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Numerical Approach to Investigate the Settlement in RCC Road Using Plaxis 2D and Its Remedial Measures

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ABSTRACT

In present scenario, the Indian Ministry Road Transport and Highways has been relentlessly promoting sustainable development to achieve both economic growth and a good living environment for future generations. Given that the provision of infrastructure and buildings is indispensable to support local economic development, the construction industry will increasingly play a vital role in shaping a sustainable environment for the residents of India, especially Nagpur. However, the construction industry has long been confronted with its adverse impacts on the environment by generating many waste materials and consuming substantial quantities of natural resources. Moreover, the lack of natural resources has resulted in a strong dependency on importing natural aggregates from overseas. Thus, there is an urgency regarding the divergence of waste materials away from the Landfill area and to source alternative materials to replace natural aggregates. As an important component of the sustainable development trend, the use of recycled waste materials in construction applications is a method to enhance resource efficiency.To realize the beneficial use of C & D material, an in-depth study was conducted to evaluate its use in road construction using PLAXIS 2D. This software accomplishes to analyse the effect of cyclic loading on construction and demolished waste underneath the rigid pavement in static, dynamic and applying geogrid as well. This dissertation report paraphrases the inclusion of sub base material as C&D waste beneath the rigid pavement to dwindle the settlement of it. The static and dynamic analysis of rigid pavement incorporating geogrid has been studied to find the effect over it with the help of PLAXIS 2D. Several models have been analysed in PLAXIS 2D with various loading from IRC 58:2002 and IRC Class AA Loading. The temperature check is also studied for the existing ongoing Roads in Nagpur Region. The result from study shows that the stresses developed at higher temperature

Keywords: PLAXIS 2D, RCC Pavement, Geogride, C & D waste

I. INTRODUCTION

Latterly, road pavements, valuing the environmental perspective and seeking to terminate all long term impacts (economic, social, environmental, or other) of this type of investments, the great magnitude for the economic development of the Country. The sustainable development concept has been subjected to various construe. The term "sustainability" at the present time is applied now a days commonly to almost every facet of life, in the reference of human sustainability on Earth, it is being increasingly used, giving special focus about the causes of global warming and climate change in atmosphere. 'Brundtland Report' 'states that the development

"meets the needs of the present without compromising With the ability of future generations for meeting their own needs". Conservation of the rapidly diminishing natural resources and preservation of the environment are to be the nucleus of sustainable development. On environment there is consequent effect of any activity, viz., and road pavement construction. A structure consisting of superimposed layers of processed material layed above the natural soil sub-grade is the road pavement, and its primary function is to distribute the applied load by vehicles on it to the subgrade.

The pavement structure should be provided with the properties like adequate skid resistance, acceptable

Riding quality of surface, favourable light reflecting characteristics, and low noise pollution. The ultimate aim is to ensure that the transmitted stresses due to Wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the subgrade.

The flexible pavement consists of layers with highest quality materials near surface and its suitability depends upon the aggregate interlock, particle friction and cohesion. The bituminous pavement is example of flexible pavement. The examples of rigid type of pavements are the concrete pavements, these are made with the help of Portland cement, they have high modulus of elasticity because of its rigidity, and tends to distribute the applied load over the wide spread area of the soil beneath it.

Until last two decades, landfill was considered as the low cost and efficient method of C&D waste management in Nagpur. But land filling is considered to be undesirable due to environmental and ecosystem hazards. Most of the landfills are now days are at the end of completing their full capacity due to construction of basement oriented buildings.

Now a days the existing bitumen roads are being replaced by RCC pavements because the lifespan of the road is more than and periodical maintenance cost is very low. The major problem faced during the replacement of RCC road are such as settlement, cracks, corner stresses, undulation, traction force, etc. therefore a vast analysis would be required for such RCC road.

Figure 1

1. Defects in RCC road:-

cracks, settelemts, undulations, cornerstress. The above problems occur due to many reasons such as improper design ,heavy load etc.

