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INTERIM RESEARCH FINDING REPORT

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Comparison between Cement and StabilRoad Stabilizer

Stabilization of pavement layers dates back to over 2000 years ago when the Romans used lime to improve the quality of the base and sub-base layers. Epps et al. [1979] state that material modification became prominent in the road and airfield constructions after the Second World War; this was predominantly due to scarcity of conventional aggregates. Currently increased in axle loads contribute towards the use of cement-stabilized layers in both road and airfield pavement constructions.

Ordinary Portland cement [OPC] is preferred for stabilizing materials, which consists of calcium oxide, calcium silicates and aluminates. The cement hydrates forming hydrated compounds in the presence of moisture, which eventually harden over time producing a cemented matrix. The cemented matrix binds the material particles together and is responsible for an increased strength. Strength of stabilized materials originates from the hydrated cement matrix, [Epps et al. 1979; Lay, 1986; TRH13, 1986]. Stabilization using cement has proven successful with most materials except with soils or gravels that contain high organic content. High organic matter retards the hydration process causing less cementation effect, [Bofinger et al. 1978 and Paige-Green, 2008]. The amount of cement in the mix plays major role in the performance and quality of material. The performance of the material along with the added cement content affects the overall properties and characteristics after stabilization. Despite of these advantages cement-stabilized layers exhibit specific problems related to material characteristics, construction procedure, as well as overall stabilization. Even though the application of cement results in improved engineering properties, the manifestation of shrinkage cracks could cause detrimental effects to the pavement structure.

This problem can be minimized by using StabilRoad additive in a significant amount with cement which fills the pores in the gel and provide adequate resistance to shrinkage after an initial expansion by changing the parameters of the bending strength of mix as a result which, chances of cracking can considerably be reduced. The use of StabilRoad with cement leads to the alteration of their functionalities and properties. Use of StabilRoad additive in cementitious materials reported improved characteristics and performance criteria.

Mitigation of Shrinkage Cracks

Some amount of moisture is present in freshly compacted stabilized layer, which is partly consumed by the hydration process, and the rest is lost through evaporation. The exposure of the layer to temperature and air [thermal effects] results in the evaporation of moisture. The rate of moisture loss [evaporation] is dependent on the prevailing temperature and humidity. As the stabilized layer dries out, it tends to reduce in size [shrink] due to the loss of moisture. However, the layer is restrained to a certain degree, which contributes to the development of tensile stresses. Shrinkage is due to the self-desiccation [drying-out] of material. Several factors, including restraints, thermal effects and material characteristics influence the rate and magnitude of shrinkage and the resultant cracking, [George, 1973; Bofinger et al, 1978].

By using the StabilRoad additive in a corresponding amount with the amount of cement, there is a reaction of nano-$SiO2$ particles with calcium hydroxide crystals leads to a reduction in size and amount of crystals. As a result, the interfacial transition zone of aggregates and cement besides the general microstructure are changed. A reduction of the material porosity not only influences the permeability properties but the loss of moisture; this alters the resultant total shrinkage.

Material Behavioral Properties and Strength

Material behavioral properties reflect mechanical and deformation properties in addition to the resultant response because of loading and non-loading effects. The mechanics of deformation and cracking behavior of stabilized layers are identified by their deformation and response criteria. Several factors affect fracture mechanics attributed to cement-stabilized materials, which includes:

a) Mode of loading pertaining to specimen geometric characteristics

b) Material bond-strength

c) Cracking behaviour

In order to ensure the quality of stabilized materials, strength tests are carried out, [Lay 1986]. UCS test was conducted using IS: 2720 Part-10. The strength of the mix was determined by varying percentages of cement and optimum doses of StabilRoad additive (4 % by weight of cement). The samples were tested after 7 and 28 days. After the curing period, the specimens were tested for their unconfined compressive strength. The results of the test specimen are presented in Table 1. The UCS value of samples contains StabilRoad with cement satisfy the IRC specified range for UCS (i.e. 4.5 to 7 MPa in 7/28 days curing period).

Table 1. Test Results of UCS with and without StabilRoad Stabilizer.

