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Soil Stabilization by Using Eco-Friendly Bio-Enzyme in Road Construction

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Abstract: In embryonic countries like India the most imperative requirement of any project after performance criteria is its economical prospect and service ability criteria. The conservative methods are time consuming and are not economically feasible. Hence, it is necessary to find out the other substitute to gratify the performance and efficiency. Bio-enzymatic effects on soil sample are discussed below. Nowadays, soil stabilization through bio-enzyme is a new and world famous technique. Soil stabilization is the method which improves properties of soil. Soil is used as sub base and base material, if strength of soil is poor, then stabilization is usually required. Bio-enzyme, a liquid organic formula is used as a soil stabilizer, which boost the engineering characteristics of soil through cationic exchange. It provides chance to enhance the characteristics of dirt roads having high percentage fines constructed with soil, through bio-enzymatic stabilization. Nowadays some bio-enzymes like Terra-Zyme, Renolith, Fujibeton and Perma-Zyme are most efficient and economical in soil stabilisation. Most important advantage of the bio-enzyme is that these are eco- friendly. To transform the engineering properties of soil, mixing of bio-enzymes in soil sample takes place. There are many factors like dose of bio enzyme, soil type and condition of field plays vital role for their efficiency. Due to unconsciousness among engineers and scarcity of standardized data soil stabilization through bio-enzyme is not widely used. However, recently in various parts of India construction of roads which are stabilized through bio-enzyme gives better performance.

Keywords: Bio-enzyme, Cationic exchange, Cost efficient, Eco-friendly, Feasibility, Non-traditional, Soil stabilizer.

I. Introduction

The importance of enzyme products for the treatment of soil and also helps for enhancement in horticultural applications gives idea of using enzyme for soil stabilization in construction of pavement was developed. The bonding capacity and wetting of the soil particles increased after adding the enzymes in soil. To accelerate a slower rate compound reaction, without end product a organic catalyst named bio enzymes are used. Because of this property a infinitesimal amount of bio enzyme is essential for soil stabilization. For an enzyme to be vigorous in a soil, it must have mobility to accomplish at the reaction site. The stoma fluid existing in the soil provide mobility of the molecules of bio enzyme, the reaction site provided by specific soil chemistry , and time taken in diffusion . An enzyme would stay active in a soil until there are no more reactions to catalyze. Enzymes would be expected to be very soil specific. An enzyme which is in liquid form and non-flammable, natural non-corrosive, non-toxic in nature dissolved from vegetable extracts called Bio-enzyme. It also enhanced the engineering qualities of soil, foliates advanced soil compaction densities and increases strength. The reactions between organic actions and the clay are catalyzed by enzymes. Adsorbed layer thickness is reduced due to acceleration induced by enzymes in the cationic exchange process. It is difficult to mix chemicals in soil thoroughly, but bio-enzyme at optimum moisture content easily mixed with water and after that garnish soil for compaction. The diminishing availability and increasing cost of construction materials along with the uncertain economic climate forces engineers to consider more economical methods to build roads using locally available materials which are outside the existing condition.

II. Behaviour of Clay Particles

The mineralogy of clay particles produces a thin platy structure with large surface areas and a net negative charge. Because of the large surface area and negative charge in clay particles, electrostatic forces often control their behaviour in a soil water mixture rather than simple gravitational forces. To balance the negative charge positively charged ions creates a film of water around the clay particle that remains attached or absorbed on the clay surface. This layer has well-organized structure dissimilar from that of free water. The negatively charged clay platelet and the swarm of actions are referred to as an electrical double layer. The absorbed water in the electrical double layer gives clay particles their plasticity or the ability to deform without cracking. The plasticity of the soil increases with increase in thickness of the double layer. In addition, as the double layer increases the clay platelets exert greater repulsive forces and push each other further apart. In some cases, the clays can swell enough to cause significant damage to structures constructed using them. By cation exchange method the thickness of the electrical double layer can be reduced. The cations surrounding the clay particles are termed “exchangeable cat ions” because, in most cases, one type may be exchanged with cations of another type. There are some typical cations in soils like sodium, magnesium, calcium, iron, and potassium. A cation with a higher valence (positive charge) or smaller diameter can balance the negative charge on the clay particle in a shorter distance for a given concentration level. For example, if the negative charge is initially balanced by sodium cations with a 1 + charge (Na^+) and the cations are exchanged with calcium cations with a 2 + charge (Ca^{2+}), then the double electrical layer thickness will be reduced by half. This reduces the water absorbed on the clay particles, which in turn reduces the plasticity of the clay particle and the tendency for swelling. The loss of absorbed water also tends to increase the strength of the molecular structure of the clay.

III. Mechanism of Soil Stabilization with Bio-Enzyme

Bio-enzyme is an organic soil stabilizer produced by a fermentation process, which utilizes microorganism to produce enzymes, which are non-toxic and eco- friendly. When applied in soil the enzyme attaches molecules to the clay platelets, the negative charges on the clay platelets are neutralized through this process and the size of the electrical double layer shrinks. This limits further absorption of water or the resultant swelling with loss of density. Reactions, which might otherwise take years to occur, can be carried out in weeks. While some soil strength gain will become apparent within days, field research indicates that the strength will continue to increase over a period of several weeks. In a case study, one type of bio-enzyme has been used for stabilization of different types of soil with varying index properties. Detailed laboratory tests were carried out to ascertain the benefits in terms of reduction in design thickness. To calculate the suitability of bio-enzyme as soil stabilizer, five types of soil were taken for the study with low clay content to very high clay content. Several Laboratory tests were done to determine the engineering properties of soil and strength characteristics of soil with and without bio-enzyme stabilization.

