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## Effect of Nanochemicals on WBM Subbase of Flexible Pavements

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**ABSTRACT:** Roads are the lifeline for the sustained growth of an economy. But its design life is not fully met with, as its engineering properties such as strength and permeability characteristics are affected due to various factors such as improper laying & compaction, poor quality materials, moisture ingress etc. The main objective of this paper is to evaluate the potential use of Nano-chemicals in stabilisation of one of the layers of flexible pavements i.e., WBM Subbase by improving its engineering properties such as strength and permeability. Terrasil and Zycobond are the Nano-chemicals selected for the study; which is added with the Basic WBM mix, which includes Coarse Aggregates (CA) of 40mm down and Quarry Dust (QD) of 4.75mm down whereas Treated mix includes addition of Nano-chemicals with the Basic mix and then the strength and permeability tests are conducted for varying mix proportions of aggregates and screeners of Basic and Treated mixes at their Optimum Moisture Content (OMC) and the obtained test results are compared for both the mixes. Therefore, the results of the CBR tests show the percentage improvements in the values from 43.75% to 66.67 % which is taken as the optimum mix proportion (60% CA & 40% QD) by using Nano-chemicals. Similarly, permeability test results for WBM mix showed improved coefficient of permeability values by 26%.

**KEYWORDS:** CBR, Permeability, Nano-chemicals, OMC, WBM Subbase.

### I. INTRODUCTION

Roads are a vital component in nation building and one of the most effective modes to establish socio-economic and political network. Based on the structural behaviour, road pavements are of two types, rigid and flexible pavement. Flexible pavement is taken for the study.

Flexible Pavement will transmit wheel load stresses to the lower layers by grain-to-grain transfer through points of contact in the granular structure and will be distributed to a wider area. Hence, the design of these pavements uses the concept of layered system which consists of a bituminous material surface course and an underlying base and sub-base courses laid above the subgrade. Subbase is often the main load-bearing layer of the pavement. Its role is to spread the load evenly over the subgrade. The materials used may be either unbound granular, or cement-bound. The quality of Subbase is very important for the useful life of the road and can outlive the life of the surface, which can be scrapped off and after checking that the Subbase is still in good condition, a new layer can be applied. Hence, **Sub-Base Stabilisation** is taken into the study and its engineering properties are to be improved. In the present study, Strength characteristics of WBM Subbase are evaluated by California Bearing Ratio (CBR) test and the permeability characteristics by Constant Head Permeameter. Water Bound Macadam (WBM) is selected as a type of material for Subbase. WBM is one of the types of flexible pavement. WBM road layers are made of crushed or broken aggregates, mechanically interlocked by rolling and voids filled with screening and binding material with the assistance of water. WBM course can be used for surface, base and sub-base courses. Quarry Dust, by-product from crusher stone plant is utilized as a Screener and Conventional aggregates are used for coarser fraction in WBM mix.

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## II. LITERATURE SURVEY

A number of researchers have worked in improving the engineering properties of road course materials which are practical and economical using Nano-chemicals. The following literature review describes the important research results regarding the feasibility for the use of Nano-chemical - Terrasil for road base materials in enhancement of its engineering properties. They came out with the common dosage of 0.041% of Terrasil as optimum proportion with the soil samples.

The work of Laboratory investigation of soil stabilization using Nano-chemical is carried out by Lekha et al, (2013) studied the behaviour of black cotton (BC) soil with and without modification with compound named Terrasil, demonstrated particular estimations and cured for 7 – 28 days. The crucial geotechnical properties of soil were CBR qualities which increase with the addition in rate of stabilizer. Vulnerability is seen to be nil for treated soil. The recognition record communicates those Unconfined Compression Strength (UCS) quality augmentations with development in measurements of stabilizer and curing period.

Improvement of soil properties as a road base material using Nano-chemical solution was studied by Rintu Johnson et al, (2015).The soil was collected from Kunnamangalam of Calicut district in Kerala and the Terrasil Nano chemical was collected from Zydex Industries Ltd. for stabilization studies. Experimental programme was carried out on both clay and cement treated clay, added with different dosages of Terrasil. Specimens were prepared with 0.05%, 0.07% and 0.09% Terrasil and 1% cement by weight of soil. Results obtained were compared and studied. It is found out that, with the increment in the dosage of Terrasil, the CBR quality of soil blended with the ideal dose of 0.07% Terrasil chemical is enhanced around 6 times the CBR quality of untreated clay soil. Treated soil was observed to be impermeable. Optimum dosage of Terrasil was obtained as 0.07% by weight of soil and the strength was maximum for 4% cement content.