Figure 2

Figure 3

Figure 4

Figrue 5

II. LITRETURE REVIEW

Auxi Barbudo et al. reviewed that Construction and Demolition Waste is a priority waste stream in the European Union. Currently, the production of CDW in Spain is around 20 million tons (430 kg/habitant year). The Waste Framework Directive requires Member States to recycle 70% of CDW before 2020. Recycled aggregates (RA) which are obtained from the CDW conveniently treated in recycling plants, can be used in civil engineering and building works. The recycling rate in Spain is approximately 40%, very far from recycling rates in other countries such as the Netherlands, Denmark and Germany that exceed the recycling rate of 80%. This work is extracted from "Catalogue of pavements with recycled CDW aggregates (CRA)", redacted with the aim of promoting the use of recycled materials in roads in the framework of a sustainable perspective and immersed in the future policies of the European Union.

Kamal H. Khayat, Seyedhamed Sadati reviewed that the research is to evaluate the feasibility of using high-volume recycled materials for concrete production in rigid pavement. The goal was to replace 50% of the solids with recycled materials and industrial by-products. The performance of concrete mixtures made with different fine and coarse recycled concrete aggregate (RCA) contents and binder types was investigated. Both single-layer rigid pavement and two-lift concrete pavement (2LCP) were considered. The investigation highlighted in this report evaluates the feasibility of developing concrete mixtures with high volume of recycled materials for the construction of sustainable rigid pavement. The goal of the project is to replace 50% of the cement and virgin aggregate with SCMs and RCA.

Dr. Pandu Kurre et al. reviewed that Several Instances That Pavement Performance Is Greatly Affected By The Usage Of Poor Quality Of Soil Subgrade Which Causes Severe Damage And Distress. With The Growing Tendency To Utilize Marginal Soils, There Arises The Need To Understand The Fundamental Behavior Of The Materials In Order To Make Suitable Amendments In Design Parameters, Especially In The Subgrade Construction Of Pavements. This Paper Presents The Shear Strength Behavior Of Geotextile Reinforced Marginal Soil Without And With Cement Modification And Compares Its Performance With That Of Conventional Soil Subgrade (Gravel). The Study Revealed That The Cement Modified Marginal Soil Has Become Non-Plastic With Its Performance Close To That Of Gravel Subgrade.

III. METHODOLOGY

Material Testing

Construction and demolition waste:- Construction and demolition waste is generated from construction industries/structures; whenever the structure is demolished C&D waste is generated. It consist of concrete, steel, tiles, wood, bricks, plastic, etc. the composition of the C&D waste depends upon its structure. It is said that there is no adequate or satisfactory data for accessing to the amount of waste material generated in Nagpur.

This is because there is no separate regulatory framework for handling the C&D waste management within the city, as it is considered in the solid waste management. Due to which it is getting difficult to access the information of to handle the construction and demolition waste material. As a report prepared by ministry of environmental and forest in 2008 determining that 0.35 million tons per day of waste material is generated in the country. On these basis 200 million tons MSW is produced annually.

Figrue 6

Table 1

Sr. no.	Components of C &D waste	(%) TIFAC
1.	Soil/ sand/ aggregate	36.0
2.	Bitumen	2.0
3.	Steel	5.0
4.	Concrete	23.0
5.	Wood	2.0
6.	Others	1.0

Particle size Distribution

Sieve analysis test is performed to know the different size of particle present during the test. This is commonly used in civil engineering to assess the particle size distribution curve of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass

