ECONOMIC ANALYSIS OF FLEXIBLE PAVEMENT BY USING SUBGRADE SOIL STABILISED WITH ZYCOBOND AND TERRASIL

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Abstract: When poor quality soil is encountered at construction site, the structure can be designed accordingly or the unsatisfactory soil can be replaced with a suitable soil borrowed from nearby area. Another option is to modify the properties of the existing soil so that it meets the design requirements. This last alternative has led to the development of soil stabilization techniques. Cementing method of soil stabilization is an established procedure of improvement of ground used as sub-grade for pavements. In view of this, apart from the conventional cement, several commercial stabilizers have emerged in the last few years. In line with this, an attempt has been made in the present study to evaluate the effectiveness of one of the new commercial stabilizers viz., Zycobond, Terrasil manufactured by Zydex industries. In this paper, the economic analysis has been done on both flexible and rigid pavements. These cost analyses play a great role on the decision-making stages in selection of pavement types. The pavements were designed under different traffic conditions and soils treated with zycobond and Terrasil. Thickness design of flexible pavement has been conducted as per the IRC:SP:72 2015. Costs are calculated and construction costs have been determined for both flexible and rigid pavements according to BoQ based on MORTH and compared.

1. INTRODUCTION

The research aims at assessing the economic viability of using terassil and zycobond for flexible and rigid pavement in road construction.The materials used in the present work are clayey soil, zycobond and terrasil.Characterization of these materials is as given in the following sections.

1.1 Characteristics of Clayey Soil

Clayey subgrade soil is used in the present work was collected from Kothapally village near Bheemadevarapally mandal, Karimnagar district, Telangana. The index and engineering properties of the soil used in this work are presented as in Table 1.

Table 1. Characteristics of the Subgrade Soil before Stabilization

Parameter	Value
Specific gravity	2.58
Differential Free Swell %	90
Liquid Limit %	60
Plastic Limit %	35.4
Plasticity Index %	24.6
Gravel Size Particles %	0%
Sand Size Particles %	33%
Silt Size Particles %	42%
Clay Size Particles %	29%
MDD (ISHCT)	1.74g/cc
OMC (%)	16.5%
Classification as per IS:1498-1970	CH
UCC kg/cm^2	1.82
CBR Unsoaked %	2.7
CBR Soaked 4days %	2.18

1.2. Characteristics of Zycobond

Zycobond is a sub-micron acrylic copolymer emulsion with long life of above 10 years for bonding soil particles. It imparts water proofing and resists water ingress through the unpaved areas like shoulders and slopes.Characteristics of the chemical stabilizer used in this work are shown in Table 2. It is manufactured by ZYDEX INDUSTRIES.A photograph of it is shown in Fig.1

Fig.1 Zycobond Sample

Table2 Properties of Zycobond

Property	Value
Colour	Milky White
Odour	No
Flash point	above 100^{0}C
Explosion hazard	No
Ignition temperature	above 200^{0}C
Solubility in water	Dispersible
pH value	5-6

1.3. Characteristics of Terrasil

Terrasil is nanotechnology based 100% Organosilane, Water soluble, Ultraviolet and Heat stable, Reactive soil modifier to waterproof soil subgrade. It is available in concentrated liquid form and is to be mixed with water in specified proportion before mixing with the soil.

Characteristics of the chemical stabilizer Terrasil used in this work is shown in Table 3. It is manufactured by ZYDEX INDUSTRIES.A photograph of it is shown in Fig.2

Fig. 2 Terrasil Sample

Table.3 Technical specifications of Terrasil

Property	Description
Appearance	Pale yellow liquid
Solid content	68+2%
Viscosity at 25^{0}C	20-100 cps
Specific gravity	1.01
Solubility	Forms water clear solution
Flash Point	Flammable 12^{0}C
Dosage	1% per m^3

2. LITERATURE REVIEW

A few reviews of the significance research work under taken by different researchers on this subject is briefed below:

