REDUCTION IN CARBON FOOTPRINT BY AGGREGATE STABILISATION

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ABSTRACT

A carbon footprint may be defined as the total amount of greenhouse gases primarily carbon dioxide released into the atmosphere by a particular human activity. A carbon footprint can be a broad measure to be applied to the actions of an individual, a family, an event, an organization, or even an entire nation. It is usually measured as tons of CO_2 emitted per year, a number that can be supplemented by tons of CO_2-equivalent gases, including methane, nitrous oxide and other greenhouse gases. The Indian road sector is constantly looking for the new technologies and innovations for the improved construction efficiency, conservation of resources, saving in construction cost as well as protecting the environment. The conventional method of road construction for the flexible pavement required significant amount of aggregate, other construction material and energy. UP PWD has adopted the latest technology of road construction including recycling and stabilization of pavement layers resulting in saving of huge quantity of aggregate, bitumen as well as transportation and energy. This paper outlines the case studies of projects executed by UP PWD using emulsion/foamed bitumen as a stabiliser of base layer and the resultant effect of carbon footprint.

1. CARBON FOOTPRINT GLOBAL AND COUNTRY ASSESSMENT

Five countries and the European Union emit the largest amounts of greenhouse gas emissions, together accounting for 63%, globally. China accounts for 27%, the United States for 13%, the European Union for 9%, India for 7%, the Russian Federation for 5% and Japan for 3%. These countries also have the highest CO_2 emission levels. In 2017, most of the five largest emitting countries and the European Union showed a real increase in greenhouse gas emissions, with India (+2.9%), China (+1.1%), European Union (+1.1%), Russian Federation (+1.0%) and Japan (+0.3%) (Except for the United States, where emissions remained constant, at 0.1%).

India's CO_2 emissions grew by an estimated 4.6% in 2017 and expected to rise to 6.2% due to its strong economic growth of 8% in 2019. Measured per person, India's emissions are still very low, at only 1.92 tonnes of CO_2 per capita (2017), which is much lower than the world average of 4.2 tonnes. But those emissions have been growing steadily, with an average growth rate of 6% over the past decade of 6%.

With India being the world's fourth largest emitter of CO_2, it is important to understand what the country's emissions are currently and where they might be headed. Given India's early stage of economic development, low per-capita emissions and its large population, there is significant scope for its emissions to increase. India's pledge under the Paris Agreement is to reduce the carbon intensity by 33-35% by 2030, compared to 2005 levels. Given projections of very strong economic growth over this period, emissions are expected to grow significantly.

2. STABILISATION

A huge amount is invested for maintenance, construction and up-gradation of roads in our country. Statistics show that the most investments are used on roads in comparison to other general infrastructures. The roads built with conventional methods do not satisfy the huge volume of loads any more. However, in developing countries like us there are many limitations e.g. limited time schedule, lack of good quality material, over loading passing trucks and above all budgetary allocations. The conventional methods may be costly and execution time consuming, new methods must be adopted for roads to increase the bearing capacity of the pavements.

The concept of soil modification through stabilization with additives has been around for several years. Even today, stabilization with manufactured additives such as lime, lime fly ash, Portland cement, bituminous materials, fibres and geo- synthetics are gaining popularity. Attention has been focused on substitute materials. In the cement stabilization, the cement and water, when combined, form

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cementitious calcium silicate hydrate and aluminates hydrates, which bind soil particles together and make the matrix compact.Stabilization of soils and aggregates with bitumen differs greatly from cement stabilization. The basic mechanism involved in bitumen stabilization is a waterproofing phenomenon. Soil particles are coated with bitumen that prevents or slows the penetration of water, which could normally result in a decrease in soil strength. The role of combined cement and bitumen emulsion is to increase the stiffness and elasticity of the stabilized layer.

Stabilization is the process of mixing a stabilizer, i.e; cement, with soil or imported aggregate to produce a material whose strength is greater than that of the original unbounded material. The use of stabilization to improve the properties of a material is becoming more widespread due to increased strength and load spreading ability that these materials offer. Stabilization technology is extremely relevant for heavily trafficked pavement where its benefits are being appreciated. There are different reasons for using stabilisation, ranging from lack of good quality materials to a desire to reduce quantum of aggregate, consume less energy & saving the natural resources & hence safeguarding the environment.

