
	7.5	52	325.88	56	350.95	57	357.22
	10.0	59	369.75	61	382.29	63	394.82
	12.5	66	413.62	67	419.89	71	444.96
CBR at 2.5 mm (%)		13.49		14.64		15.78	
CBR at 5 mm (%)		14.64		15.55		16.32	
CBR Reported (%)		15.50					

This data is followed by the graph between penetration and standard load on the specimen with 5% of waste rubber in the next page. The curve we get is typical load vs penetration curve thus the percentage of 5% of waste rubber do not alter the curve style which we plot between load and penetration.

Load VS Penetration Graph



Results:

CBR at 2.5 mm penetration	14.64
CBR at 5 mm penetration	15.50
Correcected CBR at 2.5 mm penetration	-
Correcected CBR at 5 mm penetration	-
CBR reported as (%)	15.50

CBR values at 2.5 mm penetration was found to be 14.64. And the CBR value at 5mm penetration was found to be 15.50. This whole test was completed almost in 5 days and 3 moulds were tested upon to get the above results.

PARAMETERS AT 7.5% TYRE WASTE
MODIFIED PROCTOR TEST

Result of Modified Proctor Test

[As per IS 2720, Part-8]

Subgrade sample from Nowgam borrow area. Inclusion of **7.5%** waste Rubber.

B	Mould No. 3		Wt. Of Mould = 4148gm			Volume of Mould(V) = 1000cc	
C	Trail No.		1	2	3	4	5
D	Wt of wet sample plus mould	gm	6028	6127	6206	6170	-
E	Wt of wet sample	gm	1880	1979	2058	2022	-
F	Wet density of sample	gm/ cc	1.880	1.979	2.058	2.022	-
G	Container No.	No.	38	91	71	52	-
H	Wt of empty container	gm	46.20	25.30	34.00	25.10	-
J	Wt of wet sample plus container	gm	118.50	106.50	124.90	78.30	-
K	Wt of dry sample plus container	gm	112.30	97.60	114.80	70.90	-
L	Wt of water	gm	6.20	8.90	10.10	7.40	-
M	Wt of dry sample	gm	66.10	72.30	80.80	45.80	-
N	Water Content(100x L/M)	%	9.40	12.30	12.50	16.20	-
P	Dry Density	gm/ cc	1.72	1.76	1.83	1.74	-

RESULT OF CBR

[As per IS 2720, Part 16]

Sub grade sample from Nowgam borrow area. Inclusion of 7.5% of waste rubber

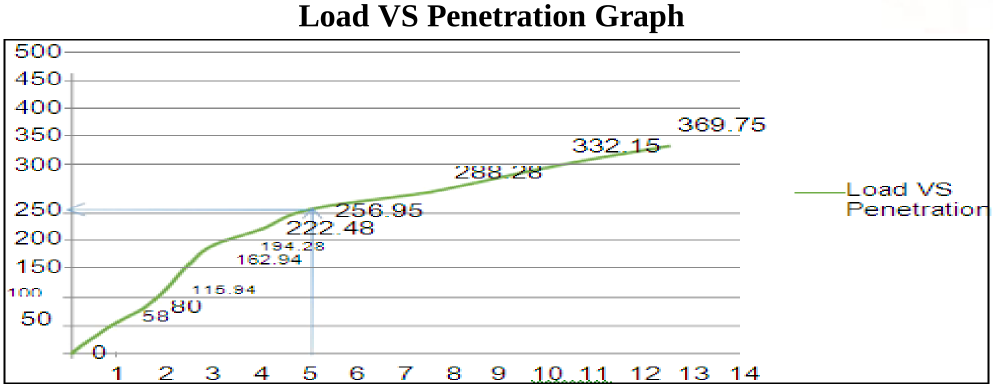
S.N o.	Description	Mould No. 33		Mould No. 36		Mould No. 38	
A	No. of Layers	5		5		5	
B	No. of blows per layer	56		56		56	
C	Condition of sample while soaking	Before	After	Before	After	Before	After
D	Wt. of mould (gm)	7728		7796		7830	
E	Wt. of wet sample plus mould (gm)	12310	12338	12283	12312	12328	12352
F	Wt. of wet sample(gm)	4582	4510	4487	4516	4498	4522
G	Volume of mould(cc)	2250	2250	2250	2250	2250	
H	Wet density(gm/cc)	2.04	2.00	1.99	2.01	1.99	2.01

The table above the various schematic calculations and values of the different parameters while conducting the CBR. There are various values of the CBR moulds which were casted. The specimen was having 7.5% of rubber mix. We can see that there was not any increase in the wet density the reason being the extra voids created by the waste rubber which otherwise were having good absorption properties. Thus it is evident from these results as well that any extra amount of rubber waste than 55 is not feasible and will try to bring down the geotechnical properties of that very specimen. The values are of before soaking and after soaking. This will be followed by load penetration table on the next page.