Supakij Nontananandh et al. (2009) Carried research on clayey soil with cement to investigate major hydration products which contribute strength development by using X-ray diffractometer (XRD).Ordinary Portland cement was mixed with the soil at a mix proportion of 200 kg/m^3. Cylindrical specimens were prepared for unconfined compression strength tests at curing times of 3, 7, 14, 28 and 90 days, respectively. Subsequently, X-ray diffraction (XRD) analysis was performed after strength tests. Experimental results showed that strengths of the soil significantly increased with curing time, especially at short term (before 28 days) while, strengths slightly changed at long term. They concluded that strengths of a soft marine clay significantly increased when mixed with cement at a suitable content. It was found that growths of CSH and ettringite with curing time were similar to strength characteristic curves. Strengths were increased proportionally with amounts of the major hydration products such as CSH and ettringite that formed. It was therefore concluded that hardening effects of the cement-stabilized marine clay was substantially influenced by the formation of the major reaction products such as calcium silicate hydrate (CSH) and ettringite.

Degirmenci et al. (2007) investigated phosphogypsum with cement and fly ash for soil stabilization. Atterberg limits, standard Proctor compaction and unconfined compressive strength tests were carried out on cement, fly ash and phosphogypsum stabilized soil samples. Treatment with cement, fly ash and phosphogypsum generally reduces the plasticity index with increase in MDD with cement and phosphogypsum contents, but decreased as fly ash content increased. The OMC decreased and UCS increased with addition of cement, fly ash and phosphogypsum.

Ramakrishna and Pradeep Kumar(2006) had studied combined effect of rice husk ash (RHA) and cement on engineering properties of black cotton soil. RHA up to 15% in steps of 5% and cement up to 12% in steps of 4% were added. RHA and cement reduced the plasticity of the expansive soil. The dry density of soil increased marginally with increase in OMC after 4% cement addition. MDD of soil decreased and OMC increased with the increase in the proportion of RHA- cement mixes. The UCS of Black cotton soil increased linearly with cement content up to 8% and at 12%, strength rate reduced. The soaked CBR of the soil was found to be increased with cement and RHA addition. Similar trends to that of UCS were observed with the increase in CBR rate. At 8% cement content, CBR value of soil was 48.57% and with combination of RHA at 5%, 10% and 15%, the values were 54.68%, 60.56% and 56.62%, respectively.

Amu et al.(2005) studied cement and fly ash mixture for stabilization of expansive clayey Soil. Three different classes of sample (i) 12% cement, (ii) 9% cement + 3% fly ash and (iii) natural clay soil sample were tested for maximum dry densities (MDD), optimum moisture contents (OMC), California bearing ratio (CBR), unconfined compressive strength (UCS) and the Undrained Triaxial tests. The results showed that the soil sample stabilized with a mixture of 9% cement + 3% fly ash is better with respect to MDD, OMC, CBR, and shearing resistance compared to samples stabilized with 12% cement, indicating the importance of fly ash in improving the stabilizing potential of cement on expansive soil.

Lu Jiang et al. (2004) studied the stabilization effects of surplus soft clay with cement and GGBS. Addition of slag in cement induced higher strength than cement alone for longer curing time. The strength characteristics are determined by addition of 10%, 15%, 20%, 30% cement to weight of dry soil. Clay sample mixed with 10%cement and GGBS of 10%,15%,20% of dry soil and another clay sample mixed with 15%cement and GGBS of 10%,15%,25% is kept curing for 7,14,28 days. The test results showed that the slag is successful to partially replace the cement content for stabilising soft clays.

3. METHODOLOGY

The design procedure adopted and the economic cost calculations are described below:

3.1. Design of Flexible Pavement as per IRC:SP:72-2015

3.1.1. Pavement Thickness and Composition Before Stabilization

For the Traffic of 2MSA, referring to the Traffic category in the range 1,500,000 to 2,000,000 and the Subgrade category of CBR 2 to 3, any of the following two alternate designs may be adopted, based on cost economics.

a) Using gravel base and sub-base : A total thickness of 725mm. However 200mm modified soil, 250mm granular sub-base, 225mm base of gravel and 50mm bituminous macadam provided. The specifications for a Gravel Road as per Clause 402 of the specifications for Rural Roads should be adopted.

b) Using cement treated base and sub-base : A total thickness of 400mm as per Fig.6.However 125mm cement treated sub-base, 150mm cement treated base, 75mm crack relief aggregate layer and 50mm bituminous macadam provided. The specifications for a cement stabilized base and sub-base , as per clause 404 of the Specification for Rural Roads should be adopted.