The focus on the evaluation of engineering properties of adjacent soil material with and without using Nano-chemical was studied by Chaudhari Riddhi et al (2016).Terrasil stabilizer of 0.04% percent dose is used to explore the changes in CBR values for the thickness of adaptable flexible pavement design. The procedure not just offers the capacity to improve the designing attributes of an unsatisfactory soil, additionally offers the specialist a more supportable way to deal with bituminous road development. The results shows that soil mixed with 0.041% Terrasil (as per Zydex Laboratory test protocol) is economical and beneficial. Also load carrying capacity is increased. Thus, it just satisfies from economy point of view, benefit associated with the utilization of chemical stabilizer such as Terrasil for enhancing the sustainable development in road construction needs to be worked evaluated.

Nandan Patel et al, (2015) on their work on scientifically surveying the usage of Terrasil chemical for Soil Stabilization, emphasized that it is the responsibility of the road authorities to use the local material and correct the soil properties using additives enhancing the strength of soil and make the road durable. The examination was completed to focus first soil engineering properties (with and without stabilizer), standard compaction ;four days soaked California Bearing Ratio (CBR), permeability test and cyclic loading test according to codal procurement i.e. 0.041% by dry aggregate weight of soil test, according to the convention of Zydex Industries, Vadodara. Test outcome demonstrates that the designing properties got modified and the CBR on stabilized clayed samples increased considerably, which reflects the lower thickness in correlation with natural characteristic soil properties.

A Case Study on Soil Stabilisation using Nano-materials for rural roads was studied out by Anwar Hussain et al, (2016).A trial section along sector 19, Gandhinagar, Gujarat, where CBR analysis was carried out to determine the insitu stiffness of the cement stabilised road base material with Nano-chemicals. It was an expansive soil entirely different from normal well drained soil in their morphological, physical and chemical characteristics. Experimental studies indicate that mixing of Nano-chemicals with cement in soil reduces the Plasticity Index and increases the compaction characteristics, CBR and other strength parameters like UCS.

The above earlier studies were made for Terrasil compound but in the present study, Nano-chemicals of Terrasil and Zycobond are utilised together with dilution in the water and its effects on WBM Subbase characteristics are carried out.

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## III. PROPOSED METHODOLOGY AND DESIGN

Quarry Dust and Conventional Coarse Aggregates are collected from Chennai, TamilNadu and Nano-chemicals - Terrasil and Zycobond from Zydex Industries, Chennai. Various properties tests are carried out for collected materials (Aggregates and Screeners) and the limits are set as per IS code procedures and their values are shown in the table 1 and 2. After they satisfy the quality control checks, the engineering properties tests such as CBR and permeability tests are carried out for Basic and Treated WBM mixes. Prior carrying out engineering properties tests, it is important to determine the compaction characteristics of WBM mixes. Standard Proctor Compaction tests are conducted for varying WBM mix proportions in order to determine their corresponding OMC and Maximum Dry Density (MDD). Mix proportions are labelled as G1, G2, G3 and G4 and their corresponding proportions adopted are shown in the table 3. WBM mix for varying proportions are prepared separately by mixing Coarse Aggregates and Quarry Dust at their corresponding compaction values (raw water for OMC) and this is treated as Basic mix. Similar to Basic mix, Treated mix is also prepared with the only exception that, diluted Nano-chemicals i.e., 1:0.5:300 (Terrasil: Zycobond: Water) has to be added instead of raw water with the compaction characteristics same as Basic mix.