LOAD PENETRATION DATA

General Information	Penetration (mm)	Proving Ring Reading	Load (kg)	Proving Ring Reading	Load (kg)	Proving Ring Reading	Load (kg)
Dynamic Compaction	0.0	0	0	0	0	0	0
	0.5	5	31.34	5	31.34	7	43.87
Period of Soaking 4 days	1.0	7	43.87	8	50.14	8	50.14
	1.5	11	68.94	12	75.20	12.5	78.34
Wt. Of Surcharge 5kg	2.0	18	112.81	18.5	115.94	19.5	122.21
	2.5	25.5	159.81	26	162.94	26.5	166.07
Proving Ring No. and Capacity 14, 30KN	3.0	30	188.01	31	194.28	32.5	203.68
	4.0	36	225.61	35.5	222.48	39	244.41
Proving Ring Load factor: 6.267	5.0	39	244.41	41	256.95	42.5	266.34
	7.5	43.5	272.61	46	288.28	48	300.83
	10.0	50	313.35	53	332.15	56	350.95
	12.5	57	357.22	59	369.75	63	394.82
CBR at 2.5 mm (%)		11.66		11.89		12.12	
CBR at 5 mm (%)		11.89		12.50		12.96	
CBR Reported (%)		12.50					

Load VS Penetration Graph



This graph above between penetration and standard load on the specimen with 7.5% of waste rubber shows somehow irregularity at the first then arises as a smooth curve. This irregularity is because of the presence of voids which is left there due to improper compaction. These CBR moulds when casted they were not responding well to the compaction because of more waste rubber percentage. The curve we get in 5%waste rubber specimen was typical load vs penetration curve, thus the percentage of 5% of waste rubber do not alter the curve style which we plot between load and penetration. But here in this case

there are some irregularities at first which is caused due to the uneven compaction. Also it shows that the load corresponding to the 5mm penetration is lower than the loading at the same penetration in 5% waste tyre specimen. It can be concluded that from the curve as well as CBR that we got, that the 7.5% of waste rubber proves not effective as reinforcing material in the soil thus choice of taking this percentage of waste rubber gets eliminated. So, in the next part we will be studying about the change in CBR value when the waste rubber is increased to 10% for our concluding results.

RESULTS:

CBR at 2.5 mm penetration	11.89
CBR at 5 mm penetration	12.50
Correcected CBR at 2.5 mm penetration	
Correcected CBR at 5 mm penetration	
CBR reported as (%)	12.50

CBR values at 2.5 mm penetration was found to be 11.89. And the CBR value at 5mm penetration was found to be 12.50. This whole test was completed almost in 5 days and 3 moulds were tested upon to get the above results. This CBR value is less than the CBR value we got when we had mixted 5% of waste rubber in the soil specimen. But at the same time it can be seen that the CBR value is slightly higher than the VBR value of the specimen itself. This proves the point that to some extent rubber can be used as reinforcing material but only in a definite proportion. Although 7.5% of waste rubber also enhanced the CBR but it definitely degraded the other geotechnical properties like OMC and MDD. Also there is more certainty of having voids in the specimen with 7.5% of waste rubber mixed in it. As at this percentage of waste rubber the specimen do not respond to the compaction well Also we take the sample from the oven after 24 hours there was still some water content held within the yhreads of waste rubber tyres and it was visible to the naked eye that the material was lacking good adhering properties. So it is not useful enough to provide the sub grade with 7.5% of waste rubber although it enhances the CBR to some extent but renders the other properties to the soil which prove to be a ghastly to the soil in sub grade. Now in next segment we will study effect of using 10% of waste rubber for concluding results.