IV. New Approach of Design

Bio-enzyme offers road engineer a lucrative solution with regards to the construction of roads in areas where the soil has a high percentage of fines. Bio-enzyme stabilized soil can be used as a sub base, base or driving surface depending upon the requirements of the road. In areas where low traffic intensities restrict substantial investments in road construction, such as forestry, rural and agricultural areas, the economy still needs to be stimulated by a decent infrastructure. Roads, which form an important part of this infrastructure, should have limited life-cycle cost and a long life span to benefit the local economy. Soil stabilization with bio-enzyme provides governments an opportunity to provide high quality road structures to developing areas with low cost. In such areas stabilized soil can provide a good riding smoothness without an asphalt layer for a considered amount of time. Tarring can take after three or more years when the budget has sufficient means or the road can be utilized as a dirt road for a considerable amount of time. This design concept is being followed by some private agencies in some countries such as Brazil and Peru. In India, also, this design approach has been adopted as experiment field trial sections.

The performance of field trials will determine and validate the new concept. In the new design approach, a bio-enzyme treated soil layer (with 20% aggregates of 40 mm) is laid in place of granular base course thus saving arises in terms of pavement thickness and aggregates. The details are shown in Tables I & II.

Table I: Pavement Design Thickness on Clayey Soil without Stabilization

Cumulative Traffic (MSA)	*Total Pavement Thickness (mm)*	*Pavement Design Thickness*			
		Bituminous Surfacing		*Granular Base (mm)*	*Granular Sub Base (mm)*
		Wearing Coarse (mm)	*Binder Coarse (mm)*		
1	675	22PC	-	230	440
2	725	22PC	50BM	230	445
4	760	22PC	70BM	255	445
6	800	25SDBC	70DBM	255	455
10	860	22BC	100DBM	255	455

Table II: Pavement Design Thickness on Clayey Soil with Stabilization

Cumulative Traffic (MSA)	*Total Pavement Thickness (mm)*	*Pavement Design Thickness*			
		Bituminous Surfacing		*Granular Base (mm)*	*Granular Sub Base (mm)*
		Wearing Coarse (mm)	*Binder Coarse (mm)*		
1	435	22PC	-	230	210
2	495	22PC	50BM	230	220
4	535	22PC	50BM	255	235
6	580	25SDBC	55DBM	255	255
10	665	44BC	70DBM	255	305

V. Benefits

Bio-enzymatic soil stabilization has immediate positive influences on the financial system of rural areas where the road network has been stabilized. Consumption of fuel in vehicles will be reduced because of the enhanced traffic flow on these roads**.** Table III shows the comparative results of conventional and bio-enzyme design with 12% saving in economy in roads with bio-enzyme stabilization. Consumption of bio-enzyme can have an affirmative effect on the atmosphere. First of all, bio-enzymes are non-aggressive products, which do not completely change the chemical composition of the soil, which they stabilize. Being non-hazardous in nature, they do not pose a health hazard to the labourers used in the construction of roads. And by providing engineers with the possibility to utilize a relatively wider range of soil types and reducing the need for large quantities of crushed rock in the construction of roads, they reduce the need for mining of aggregates for road construction.

Table III: Design Comparison for a Road with CBR 4 and MSA = 1

Soil	*Conventional Design*			*Bio-enzyme Design*		
		Cost/m^2	*Thickness mm*	*Thickness mm*	*Cost/m^2*	
1	Sand Gravel mix	76.50	255	-	-	Sand gravel mix
2	WBM-grade II	45.75	75	225	240	WBM grade II
3	WBM grade II	45.75	75	-	-	WBM grade II
4	WBM grade III	50.25	75	-	-	WBM grade III
5	Pre mix carpet with seal coat	80.00	20	8	22.50	Only seat coat
	Total	298.25	500	233	262.50	
	Savings					35.75(12%)

VI. Conclusion

From the above discussion following conclusions can be drawn:

1. The bio-enzymes are non-hazardous, crude and recyclable in nature and not harmful for humans, fish, vegetation or animals, in normal use. These are made from untreated materials and are ecological.
2. By using bio-enzyme, aggregate free pavement is achievable as its use promotes the use of nearby existing material.
3. Bio-enzyme act as a dust control agent, as it reduces 75% dust on un-surfaced roads in several construction works.
4. A bio-enzymatic soil stabilizer offers decrease life cycle cost of roads by reducing the construction and maintenance cost. As compared to other traditional soil stabilization methods, it is proven more economical that bio-enzyme used in pavement construction. With the use of bio-enzyme, construction cost of project can be abridged.
5. By varying the cationic structure of soil, bio-enzyme raise the load bearing capacity of soil of such an extent that the soil, which is deemed inappropriate for conventional road construction purposes, can be utilized in the construction of high quality road structures.
6. Bio-enzymes provide elasticity and resilience to the pavement and also decrease the crack formation.
7. Hardness and compressive strength of stabilized soil are increased by using bio-enzymes in soil stabilization.
8. Shrinkage and swelling properties of clays are diminish with the use of bio-enzymes.
9. Bio-enzyme application does not require specialized equipment; ordinary road construction equipment is more than sufficient to execute satisfactorily the stabilization of soil.

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