Sample Designation	**Curing Periods (Days)**	**UCS (MPa)**
Sample1 (3 % Cement)	7	2.7
Sample2 (4 % Cement)		3.4
Sample3 (5 % Cement)		4.2
Sample 4 (3% Cement + 4% Stabil Road)		3.7
Sample 4 (4% Cement + 4% Stabil Road)		4.7
Sample 4 (5% Cement + 4% Stabil Road)		5.8
Sample1 (3 % Cement)	28	3.1
Sample2 (4 % Cement)		4
Sample3 (5 % Cement)		4.9
Sample 4 (3% Cement + 4% Stabil Road)		5.1
Sample 4 (4% Cement + 4% Stabil Road)		6.2
Sample 4 (5% Cement + 4% Stabil Road)		7.1

To assess the gain in strength of stabilized soil in terms of California Bearing Ratio (CBR) value, CBR tests were carried out as per IS: 2720 Part-16. The tests were conducted on various mixtures of Soil, Cement and Stabilizer as shown in Fig.2. The percentage of cement was fixed on the basis of results to 2% by weight of soil and the percentage of stabilizer was varied from 0.5% to 1.5% by weight of cement. Samples were prepared for both, Soaked and Unsoaked CBR tests.

Table 2: Comparison of compaction characteristics (Soil+Cement)

Compaction Characteristics	0 % Cement	2% cement	3% cement
Unsoaked CBR (%)	12	21.28	24.12
Soaked CBR (%)	**2.12**	**11**	**14**

Table 3: Comparison of compaction characteristics (Soil+Cement + Stabil Road)

Compaction Characteristics	2 % Cement + 0.5% Stabil Road	2 % Cement + 1.0% Stabil Road	2 % Cement + 1.5% Stabil Road
Unsoaked CBR (%)	19.55	26.96	21.75
Soaked CBR (%)	**9.45**	**12.92**	**11.12**

A series of CBR tests were conducted using different percentages of cement presented in Tables 2 & 3. The Soaked CBR values showed a remarkable increase from 2% to 11% and further 14% with addition of cement. The un-soaked CBR values changed substantially from 12% to 21% and further 24% with addition of cement. Similarly by adding 1% StabilRoad additive with cement soaked CBR and un-soaked CBR values also changed substantially. After adding 1.5% StabilRoad additive with cement the CBR value decreased when compared to test specimen containing 1% StabilRoad stabilizer.

Figure 2. CBR Test

Durability Test

Long-term behavior of cement-stabilized materials depends on the assessment of their durability. Durability is a time-reliant factor influenced by the present state of the material pertaining to the level of weathering. In evaluating the durability of stabilized materials, wetting and Drying test, Freezing and Thawing test are carried out as per IS 4332 Part 4. The durability of a cement-stabilized layer is primarily concerned with the effect of chemical reversal associated with moisture intrusion and movement, [Paige-Green et al. 1990]. In order to ensure that the cement-stabilized layer is capable of providing a long-term service, implementation of control measures during design and construction are emphasized. Core samples of StabilRoad (Cement+StabilRoad) stabilized base were collected from Lalru, Punjab and durability tests were performed. All the samples (Both conditioned and unconditioned) satisfies IRC: SP-89:2018 criteria. The test results are shown in Table 4.

Table 4: Result of Durability Test

	Freeze and Thaw	
Sample Designation	**Weight Loss after 12 Cycles (in gm)**	**Weight Loss (%) after 12 cycles**
FT-1	123	1.58
FT-2	81	1.03
FT-3	95	1.06
FT-4	69	0.94
FT-C1	68	1.00
FT-C2	22	0.32
FT-C3	48	0.89
FT-C4	82	1.17

FT-C5	47	0.75
Wetting and Drying		
WD-1	203	2.70
WD-2	229	2.30
WD-3	231	2.47
WD-4	209	2.35
WD-C1	252	2.66
WD-C2	189	2.25
WD-C3	203	2.70
WD-C4	253	2.07

Merits:

1) Apart from improved strength and durability characteristics, materials stabilized with Stabilroad additive along with cement results in lower dosage of cement as compared to the conventional cement treated base course/sub-base course.
2) Materials stabilized with Stabilroad additive not only yields better strength but also results in improved elastic and thermal properties of the mix, hence chances of cracking and shrinkage cracks reduced significantly.
3) The layer treated with Stabilroad additive with cement can be treated as top layer even without BC for low volume roads.
4) Layer thickness of bound layers like PQC, CC, DBM or BC can be significantly reduced as a result of strong and durable supporting base beneath top layer.
5) Layers treated with Stabilroad additive along with cement can be designed for as low as less than 2 MSA to much higher MSA catering to rural roads to highways, airfield constructions and high load bearing container terminals and berth area at ports.
6) Fuel cost is saved as it is in situ stabilization technique, so the complete construction activity can be carried out at site in one single go.
7) It gives us a stable base and also accelerates cement hydration process.
8) There is little or no significant need for the purchase and transportation of virgin aggregates.

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