PARAMETERS AT 10% TYRE WASTE

MODIFIED PROCTOR TEST

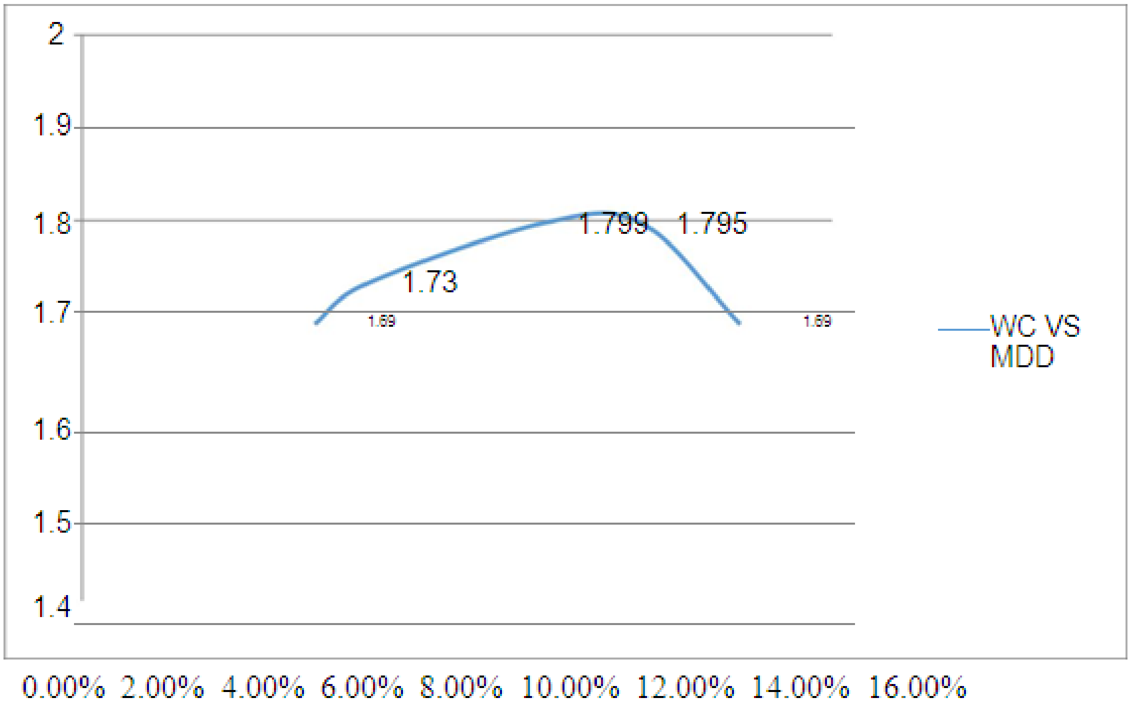
Result of Modified Proctor Test

[As per IS 2720, Part-8]

Sub grade sample from Nowgam borrow area. Inclusion of 10% waste Rubber.

B	Mould No. 4		Wt. Of Mould = 4151gm			Volume of Mould (V) = 1000cc	
C	Trail No.		1	2	3	4	5
D	Wt of wet sample plus mould	gm	5980	6052	6190	6176	6108
E	Wt of wet sample	gm	1829	1901	2039	2025	1957
F	Wet density of sample	gm/cc	1.829	1.901	2.039	2.025	1.957
G	Container No.	No.	1	2	3	4	5
H	Wt of empty container	gm	24.50	24.80	35.60	24.40	47.20
J	Wt of wet sample plus container	gm	89.70	105.60	107.20	85.20	110.60
K	Wt of dry sample plus container	gm	84.60	98.30	98.80	78.30	102.20
L	Wt of water	gm	5.10	7.30	8.40	6.90	8.40
M	Wt of dry sample	gm	60.10	73.50	63.20	53.90	55.00
N	Water Content (100x L/M)	%	8.48	9.93	13.29	12.80	15.57
P	Dry Density	gm/cc	1.69	1.73	1.799	1.795	1.69

Maximum Dry Density Graph



The graph is plotted between water content on the X-axis and the Dry density on the Y-axis. The point at which the dry density is maximum, we will have the OMC of the sample at the same point on X-axis. The OMC of the sample was calculated to be 13.29% and the MDD was 1.799 gm/cc.

To know:
Weight of Rammer is 4.89 kg
Number of blows are 25
Number of layers are 5

MDD is 1.799gm/cc
OMC is 13.29%

All the graphs plotted between dry density and water content was similar in geometry. The represented a parabola. Hence it is concluded that indeed there is the variation of MDD and OMC when there is the variation of waste rubber proportion in the specimen but the graphs have no effect on the variations by the inclusion of waste rubber in any proportion. In next section we will be talking of the changes in the CBR values by the inclusion of 10% rubber waste.

Result of CBR

[As per IS 2720, Part 16]

Sub grade sample from Nowgam borrow area. Inclusion of 10% waste rubber.