Table 1: Properties of Quarry Dust

Parameter	Obtained Value
Grain size analysis	
Gravel (%)	97
Sand (%)	3
Fines (%)	0
Coefficient of Curvature	4.67
Coefficient of Uniformity	0.75
I.S Classification	Poorly Graded
Liquid Limit(%)	NP
Plastic Limit(%)	NP
Specific gravity	2.63
Compaction characteristics	
OMC (%)	11.1
MDD(g/cc)	1.97
CBR(%)	12.5

Table 2: Properties of Coarse Aggregates

Parameter	IS Code	Obtained Value	Limits as per IRC:19-2005
Gradation	IRC	40mm down	Grade 3
Specific gravity	IS:2720 Part 3	2.67	
Flakiness Index	IS:2720 Part 1	8%	<15%
Water Absorption Value	IS:2720 Part 3	1.2%	0.1-2%
Aggregate Impact Value	IS:2720 Part 4	13.27%	<30%
Aggregate Crushing Value	IS:2720 Part 4	22.74 %	<30%
Aggregate Abrasion Value	IS:2720 Part 4	30%	<40%

Table 3: WBM Mix Proportions

Mixes	G1	G2	G3	G4
CA:QD	40%:60%	50%:50%	60%:40%	70%:30%

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## CBR test

CBR tests are determined at unsoaked (OMC) conditions. CBR setup is arranged firstly and then the Basic mix is filled into the CBR mould and given light compaction of 62 blows as per ASTM D1883-05 for each of the three layers. Then, surcharge disc of 2,5Kg is placed on the top of the sample and subjected to CBR testing and the load dial readings are noted down. The step is repeated for all the mix proportions of both the mixes. Then load dial readings which are in divisions are converted into Kg by the following procedure. Correction factor ( $N_R$ ) = 8.4 N/div.  $N_R$  is multiplied with Load dial readings (div) to convert into 'N' and then expressed as 'Kg'. Then, the CBR (%) and the values are tabulated separately for mixes and optimum mix proportion is concluded based on their % enhancement.

## Permeability test

Constant Head Permeability type is adopted and is tested for both Basic and Treated mix for optimum mix proportion only which was concluded from the CBR test. Tests are conducted for three trials and its coefficient of permeability (k) value is found out for all those trials and its average value is considered as overall k value and it is calculated separately for both the mixes.

## IV. EXPERIMENTAL RESULTS

The results of compaction characteristics of various mix proportions are discussed firstly, followed by the effect of Nano-chemicals on WBM Subbase which is discussed under three headings as follows.

- Effect on CBR value
- Effect on permeability characteristics
- Comparison of result values

**Compaction characteristics:** Varying percentages of Quarry Dust and Coarse Aggregates are mixed as per mix proportions and subjected to IS light compaction test which as per IS: 2720 Part VII and the results are listed below in the table below and fig 1. Four trials are conducted for each mix proportions at moisture contents starting from 3%, then 5%, 7% and 11% and then dry densities and actual water contents are found out.

Table 4: Compaction Test results for mixes

Mix	Trials	Wet Density g/cc	Moisture content w %	Dry Density g/cc
G1	1	2.072	3.6	2
	2	2.26	5.8	2.14
	3	2.24	7.1	2.09
	4	2.07	9.8	1.89
G2	1	1.96	3.2	1.9
	2	2.29	5.4	2.18
	3	2.19	8.5	2.02
	4	2.09	10.3	1.9
G3	1	1.96	3.4	1.9
	2	2.305	4.8	2.2
	3	2.136	6.8	2
	4	2.03	8	1.88
G4	1	2.039	2.5	1.99
	2	2.32	4.5	2.22
	3	2.130	6.5	2
	4	2.042	7.5	1.9

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Graph is plotted between moisture content and dry density for all mix proportions G1,G2,G3 and G4 as shown in the fig below and the corresponding OMC and MDD values for mixes are obtained from the graph below and tabulated separately.