3. STABILISATION OF WMM LAYER

The main objective of stabilization is to improve the performance of material by increasing its strength, stiffness and durability. The addition of even small amount of stabilizer, for example up to 2 percent cement can modify the properties of a material. Large amount of stabilizer will cause a large change in properties of that material, for example 5 to 10 percent of cement added to clean gravel will cause it to behave like concrete & the pavement layer will be subjected to large shrinkage cracks.

The strength of stabilized material will depend on many factors. These include:

- The chemical composition of the material to be stabilized
- The stabilizer content
- The degree of compaction achieved
- The moisture content
- The success of mixing the material with the stabilizer
- Subsequent external environmental effects

Not all materials can be successfully stabilized, for example if cement is used as the stabilizer with sandy soil; it is more likely to yield satisfactory results as compared to soft clays. IRC-37 "Guidelines for the Design of Flexible Pavement" usually suggests stabilization of granular layer with small quantity of cement ranging from 2% to 4%. IRC-37 also suggests usage of Reclaimed Asphalt Pavements with the use of emulsion or foamed bitumen. With these guidelines, UPPWD completed many projects, which proved to be cost and performance effective. Stabilisation of base layer with emulsion and cement is also found effective and successfully executed in UPPWD.

4. CASE STUDIES OF THE EXECUTED PROJECTS

UPPWD started the concept of pavement layers stabilisation from 2013 by taking up few pilot projects in District Unnao and after successful completion and performance evaluation of the projects, number of other projects were started from Oct 2016. An international conference was organised by department in Dec 2017 on the subject topic. The conference was attended by Union Minister of Road Transport and Highways along with Chief Minister and Deputy Chief Minister of State along with Ministers of PWD, Principal Secretaries, officers of other States. eminent scientists of CRRI, IITs, consultants, highway engineers. Based on the discussions and deliberations, the stabilisation technique was broadly adopted in all projects of up gradation of roads, construction of village roads and maintenance of roads of state in year 2018-19.

The case studies of two projects executed in Hardoi and Azamgarh districts of Uttar Pradesh by the stabilisation of WMM by emulsion and cement shall be discussed in this paper.

4.1 Case Study-1: Widening and Strengthening of State Highway-5, Lumbini-Duddhi Road to two lane with paved shoulder

Widening & Strengthening of State Highway-5, Lumbini-Duddhi Road km 206.00 to 228.00 (length 22 km) was taken up using stabilization of WMM by foamed bitumen and cement. The stretch with existing granular crust of 22 cm was in dilapidated condition with huge traffic load having PCU of 15199 and CVPD of 1989. The Work was executed by stabilised WMM with following design parameters.

Table-1 Design Parameters

MSA	39
CBR 90th percentile in %	5%
Existing width	7.00 m
Proposed width	10.00 m
Crust Composition	
Existing granular Crust	220 mm
GSB in widening	220 mm
WMM stabilised by 1% Cement and 2% foamed bitumen	230 mm
DBM	70 mm
BC	40 mm

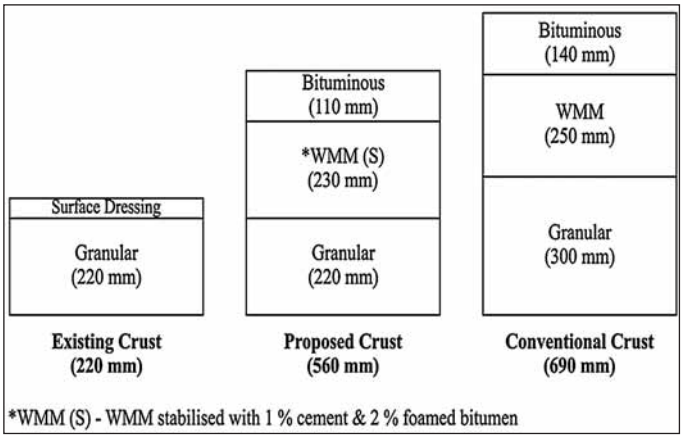

Photo-1

Construction of road work was completed in 2017. Inspection of road was carried out periodically to evaluate the condition and performance. The pavement was found in good condition and no cracks were appeared in the pavement.