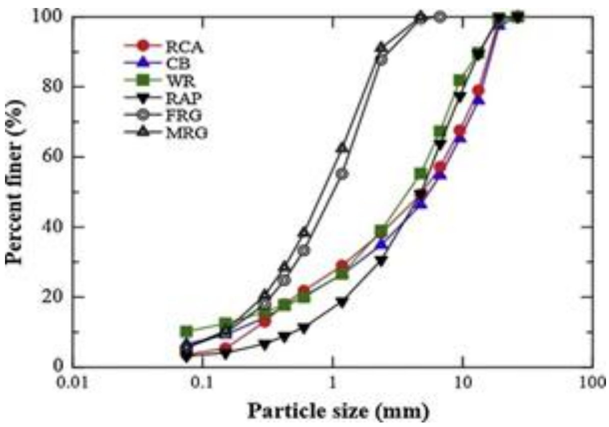

Figure 7

Direct Shear Test

A direct shear device measuring 60 mm x 60 mm x 60 mm depth was used for testing of the C & D waste. In the direct shear tests, the upper half is fixed to the frame of the apparatus. Whereas the bottom half can be moved relative to the top half with the assistance of an actuator controlled by an electric motor, thus shearing the soil specimen along the horizontal failure plane. In this study, a rigid steel plate was used as the loading plate, which applied 1.1 kPa itself to the test sample. The direct shear test device is capable of applying a vertical and shear force of up to 100 kN. The normal force applied on the rigid plate and shear force exerted during shearing were measured with the help of two load cells. The data were collected with a computerized data acquisition system.

The samples used for the direct shear tests were prepared by adding the corresponding optimum moisture contents to the dry materials and thoroughly mixing the material. The samples were then compacted in the shear box in three layers to the maximum dry density achieved from modified compaction test. The compaction process was carried out by using a small vibratory compactor.

Before the compaction of samples in the shear box, the upper and lower boxes of the shear box were assembled by keeping the two alignment pins in place to ensure that the upper and lower halves are aligned properly. The total weight of material to be filled in the shear box is computed based on volume of the shear box and the maximum dry density of the material obtained from compaction tests.

Unconfined Compression test

Unconfined Compression Strength (UCS) test is one of the most common and simplest tests that can be carried out utilizing minimum laboratory facilities. It is commonly used as a key design index parameter for estimating the stiffness of pavement material used in mechanistic pavement design methods. This test includes the application of an axial vertical load through loading platens, using strain-control or stress-control conditions, to a cylindrical sample of laterally unconfined soil. The unconfined compressive strength (UCS) is defined as the maximum unit stress obtained from monotonic load testing. In this investigation, the UCS tests were undertaken on the C&D waste samples after the samples were taken from demolished materials with the core cutter sampler. The UCS specimens were prepared as a split mould of 50 mm diameter and 100 mm in height.

Table 2

SAMPLE 1		SAMPLE 2		SAMPLE 3	
0	0	0	0	0	0
0.15	0.05	0.15	0.035	0.15	0.015
0.3	0.08869	0.3	0.078	0.3	0.0684
0.6	0.3455	0.6	0.3455	0.6	0.3455
0.9	0.58629	0.9	0.521	0.9	0.5111
1.2	0.8745	1.2	0.8745	1.2	0.8745
1.5	1.121	1.5	1.00121	1.5	1.1
1.8	1.213	1.8	1.2232	1.8	1.213
2.1	1.32	2.1	1.411	2.1	1.32
2.4	1.456	2.4	1.5232	2.4	1.456
2.7	1.621	2.7	1.688	2.7	1.621
3	1.7123	3	1.67	3	1.7423
3.3	1.5654	3.3	1.5654	3.3	1.55213
3.6	1.37444	3.6	1.37444	3.6	1.37444
3.9	1.07731	3.9	1.07731	3.9	1.07731
4.2	0.93524	4.2	0.93524	4.2	0.821
4.5	0.78787	4.5	0.6741	4.5	0.71

