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Stablisation of Expansive Soils by Fly-ash & Wool Waste

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ABSTRACT- In the current study, an effort has been made to stabilise the local expansionary soils using the appropriate mix of locally accessible industrial waste with or without lime. In this study, a sample of high expansive soils was employed taken from Rajpura (PB) and a sample of low expansion soils. Industrial waste like fly ash and wool from local businesses are utilised as additions to stabilise soil both. Fly ash and wool waste are individually added to soils with varying quantities (from 5 to 30 percent) and the weight of a dry soil blend increases by 5 percent. The geotechnical qualities of solar mixes are examined by a range of experiments such as CBR, unconfined compression, triaxial compression and consolidation tests. After 9 days of water treatment, the uncontained compression and triaxial compressive tests are performed on the soil-fly ash and soil-wool waste samples. The samples of soil-fly ash and soil-wool waste are shown to reduce the plasticity, swelling and compressibility by increasing additives and increasing matching CBR, shear strength and permeability.

KEYWORDS-Stablisation; Eco-friendly; Economical; Waste Reduction.

I. INTRODUCTION

Large-scale industry and contemporary urbanization have given rise to a surge in infrastructure demand in the nation. The construction industry is left with no option except to carry out building operations on any available property, regardless of appropriateness or other factors. As a result, if land is deemed to be inappropriate, adoption of sound and efficient engineering procedures is needed. In the past, inappropriate ground (clay which is soft and compressible, expansive clay, and deformable subsoil) had been harmful to normal foundation. However, after being modified, it may be used for building purposes. Extreme seasonal fluctuation in weather is required to develop expansive soils, which are formed from the breakdown of basic igneous rocks when weather is very variable.

II. LITERATURE REVIEW

Soil stablisation can be defined as bringing the change in the soil properties, in order to make the soil safe for the future constructions or we can say that soil is future ready. There are various methods by which the stability of the soil can be achieved that includes:

- Chemical
- Mechanical

In India, the weathering of basalt rocks produces these fertile soils. Additionally, this soil deposit comes from sedimentary rocks of many different ages, among them very ancient sedimentary deposits. There are both montmorillonite and elite in the clay fraction [10]. Conventional foundation for motor ways, embankment, backfill of retaining walls, and the like is troublesome when it comes to expansive soils. In tropical and temperate zones, as well as regions with lower rainfall and poor drainage, these soils are found. The average yearly precipitation is more than the average yearly evaporation. [1], [2] and [3]. In various locations of the globe, including Africa, Australia, India, South America, the United States, and Canada, expansive soils have been documented. Though expansive soils may be found practically everywhere, this does not indicate that they don't exist everywhere else. [4], [5] and [6].
Using creative and cost-effective procedures, geotechnical engineers have found it difficult to enhance the engineering/geotechnical features of expansive soil. Stabilization processes may help to enhance the engineering/geotechnical qualities of expansive soil. The term "stabilisation" encompasses numerous soil modification techniques that aid in the engineering functions of soils. When it comes to methods of stabilisation, there are two main groups: (a) an adjustment to an existing soil property that doesn't include any new ingredients, such as mechanical manipulation, and (b) an adjustment to the soil's properties with the aid of new ingredients, such as chemical manipulation [9]. Finally, after much thought, it was determined that industrial waste such as fly ash, rice husk ash, Wool waste, blast furnace slag, and so on might be put to use. As a result, the widespread use of cheap admixtures to replace or supplement cement or lime in soils that have already been stabilised by cement or lime will play a significant role in reducing the overall cost of construction works where expansive soils are encountered as well as providing a benefit to society in the form of improved industrial waste disposal. Thus, this research meets the demands for waste

disposal that is both safe and environmentally responsible for the community, as well as engineers' want for more effective and economical building materials [6], [7], and [8].

III. EXPERIMENTAL METHODOLOGY

The purpose of this experimental study is the extensive examination of the stabilization/modification of the expansive soil accessible locally utilising industrial waste, e.g., fly ash and lime waste. The programme of experiments conducted in this study includes index tests, compaction tests, shear tests, unconditional compressive strength tests, CBR tests and consolidation tests to assess individual swelling, compaction, strength, compressibility and drainage properties, in conformity with approved standards on soil alone as well as in stabilized soil. Two different local soils are used as parent material, one of which is high expansive (designated as soil-1) and the other one is low expansive (designated as soil-2). Two industrial wastes such as fly ash and Wool waste have collected from the local industries and lime has been procured from local market for use in the aforesaid. There are two distinct local soils employed as parents, one very expansive (soil-1) and the other mild expansionary (designated as soil-2). Two industrial waste such as fly ash and wool wastes from local companies have been gathered and the local market has been used to produce lime for the research.