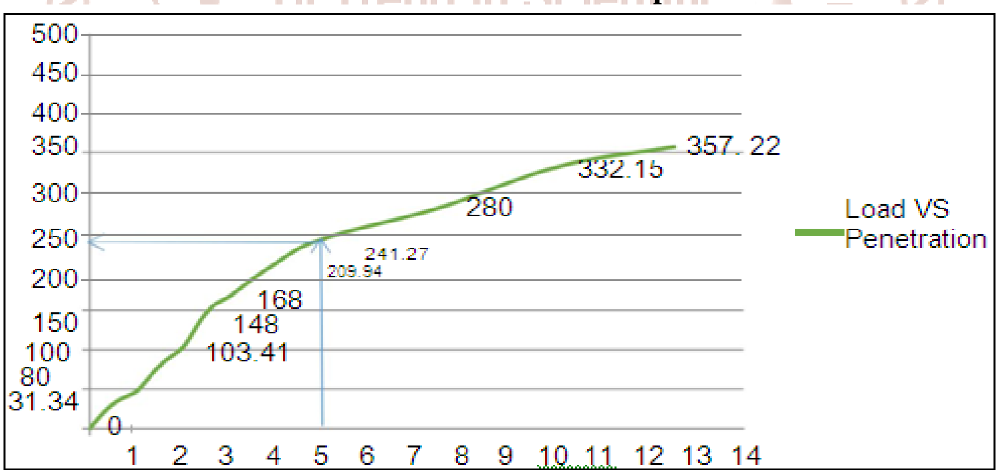
S. No.	Description	Mould No. 1		Mould No. 2		Mould No. 3	
A	No. of Layers	5		5		5	
B	No. of blows per layer	56		56		56	
C	Condition of sample while soaking	Before	After	Before	After	Before	After
D	Wt. of mould (gm)	7835		7913		7957	
E	Wt. of wet sample plus mould (gm)	12206	12231	12174	12197	12253	12276
F	Wt. of wet sample (gm)	4371	4396	4261	4284	4296	4319
G	Volume of mould (cc)	2250	2250	2250	2250	2250	2250
H	Wet density (gm/cc)	1.94	1.95	1.89	1.90	1.91	1.92

Load Penetration Data

General Information	Penetration (mm)	Proving Ring Reading	Load (kg)	Proving Ring Reading	Load (kg)	Proving Ring Reading	Load (kg)
Dynamic Compaction	0.0	0	0	0	0	0	0
	0.5	4	25.06	5	31.34	6.5	40.74
Period of Soaking 4 days	1.0	6	37.60	7.5	47	8	50.14
	1.5	9	56.40	10.5	65.80	11	68.94
Wt. Of Surcharge 5kg	2.0	14	87.73	16.5	103.41	17	106.54
	2.5	23.5	147.27	24	150.41	24	150.41
ProvingRing No. And Capacity 14, 30KN	3.0	26	162.94	26	162.94	26.5	166.07
	4.0	33	206.81	33.5	209.94	32.5	203.68
Proving Ring Load factor: 6.267	5.0	38	238.15	38.5	241.27	39	244.41
	7.5	43	269.48	44	275.75	45.5	285.14
	10.0	52	325.88	53	332.15	53.5	335.28
	12.5	56	350.95	57	357.22	59	369.75
CBR at 2.5 mm (%)		10.75		10.98		10.98	
CBR at 5 mm (%)		11.59		11.74		11.89	
CBR Reported (%)				11.74			

This table of inclusion of 10% of waste rubber in the specimen showed that the calculated CBR was the least of all the values hence the concentration of waste rubber quantity exceeding 5% is not feasible. The graph between the penetration and the standard loading is illustrated on the next page of this report.