Figure 8

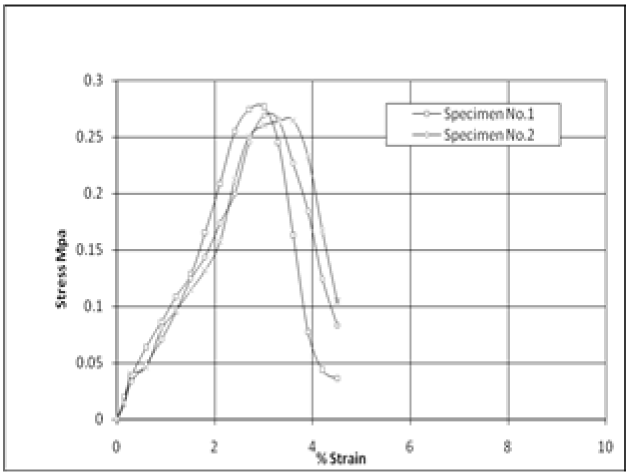

Figure 9

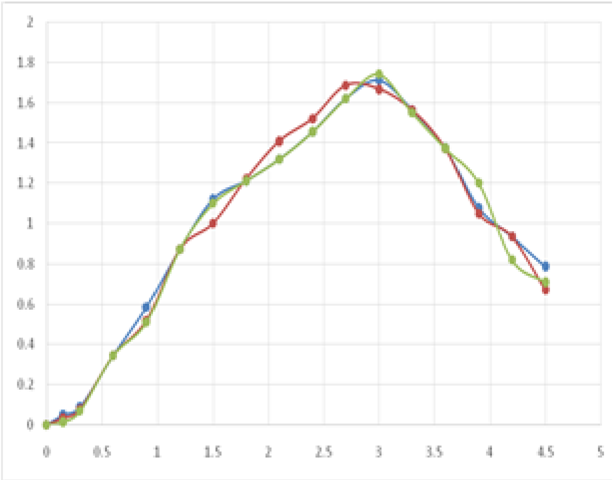

Figure 10

Properties of Material

Table 2

Sr. no.	Soil	Sub-base	C&D
C	12	0	0
Ø	26	41	43
E	30000 kPa	30000 kPa	30000 kPa
Poisson's Ratio	0.3	0.4	0.5

Analysis by Plaxis 2D

Plaxis is finite element software developed at the Technical University of Delft for Dutch Government. Initially, it was intended to analyze the soft soil river embankments of the lowlands of Holland. Soon after, the company Plaxis BV was invented, and the program was extended to cover a broader range of geotechnical issues. The Plaxis program started at Delft University of Technology in early 1970's when Peter Vermeer started to do a program of research on finite element analysis on the design and construction of Eastern Scheldt Storm-Barrier in Netherland.

Initial finite element code was developed to calculate the elastic-plastic plane using six-nodded triangular elements. In the year 1982 Rene DeBorst under the supervision of Pieter Vermeer, performed his master's program related topic on the analysis of cone penetration test in clay. The study of axisymmetric led to the existence of Plaxis. The study was on six-nodded triangles in the element. This 15 – noded triangle was developed thus increasing the number of nodes in the element. The usage of 15-noded triangle is the simplest element for any analysis in axisymmetric.

Then the experts De Borst and Vermeer implement the 15-noded triangle in Plaxis thus solving the problem of cone penetrometer. The development of Plaxis proceeds with the problem to solve the soil structure interaction effects. This led to the study on beam element by Klaas Bakker under the supervision of Pieter Vermeer. The outcome of the experiment using beam element was applicable to flexible retaining wall and later application to the analysis of flexible footings and rafts.

Baker's work formulated the implementation of 5-noded beam element in Plaxis (Bakker et al (1990), Bakker et al (1991)). The 5- nodded beam element is compatible to the 15-noded triangular elements (has 5 nodes).Baker's work was novel for the invention of hybrid method introducing the displacement of degree-of –freedom to the element behaviour. The lack of degree of freedom has made solution to reduce the number of variables thus simplified the element.