4.2 Case Study-2: Widening and Strengthening of Pallia - Shahjahanpur - Hardoi - Lucknow Road (SH-25) to 2 lane with paved shoulder

Widening and strengthening of km.158.500-180.000, km.182.800-215.000 & km. 217.000-224.000 (50.700 km) of Pallia- Shahjahanpur-Hardoi-Lucknow Road (SH-25) to 2 lane with paved shoulder was sanctioned under State Fund using the stabilization of WMM with emulsion. The stretch is an important highway of State of Uttar Pradesh connecting Central UP to the Indo-Nepal border and passing through the world famous mango belt of Malihabad (Lucknow). The pavement stretch was upgraded to two lane with paved shoulder as per following design parameters.

Table-2 Strain Calculation by IITPAVE

Sl. No.	Strain	Allowable Strain	Computed Strain
1	Vertical Compressive strain at top of sub grade	392.94×10^{-6}	389.10×10^{-6}
2	Horizontal Tensile strain at top of Bituminous surface	216.34×10^{-6}	146.20×10^{-6}

The existing pavement was widened by GSB on either side and above it, fresh WMM material stabilized with 1% cement and 2% foamed bitumen was laid as per design carried out by IIPAVE. 70 mm DBM and 40 mm BC was also placed as per design.

Photo-2

Table-3 Design Parameters

MSA	31
CBR 90th percentile in %	5.42
Existing width	7.00 m
Proposed width	10.00 m
Crust Composition	
Existing Granular Crust	350 mm
widening of pavement	GSB-275 mm,WMM-75 mm
WMM stabilized with 1% cement and	
3.5% emulsion	75 mm
DBM	100 mm
BC	50 mm

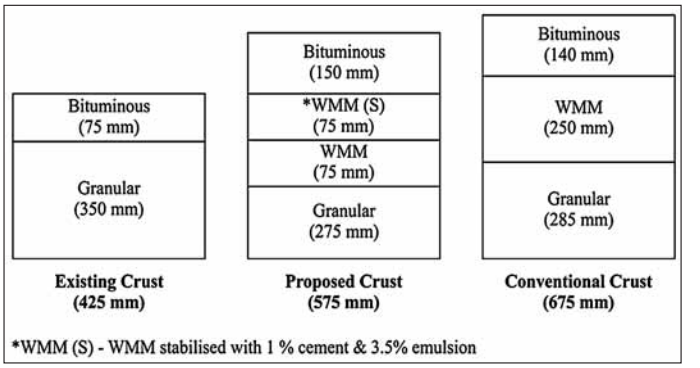

Table-4 Strain Calculation by IITPAVE

Sl. No.	Strain	Allowable Strain	Computed Strain
1	Vertical Compressive strain at top of sub grade	412.88×10^{-6}	358.00×10^{-6}
2	Horizontal Tensile strain at top of Bituminous surface	229.19×10^{-6}	151.00×10^{-6}

Photo-3

Photo-4

Construction of road work was completed in 2018. Inspection of road was carried out periodically to evaluate the condition and performance. The pavement was found in good condition and no cracks were appeared in the pavement.

5. ADVANTAGES OF STABILISATION WITH EMULSION

Stabilization of aggregate with emulsion (confirming to MoRTH/WMM grading) is much easier as compared to stabilization of aggregate with cement because proper stabilization of aggregate with cement requires cement spreaders and recycler. Normal to medium traffic can be easily allowed directly over emulsion stabilized layer after few hours, whereas in case of cement stabilized layer only after 7 days, light traffic can be allowed. Execution and quality control of emulsion stabilization is easier than aggregate stabilized with cement. There are many advantages in this technique.