Load VS Penetration Graph



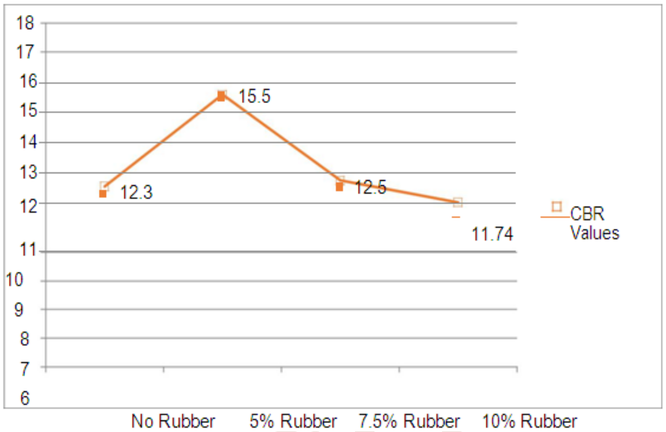
This graph above between penetration and standard load on the specimen with 10% of waste rubber shows somehow irregularity at the first then arises as a not so smooth curve. This irregularity is because of the presence of voids which is left there due to improper compaction. These CBR moulds when casted they were not responding well to the compaction because of more waste rubber percentage. The curve we get in 5%waste rubber specimen was typical load vs penetration curve, thus the percentage of 5% of waste rubber do not alter the curve style which we plot between load and penetration. But here in this case there are some irregularities at first which is caused due to the uneven compaction like was the case with 7.5% of waste rubber specimen. Also it shows that the load corresponding to the 5mm penetration is lower than the loading at the same penetration in 5% waste tyre specimen even lower than other all results. It can be concluded that from the curve as well as CBR that we got, that the 10% of waste rubber proves not effective as reinforcing material in the soil thus choice of taking this percentage of waste rubber gets eliminated. So concluding our results that upto 5% of rubber mix proves to enhance the CBR value of the specimen and hence can be used as the reinforcing material in the sub grade up to this percentage.

RESULTS:

CBR at 2.5 mm penetration	10.90
CBR at 5 mm penetration	11.74
Correcected CBR at 2.5 mm penetration	-
Correcected CBR at 5 mm penetration	-
CBR reported as (%)	11.74

Table 26

Graph of CBR Variations



Graphical representation above shows the how the CBR value varies with the change in waste rubber proportion. On Y- Axis there is CBR values and on X- Axis there is waste rubber content.

RESULT ANALYSIS

SUMMARY AND COMPARISON

Let us talk of the results we got. And discuss those results in this segment. We see different changes in the parameters of the soil with inclusion of different proportions of waste rubber. There was not only physical to the sample that we witnessed but there were dramatic changes in the engineering properties of the soil as sample as well after inclusion of various proportions of waste rubber. The changes follow a definite pattern. The physical state of the sample with 5% of waste rubber content was real hard mass after compacting while as the other samples having incremental proportions of rubber waste has a bit of plasticity after compacting and do not occur to be the solid mass bye eye judgment. The results can be summarized in the following spheres viz effect on compaction parameters that is MDD and OMC, effect on CBR. Different ratios of waste rubber showed different fashion in changes. So in the following part we will take each parameter one by one.

EFFECT ON COMPACTION PARAMETERS.

The compaction parameters of the soil are those dealing with the compaction test of the soil that is dealing with the Modified Proctor test. As we had done this test taking into the consideration the water quantity of 6% by weight and proceeded the test and in every sample with different proportion of waste rubber we gave the same number of blows and provided same number of layers. But the result we got was different. The sample without the inclusion of any waste rubber had 12.80% value of OMC. But this value shifted later when in the same sample was added 5% of waste rubber the results were quite different and were deviated from the original OMC. The OMC of the sample with 5% of waste rubber was found to be 11.50% which is less than the OMC of sample without rubber. What we get from here that the waste rubber even being not the uniform material as of soil itself added to the cohesiveness of the sample the soil got compacted at lower amount of water content. That is the compaction required is less in the field and makes its use economical than the soil without any rubber or so. What about the MDD? We know the maximum dry density of the soil sample was 1.979 gm/cc now after inclusion of 5% of waste rubber tyre its MDD value changed it got decreased than sample without waste rubber. What logic is behind it?