3.1.2 Pavement Thickness and Composition After Stabilization

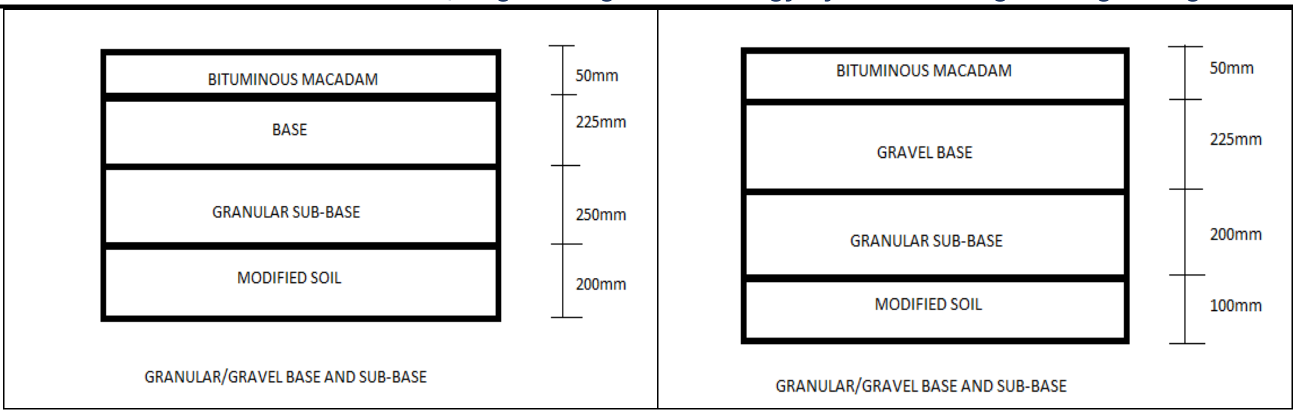
For the Traffic of 2MSA, referring to the Traffic category in the range 1,500,000 to 2,000,000 and the Subgrade category of CBR 3 to 4.

a) Using gravel base and sub-base : A total thickness of 575mm. However 100mm modified soil, 200mm granular sub-base, 225mm base of gravel and 50mm bituminous macadam provided. The specifications for a Gravel Road as per Clause 402 of the specifications for Rural Roads should be adopted.

b) Using cement treated base and sub-base : A total thickness of 350mm as per Fig.6.However 125mm cement treated sub-base, 100mm cement treated base, 75mm crack relief aggregate layer and 50mm bituminous macadam provided. The specifications for a cement stabilized base and sub-base , as per clause 404 of the Specification for Rural Roads should be adopted.

3.1.3 Comparison of pavement thickness before and after Stabilization of soil

Before Stabilization	After Stabilization
1)Total thickness of pavement 725mm if we provide gravel base and sub-base and 400mm for cement treated base and sub-base as per IRC:SP:72-2015	1)Total thickness of pavement 575mm if we provide gravel base and sub-base and 350mm for cement treated base and sub-base as per IRC:SP:72-2015



3.1.4 Cost and Economic Analysis of Flexible Pavement According to BoQ Based on MORTH

Economic analysis of flexible pavement has been conducted for the following two cases by assuming Length of road: 1000 m and width of driving lane as 3.75 m (single lane).

Case-1: Without Stabilization

Cost estimate for the flexible pavement crust thickness as obtained for without the soil stabilization is as follows:

i) Supplying and filling in with good earth for construction of subgrade and earthern shoulder in regular layers including watering, consolidation by power road roller etc complete.