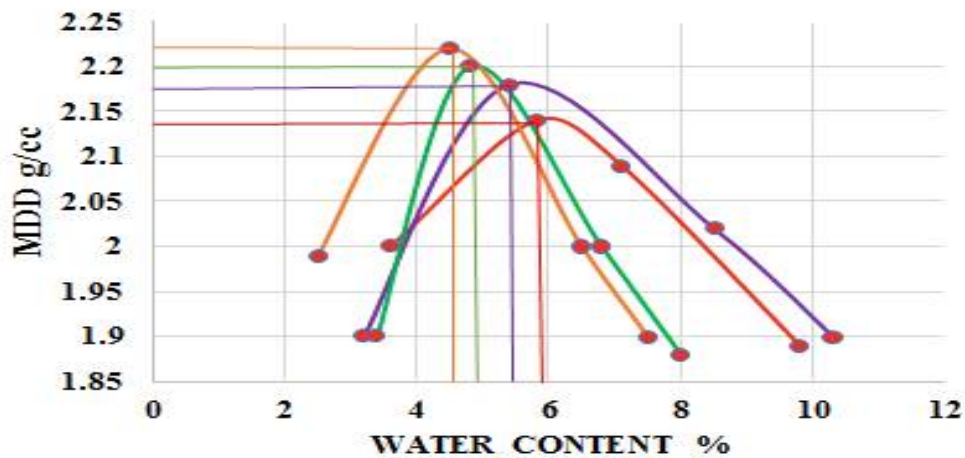


Fig 1: Compaction curve for mixes

From the compaction test results shown in the table5 and fig 2, it is identified that as the percentage of Quarry Dust is decreasing, OMC also reduces with the corresponding increase in their MDD values. At higher and lower percentages of crusher dust, opening up of voids are taking place and quarry dust particles are not sufficient to fill up these voids resulting in development of honey combed structures. For a range of 20-30% of quarry dust addition i.e., G3 and G4, the gradation mixes becomes densely compacted with attainment of high densities.

Table 5: Compaction curve for mixes

Grade	G1	G2	G3	G4
OMC %	5.8	5.4	4.8	4.5
MDD g/cc	2.14	2.18	2.2	2.22

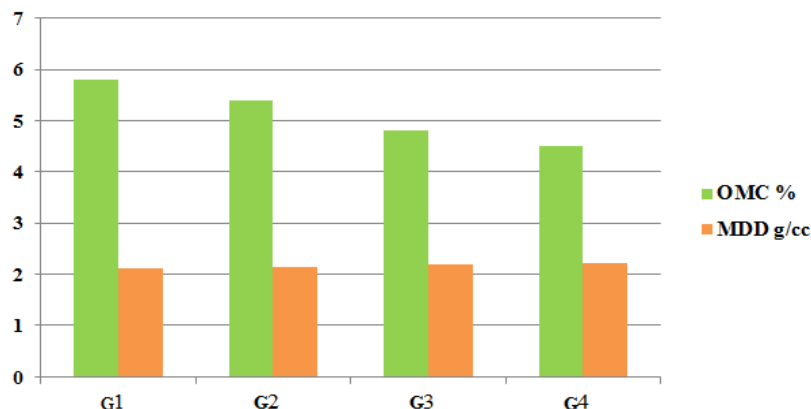


Fig 2: Mix compaction characteristics

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### Effect on CBR value

CBR tests were performed at their corresponding OMC for mixes and their results are shown in the Table for Basic mix and Table for Treated mix. Maximum load is reached by the load gauge for 7.5mm penetration and hence the penetration is stopped. Prior calculating the CBR, Load-Penetration curves are to be plotted for all mixes as shown in the Fig, for Basic mixes and Fig, for Treated mixes. These curves are to be checked for any corrections. As per Standard test procedures for CBR, if the graph continues to curve upwards, it is considered that the plunger penetration is increasing the sample density and therefore the strength, hence the correction is not applicable and also not applicable for convexity curve.