It can be seen from the above discussion that the MDD of soil-tyre mixtures reduces significantly with an increase in the percentage of waste rubber tyre. This is due to the light weight nature of shredded rubber tyre. On the other hand, the value of OMC also decreasing with an enhancement of percentage of shredded rubber tyre. This is due to the fact that the shredded waste rubber tyre has more water absorption capacity. As already it was seen that the Optimal Moisture Content of the sample without inclusion of waste rubber was found to be 12.8%. When the waste rubber was added to it as a secondary material up to 5% the Optimal Moisture Content was decreased due to the reason of good absorbing properties of waste rubber. After that when the waste rubber quantity was exceeded to 7.5% there is increase in the Optimal Moisture Content depicting there is the poor compaction of the soil which render to the creation of voids. After that when more waste rubber was added in the specimen equal to the 10% of weight of the sample there was further increment in the Optimal Moisture Content. Thus we concluded that up to 5% of waste rubber inclusion there is the drop in Optimal Moisture Content but with further increase in the rubber content the Optimal Moisture Content keeps increasing. And the Maximum Dry Density of the sample without inclusion of waste rubber was found to be 1.979 gm/cc. When the waste rubber was added to it as a secondary material up to 5% the Maximum Dry Density was decreased due to the reason being less unit weight of waste rubber than the soil. After that when the waste rubber quantity was exceeded to 7.5% there is further decrease in the Maximum Dry Density depicting there is the poor compaction of the soil plus the density of rubber being low than the soil specimen which render to the creation of voids. After that when more waste rubber was added in the specimen equal to the 10% of weight of the sample there was further decrease in the Maximum Dry Density. The effect on compaction parameters is that the MDD will decrease with increase in the waste rubber proportion and at the same time the OMC has tendency of both increasing and decreasing. Up to some proportion the OMC drop down but after then it will continue to increase due to the various reasons already discussed in the preceding sections. It can be also noted that after increment in the rubber content the specimen doesn't respond to compaction well as it was observed there was bouncing back of plunger after a blow given to the specimen with more rubber quantity

EFFECT ON CBR

The results give the idea about the variation of California Bearing Ratio of the specimen with and without the inclusion of waste rubber. It can be seen that the California Bearing Ratio of the sample without inclusion of waste rubber was found to be 12.30%. When the waste rubber was added to it as a secondary material up to 5% the California Bearing Ratio was increased due to the reason of good reinforcing properties of waste rubber. After that when the waste rubber quantity was exceeded to 7.5% there is decrease in the California Bearing Ratio depicting there is the poor adhesion of the soil and waste rubber which render to the creation of voids and lowering the strength. After that when more waste rubber was added in the specimen equal to the 10% of weight of the sample there was further decrease in the California Bearing Ratio. Thus we concluded that up to 5% of waste rubber inclusion there is the increase in the California Bearing Ratio but with further increase in the rubber content the California Bearing Ratio keeps decreasing which means more thickness of sub grade is required for laying down the pavement. Upton 5% the waste rubber acts as a good reinforcing material but when increased further it behaves as a non composite material and tends to decrease the strength of the specimen. Also the Table 27 shows the systematic variations of the CBR values with the change in the proportions of waste rubber. At 7.5% of waste rubber there was slight increase in the CBR value but that is not feasible percentage to use due to the other parameters that is increase in the Optimum Moisture Content and reduction in Maximum Dry Density. The thing with 7.5% proportion of waste rubber is that it will create avoids even after heavy compaction due to the non composite nature of two materials. The waste tyre proportion of 10% lower the value of CBR significantly hence making it clear that with increase of rubber waste there will be decrease in CBR value. Hence it is evident from the studies and the graphs plotted that the use of rubber waste can ascertain the economy of the project if used up to 5% only. CBR being the prime geotechnical parameter of sub grade in highway engineering directs the use of waste rubber in the definite proportion if possible. So it can be said that the waste tyre give the reinforcing property to the soil when used at up to a certain amount and there after decreases the adhering property of the soil particles

COMPARISON

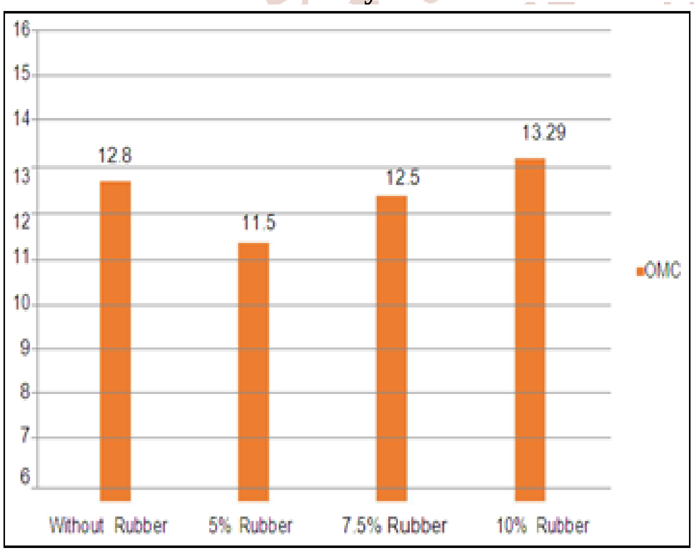
This penultimate part of the report draws the attention towards the feasibility of the study we had discussed so far in a well and organized manner. The results that we had already discussed so far gave us the idea about what rubber percentage give what results. So carrying that results forward and comparing them with each other and so that we can conclude the crux of the project.