= 221.00 per m^3 (MORTH Spec.301)

Quantity of Modified soil = 1000*3.75*0.2= 750 m^3

Total cost = 750*221.00 = 1,65,750.00/-

ii) Construction of granular sub-base by providing close graded material (Grading l), mixing by mix in place method with rotavator at OMC, and compacting with vibratory roller to achieve the desired density = 2,219.00 per m^3(MORTH Spec.401)

Quantity of Sub-base material = 1000*3.75*0.25 = 937.5 m^3

Total cost = 937.5*2,219.00 = 20,80,312.5/-

iii) Providing, laying, spreading and compacting graded stone aggregate to wet mix macadam specification including premixing the Material with water at OMC in mechanical mix plant.

= 2,298.00 per m^3 (MORTH Spec.406)

Quantity of Base material = 1000*3.75*0.225 = 843.75 m^3

Total cost = 843.75*2,298.00 = 19,38,937.00/-

iv) Providing and laying dense graded bituminous macadam with 100-120 TPH batch type HMP producing an average output of 75 tonnes per hour using crushed aggregates of specified grading, premixed with bituminous binder @ 4.0 to 4.5 per cent by weight of total mix and filler (as per MoRTH specification clause No. 507 complete in all respects).

= 7,650.00 per m^3(MORTH Spec.507)

Quantity of Bituminous macadam = 1000*3.75*0.05 = 187.5 m^3

Total cost = 187.5*7,650.00 = 14,34,375.00/-

Overall cost of Flexible pavement for laying 1km length = 56,19,374.50/-

Case-2: With Soil Stabilization

Cost estimate for the flexible pavement crust thickness as obtained for with soil stabilization is as follows:

i)Supplying and filling in with good earth for construction of subgrade and earthern shoulder in regular layers including watering, consolidation by power road roller etc complete.

= 221.00 per m$^{\wedge 3}$(MORTH Spec.301)

Quantity of Modified soil = 1000*3.75*0.1= 375 m$^{\wedge 3}$

Total cost = 375*221.00 = 82,875.00/-

ii) Construction of granular sub-base by providing close graded material (Grading l), mixing by mix in place method with rotavator at OMC, and compacting with vibratory roller to achieve the desired density = 2,219.00 per m^3(MORTH Spec.401)

Quantity of Sub-base material = 1000*3.75*0.2 = 750 m^3

Total cost = 750*2,219.00 = 16,64,250.00/-

iii) Providing, laying, spreading and compacting graded stone aggregate to wet mix macadam specification including premixing the Material with water at OMC in mechanical mix plant carriage of mixed Material by tipper to site, laying in uniform layers with paver in base course on well prepared surface and compacting with vibratory roller to achieve the desired density.

= 2,298.00 per m^3(MORTH Spec.406)

Quantity of Base material = 1000*3.75*0.225 = 843.75 m^3

Total cost = 843.75*2,298.00 = 19,38,937.00/-

iv) Providing and laying dense graded bituminous macadam with 100-120 TPH batch type HMP producing an average output of 75 tonnes per hour using crushed aggregates of specified grading, premixed with bituminous binder @ 4.0 to 4.5 per cent by weight of total mix and filler (as per MoRTH specification clause No. 507 complete in all respects).

= 7,650.00 per m^3 (MORTH Spec.507)

Quantity of Bituminous macadam = 1000*3.75*0.05 = 187.5 m^3

Total cost = 187.5*7,650.00 = 14,34,375.00/-

Overall cost of Flexible pavement for laying 1km length = 51,20,437.00/-

4. CONCLUSIONS

The following conclusions can be made based on the present laboratory investigations and the economic analysis:

(a) The use of combination of bio-enzimes such as Zycobond and Terrasil with subgrade soil is found to be a definite improvement in the engineering properties and California Bearing Ratio (CBR) value

(b) The pavement design as per IRC:SP:72-2015 reveals that there will be definite decrease in thickness of the flexible pavement

(c) The savings in construction cost of the flexible pavement is found to be Rs.4,98,937/- per km length and it is worked out to be about 8.9% of overall cost of the construction.

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