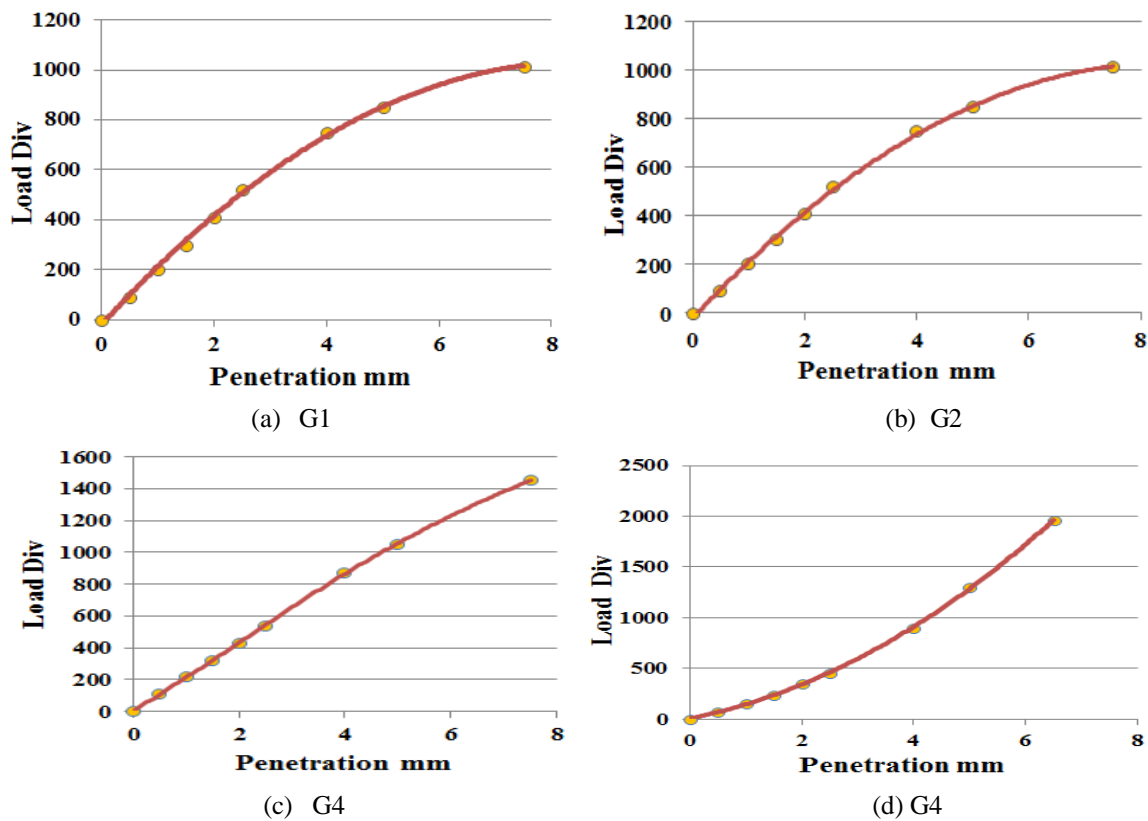


Fig 3: Load-Penetration curves for Basic mixes

From the figures above, it is concluded that the corrections are not required as they are convex upwards or continues to curve upwards for all proportions. Therefore, CBR values are computed and tabulated as shown in the table 6 and then the optimum mix proportion for CBR value is concluded based on the Treated mix values.

Table 6: CBR values for Basic mixes

Load Kg	G1	G2	G3	G4
$P_s$	453.8	762.1	899.1	1155.9
$P_t$	2055	2055	2055	2055
CBR (%)	22.08	37.08	43.75	56.25

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Similarly, CBR tests carried out for Treated mix and Load-Penetration curves are plotted for various mix proportions as shown in the figures below and checked for any corrections.