Analysis without C&D waste in the subbase:-

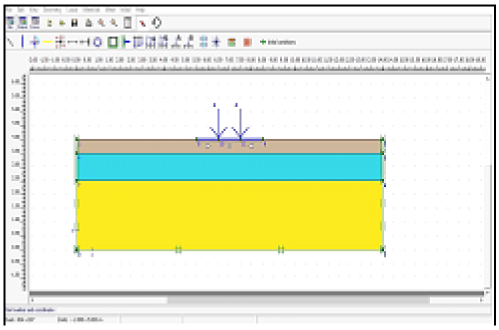

Figure 11. Numerical modeling

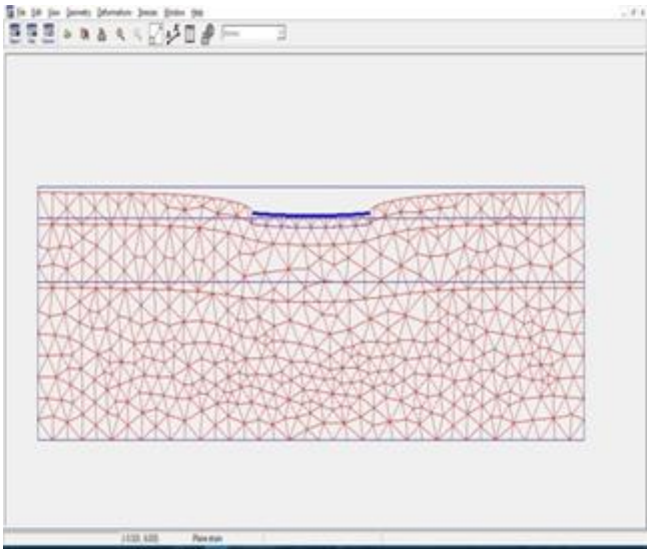

Figure 12. Mesh generations

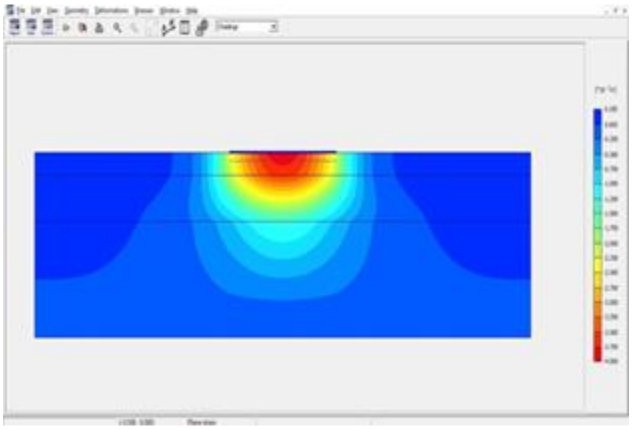

Figure 13. Vertical displacement of sub base 353.16 kN Max deformation = 4.00 mm

C&D with Geogride

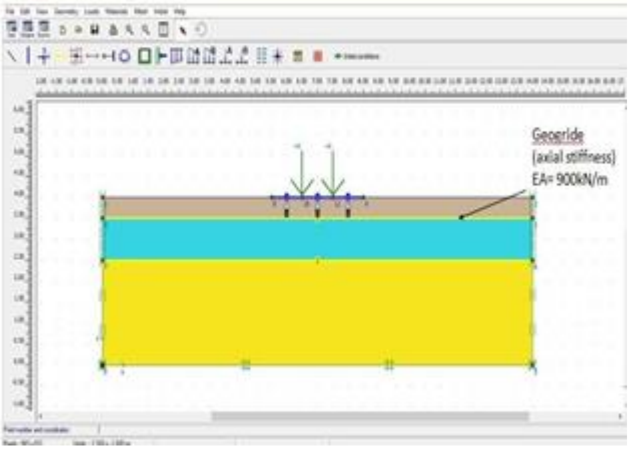

Figure 14. Application of Geogrid of axial stiffness of 900 kN/m for tandem loading of 353.16kN.