- We had know that that the sample without any waste rubber had MDD of 1.979gm/cc, OMC of 12.80% and the CBR value equal to 12.3%
- With the inclusion of 5% of waste rubber in that similar sample we had calculated that the OMC value of 11.50% which is less that the OMC of sample without rubber the reason being the good absorption value of the rubber. But the MDD was found to be 1.879 gm/cc which is also less than the MDD of original sample and here the reason is that the waste rubber is having low unit weight than the soil. Now CBR value was found to be 15.5% which is greater than the CBR value of the soil sample.
- So increasing the percentage of rubber we then introduced 7.5% of waste rubber what we see there is increase in the OMC. The reason being that these quantities of rubber leave some voids in the sample which are occupied by water and this

water don't get drained away due to compaction easily. Also there was further decrease in the MDD. The MDD found in this case was 1.830 gm/cc which were less than the two cases discussed earlier. The reason being the same less unit weight of waste rubber. The CBR in this case was found to be 12.5% which is nearly equal to the CBR value of soil sample without waste rubber.

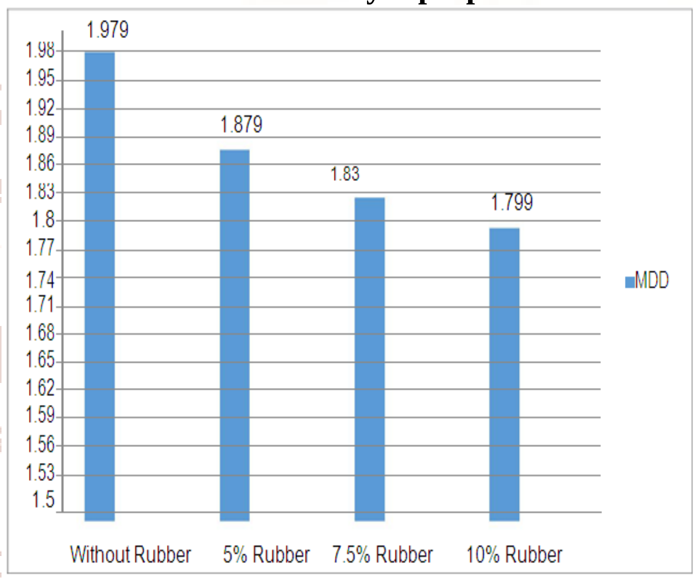
Now our final sample with the waste rubber inclusion of 10% this showed very much increase in the OMC. The OMC was found to be 13.29% which is greater of the all. The reason the sample developed this character is that there was excessive voids left in the soil sample now. The materials being different were not compacted well. They do not respond to the compaction that effectively. Also MDD was found to be 1.799 gm/cc which was lowest of all and the reason being the low unit weight of rubber. Now coming to the CBR part, the value of CBR was decreased than the original sample. The CBR was found to be 11.74%.

OMC on different Waste Tyre Content



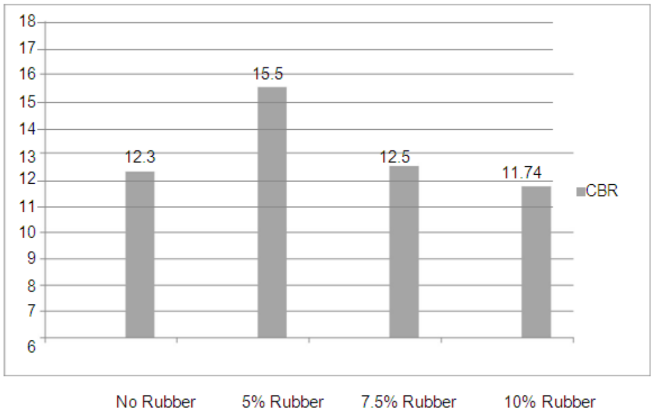
The table above gives the visual description about the variation of Optimal Moisture Content of the specimen with and without the inclusion of waste rubber. It can be seen that the Optimal Moisture Content of the sample without inclusion of waste rubber was found to be 12.8%. When the waste rubber was added to it as a secondary material upto 5% the Optimal Moisture Content was decreased due to the reason of good absorbing properties of waste rubber. After that when the waste rubber quantity was exceeded to 7.5% there is increase in the Optimal Moisture Content depicting there is the poor compaction of the soil which render to the creation of voids. After that when more waste rubber was added in the specimen equal to the 10% of weight of the sample there was further increament in the Optimal Moisture Content. Thus we concluded that up to 5% of waste rubber inclusion there is the drop in Optimal Moisture Content but with further increase in the rubber content the Optimal Moisture Content keeps increasing.