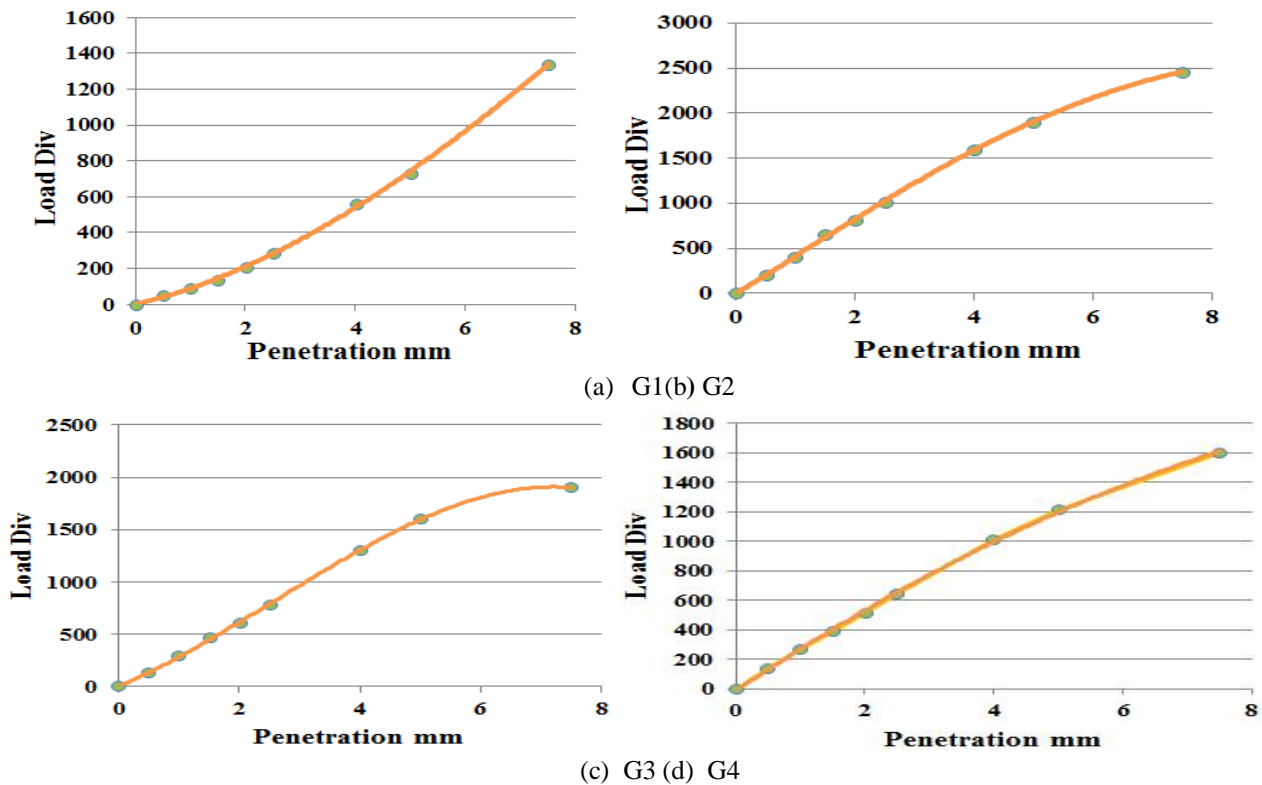


Fig 4: Load-Penetration curves for Treated mixes

From the figures, it is concluded that the corrections are not required as they are convex upwards or continues to curve upwards. Therefore, CBR values are computed and tabulated as shown in the table below.

Table 7: CBR values for Treated mixes

Load Kg	G1	G2	G3	G4
$P_s$	625.1	1040.4	1370	1563
$P_t$	2055	2055	2055	2055
CBR (%)	30.42	50.63	66.67	76.05

All the mixes satisfied the minimum CBR (%) required for Subbase based on MORTH specifications. But the optimum mix proportion was taken as G3 as its percentage enhancement is more by using Nano-chemicals when compared to rest of those mixes.

### Effect on permeability characteristics

Permeability test is conducted for optimum mix G3 which was concluded from CBR result and coefficient of permeability ( $k$ ) was found to be  $6.74 \times 10^{-4}$  cm/sec and  $4.98 \times 10^{-4}$  cm/sec for Basic and Treated mixes which is the average value of three trials conducted.

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## Comparison of mix % Improvements

From the Table, it is observed that the treated mix CBR values are increased which is because of the mix treated with diluted Nano-chemicals, renders improved density values by reducing the voids ratio. Also, permeability is found to be decreasing in case of Treated mix which is due to the material becoming dense, as changes over the water cherishing silanol gatherings to water repellent siloxane bonds takes place and it is favourable as aggregates contains more than 60% of Silica(SiO<sub>2</sub>). CBR% comparison of Basic and Treated mix are shown in the table 8.

Table 8: Percentage improvements in CBR and Permeability

Mix	Optimum CBR %	CBR %Improvement	Permeability cm/sec	Permeability improvement
Basic	43.75	34.4%	$6.74 \times 10^{-4}$	26%
Treated	66.67		$4.98 \times 10^{-4}$	

## V. CONCLUSION

The experimentation conducted shows favourable results as the CBR of WBM mix enhanced by the inclusion of Nano-chemicals and also the water proofing Characteristics of the mix is achieved. The CBR value of WBM mix increases with the increase in coarse aggregates. Nano-chemicals worked well for mix G3 as its CBR % improvement is more when compared to other Mixes. With the inclusion of Nano-chemicals, CBR value of WBM mix is enhanced by 4 times for optimum mix G3 and water proofing characteristics of WBM Mix is controlled by 25%. Therefore, as a result of increase in CBR (%), the thickness of the structure can be reduced and hence the economy and design life.

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