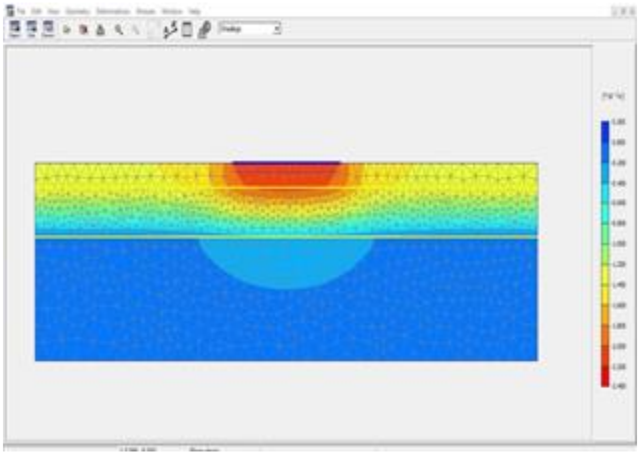

Figure 15. Settlement of 2.4 mm occurs with impact loading of 353.16 kN of Tandem loading

IV. RESULT AND DISCUSSION

As we can see that the using C&D in the sub base the amount of settlement is very much less so this will increase the life of pavement.

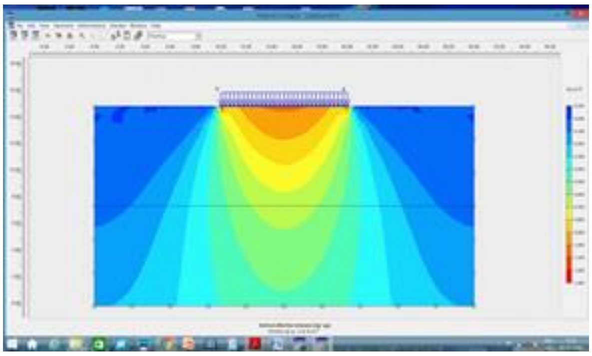

Figure 16. Vertical displacement of sub-base with using geogrid and C&D waste combined.

V. CONCLUSION

Concrete aggregate or demolished waste can be used as base and sub-base materials, in place of crushed stone aggregate for supporting a concrete pavement system. The compaction of recycled concrete aggregate is the same as that of crushed stone aggregate and gravel. The stability and the shear resistance of recycled concrete aggregate in dry conditions are higher than those of gravel and equal to or better than those of crushed stone aggregate.

Breakage of aggregate particles increases in severity from gravel to recycled concrete aggregate.

A comprehensive laboratory evaluation of the physical and shear strength characteristics of six C&D materials was undertaken using results from gradation, UCS, DST tests. The physical and shear strength characteristics of the recycled C&D materials were compared with the requirements for typical quarry materials. The shear strength parameters were subsequently analyzed and discussed. The following conclusions can be drawn on the physical properties and shear strength responses of the C & D materials.

The recycled C & D materials are classified as well-graded materials and are found to have the potential to be used in pavement base/sub base applications. Water absorption and surface roughness are found to control the compaction curves of the recycled C&D materials.

Numerical modeling of the demolished waste under rigid pavement is done by using PLAXIS 2D. After intensive modeling it is clear that the settlement in RCC slab is under permissible limit. For axle load it is found 2.1 mm and after impact load the deformation is 4.1 mm. numerical.

The use of geotextile in RCC road to wrap the demolished waste at the interfaces, deformation in slab gets reduced and which is found 2.4 mm. The existing RCC slab in Nagpur found safe for 35 cm thick, at temperature differential of 21˚C, according to IRC 58:2002 and IRC 58:2011.

5.1 Future scope

Road construction is a sector where measures need to be taken in order to reduce the energy demand and environmental impact, and, in particular, to reduce the use of raw materials cost-effectively. The APSE project aims to contribute to sustainable development by adhering to relevant EU policies and reducing the environmental impact associated with the construction of roads. It aims to this by proving technologies that facilitate asphalt recycling, use of waste and novel greener binders, all integrated appropriately into optimal and eco-innovative designs of asphalt pavements, and thereby increasing their commercial viability. Based on the research conducted, it can be concluded that potential measures with sound sustainability credentials, including alternative binders and a wide use of recycled materials (including reclaimed asphalt and recycled materials derived from construction and demolition waste), can be adopted for widespread application in the right situations.

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