- Reduction in pavement thickness
- Cost reduction
- Environment friendly due to less consumption of aggregates & energy.
- Stabilization of granular layer for base using 4% or higher cement usually develops cracks in top bituminous layer where as stabilization of base with emulsion does not result into any crack in bituminous top layer.
- Mixing of overall more percentage of cement in aggregate at site is difficult and can only be performed in proper way using cement spreader and recycler where as emulsion can easily be mixed with aggregate (WMM) at plant itself.
- Curing period of stabilized layer with cement is far more than stabilized layer of emulsion.
- Low to medium traffic can easily be allowed on bitumen stabilized layer while in cement stabilized layer, very low volume traffic can be allowed.
- Quality control of bitumen stabilized layer is easier than cement stabilized layer.
- Crack relief layer normally 75 mm to 100 mm is necessary over cemented base before applying bituminous layer to avoid shrinkage cracks where as bituminous layer DBM/BC can be placed directly over emulsion stabilized layer of base course.

6. REDUCTION OF CARBON FOOTPRINT

The most vital contribution of above type of construction technique is saving in quantity of fresh aggregate leading to reduction in project cost and more importantly reduction in carbon emission due to less mining, transportation of aggregate from quarry to construction site and saving of machines and allied T&P during the construction process. Thus overall it is having a significant step towards reduction of green house gas emissions.

The requirement of fresh aggregate was derived for two cases discussed above and total quantity of aggregate in each case is summarised below:

Table-5

Project Name	Quantity in Cum with stabilisation	Quantity in Cum with conventional method	Saving of aggregate Quantity in Cum	% Savings in qty
SH-5, Lumbini Duddhi Road	89320	117920	28600	24.25%
SH-25 Pallia-Shahjahanpur - Hardoi-Lucknow	153684	227883	74199	32.56%

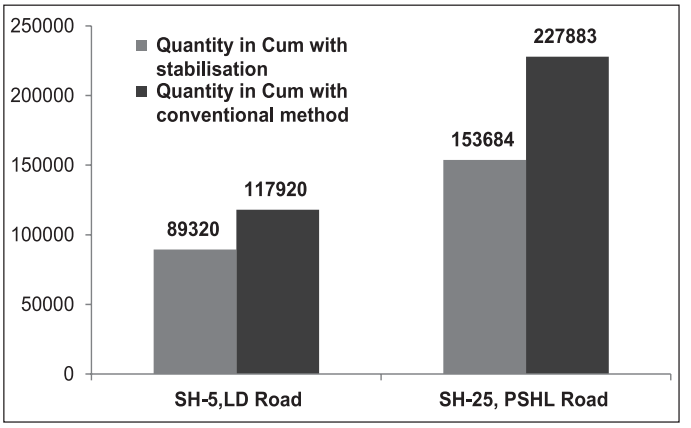

Photo-5

Based on above savings in aggregate quantity saving in carbon emission in ton equivalent CO_2 was derived as follows.

SH-5, Lumbini Duddhi Road - 14400 ton CO_2

SH-25 Pallia-Shahjahanpur-Hardoi-Lucknow - 37000 ton CO_2

Total carbon emission saved **- 51400 ton CO_2**

7. CONCLUSION:

The stabilisation technique has been in around for several years but it was not being used regularly in highway sector. As discussed above it has distinct advantages over conventional method of road construction with saving in construction time, reduction in use of fresh aggregate, less mining and transportation of material with huge environmental benefits including saving of carbon footprint.

8. ACKNOWLEDGMENT:

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OBITUARY

Prof. C. E. G Justo, Life Member of IRC, (LM-3399) passed away on 22nd June 2019. Prof. Justo had a long meritorious service as an eminent teacher for over four decades and he was an excellent researcher. Prof. Justo served as member of several technical committees of IRC. He was an eminent Highway Engineer and was awarded the **Life Time Achievement Award by the IRC** during the 78th Annual Session held at Bangalore in 2017. His rich contribution to the society was recognised by the Government of Karnataka and he was awarded the **Rajyotsava Award,** the highest State Award in 2018. He served as a faculty member at the T.K.M. College of Engineering, Kollam, University of Rookee (now IIT Roorkee) and retired as Professor of Civil Engineering at Bangalore University. He served as an Emeritus Professor at Bangalore University till 2000.

May his soul rest in peace