MDD on different Waste Tyre proportions



The table above gives the visual description about the variation of Maximum Dry Density of the specimen with and without the inclusion of waste rubber. It can be seen that the Maximum Dry Density of the sample without inclusion of waste rubber was found to be 1.979 gm/cc. When the waste rubber was added to it as a secondary material upto 5% the Maximum Dry Density was decreased due to the reason being less unit weight of waste rubber than the soil. After that when the waste rubber quantity was exceeded to 7.5% there is further decrease in the Maximum Dry Density depicting there is the poor compaction of the soil plus the density of rubber being low than the soil specimen which render to the creation of voids. After that when more waste rubber was added in the specimen equal to the 10% of weight of the sample there was further decrease in the Maximum Dry Density. Thus we concluded that the Maximum Dry Density of the soil continue to decrease by the inclusion of waste rubber due to the fact that the unit weight of waste rubber is less than the unit weight of soil sample. Hence it should be noted that the inclusion of waste rubber will always tend to decrease the Maximum Dry Density of soil.

CBR on different Waste Tyre proportions



The table above gives the visual description about the variation of California Bearing Ratio of the specimen with and without the inclusion of waste rubber. It can be seen that the California Bearing Ratio of the sample without inclusion of waste rubber was found to be 12.30%. When the waste rubber was added to it as a secondary material upto 5% the California Bearing Ratio was increased due to the reason of good reinforcing properties of waste rubber. After that when the waste rubber quantity was exceeded to 7.5% there is decrease in the California Bearing Ratio depicting there is the poor adhesion of the soil and waste rubber which render to the creation of voids and lowering the strength. After that when more waste rubber was added in the specimen equal to the 10% of weight of the sample there was further decrease in the California Bearing Ratio. Thus we concluded that upto 5% of waste rubber inclusion there is the increase in the California Bearing Ratio but with further increase in the rubber content the California Bearing Ratio keeps decreasing which means more thickness of subgrade is required for laying down the pavement. Upto 5% the waste rubber acts as a good reinforcing material but when increased further it behaves as a non composite material and tends to decrease the strength of the specimen.

SUMMARY OF RESULTS

The table below highlights the general summary of the geotechnical parameters of the specimen with and without the inclusion of waste rubber.

S. No	Geotechnical Parameter	Units	Without Rubber	5% Rubber	7.5% Rubber	10% Rubber
1.	OMC	%	12.80	11.50	12.50	13.29
2.	MDD	gm/cc	1.979	1.879	1.830	1.799
3.	CBR	%	12.30	15.50	12.5	11.4

CONCLUSION

Based on the experimental investigations and the results obtained the following conclusions are made:

1. Waste tyre mixed upto a certain proportion with soil does showed improvement in CBR value and gradual decrement in MDD.
2. Giving importance to the CBR value in design of the pavement the mixing of waste tyre in the soil is found to be effective when upto 5% by weight the waste rubber is mixed with the soil.
3. Waste tyre reinforced with soil showed improvement in CBR value with its addition upto 5% and there onwards decreased with further increase in tyre content in soaked condition.
4. Its decrement of MDD may be attributed to the loose of grip of rubber surface with the soil and also the unit weight of waste rubber is less than the soil.
5. The waste tyre in this particular soil can be effectively used in sub grade to improve its CBR value in areas where the rainfall is less and the ground water table is at a great depth below.
6. The decrement of the OMC up to 5% waste tyre mixed sample is due to the good water absorption characteristic of waste tyre and there onward with 7% and 10% waste tyre mix in the soil sample the increment in the OMC credits to the uneven compaction which leave significant amount of voids in the sample.
7. The waste tyre mix is up to 5% in proportion is feasible in the sub grade layer of pavement as it will effectively reduce the amount of soil also the significant reduction in aesthetic pollution in the ambient.
8. An increase in CBR value of 2% can significantly reduce the total thickness of the pavement and hence the total cost involved in the project.

Hence, it is concluded that the waste rubber (up to 5%) can be used for improving the geotechnical properties of the soil. In enormous utilization of waste crumb rubber for improving geotechnical properties of clay helps to solve the health and environmental problems associated with the disposal of this hazardous waste.

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