A. Mechanical Soil Stabilization

The use of mechanical energy is used to densify soil via compaction, resulting in reduced voids. Furthermore, this technique is well-suited for cohesionless soils that result from mechanical compaction, where the soil particles reassemble to interlock. However, because of the effects of fluctuating moisture levels in the field, this strategy is not practical.

B. Chemical Stabilization

Adding inorganic or organic chemicals to the soil's geotechnical qualities will enhance the qualities. Waterproofers and repellants conduct cementation and bonding functions. Inorganic stabilisers include, for example, cement, lime, fly ash, slag, sodium silicate, etc. Bituminous elements are utilised as organic stabiliser. Using a variety of chemical additives including cement, fly ash, lime, or a mixture of these, such as cement kiln dust, results in an alteration of the physical and chemical characteristics of the soil because of the cementitious linkages that are formed.

C. Cement Stabilization

Stabilization of soil may be performed with cement, which results in hardened solids that can support weight. Sub base and base course soil-cement mixes have been widely employed in the construction of roads.

D. Admixture Stabilization

Utilizing solely lime or cement to stabilize soils is expensive, thus using waste materials with just a small amount of lime or cement is suggested. The two forms of general admixture stabilization are either chemical or industrial waste.

E. Specific Gravity

Table 1 presents the impact of fly ash on the specific gravity of soils. The increase in the quantity of fly ash reduces the specific gravity of the mix of soil-fly ash. The specific gravity of fly ash is 2.47, which is smaller than the gravity of ground 1 and soil 2,69 and 2.70, respectively. The specific gravity of soil-1 and ground-2 fly ash combination is 2.58 and 2.61 with a fly ash concentration of 30 percent, respectively. The decrease in the specific seriousness of the soil mix is due to the substitution of soil with equal quantity of fly ash, which is less important than soil.

Table 1: Specific Gravity of soil with fly ash mixture

Sample Reference	Soil 1	Soil 2
Soil	2.69	2.70
Fly ash	2.47	2.47
95% soil + 5% fly ash	2.63	2.68
90% soil + 10% fly ash	2.62	2.67
85% soil + 15 fly ash	2.61	2.66
80% soil + 20% fly ash	2.59	2.64
75% soil + 25% fly ash	2.58	2.62

F. California Bearing Ratio

Table 2 presents the unsoaked and 4 days soaked CBR values of the soil and soil- fly ash mix. Fig. 1 illustrates the fluctuation of the soil-fly ash samples unsoaked soils. In the instance of soil-1, unsoaked CBR of the soil sample with a 5% fly ash concentration is not impacted. However, with a 10 percent rise in the level of fly ash, it drops to the lowest 7.62 percent. An increase in fly ash content above 10 percent will gradually raise the CBR value to a maximum of 10.26 percent with a fly ash level of 30 percent. The foregoing observations may be related to the greater OMC value (raised by 3.5%) and lower MDD value of 10 percent fly ash (decreased to 0.35 kN/m3) and vice versa, compared to soil-fly ash concentrations exceeding 10 percent.

However, in the event of soil-2, the non-sprinkled CBR values steadily increase as the fly ash concentration increases.

With soaked samples (4 days of soaking) the CBR value of soil-fly ash samples steadily increases as fly ash concentration increases (Fig. 1). Soil-1 and ground-2 soaking CBRs are 8.16 percent and 11.4 percent respectively with 30 percent fly ash content, i.e., with a fly ash content of 2.26 and 2.17 times more CBRs with soil-1 and soil-2 soaked for 4 days, respectively.

The increase in CBR after the addition of fly ash may be due to the following;

(i) Flocculation and agglomeration of the clay particles takes place by the cation exchange reaction in soil-fly ash,

resulting granular particles.
(ii) Formation of granular particles increases with the increase in fly ash content.

Table 2: Presents the unsoaked and 4 days soaked CBR values of the soil and soil- fly ash mix

Sample reference	Soil – 1		Soil – 2	
	Un-soaked CBR (%)	Soaked CBR (%)	Un-soaked CBR (%)	Soaked CBR (%)
Soil	16.99	3.61	8.22	5.25
Fly ash	35.70	13.24	35.70	13.24
95% soil + 5% fly ash	16.96	3.71	9.55	5.80
90% soil + 10% fly ash	7.62	5.87	10.58	6.20
85% soil + 15% fly ash	7.71	6.04	11.26	6.94
80% soil + 20% fly ash	8.51	6.60	13.55	8.50
75% soil + 25% fly ash	8.80	6.74	15.52	9.22
70% soil + 30% fly ash	10.26	8.16	17.40	11.40

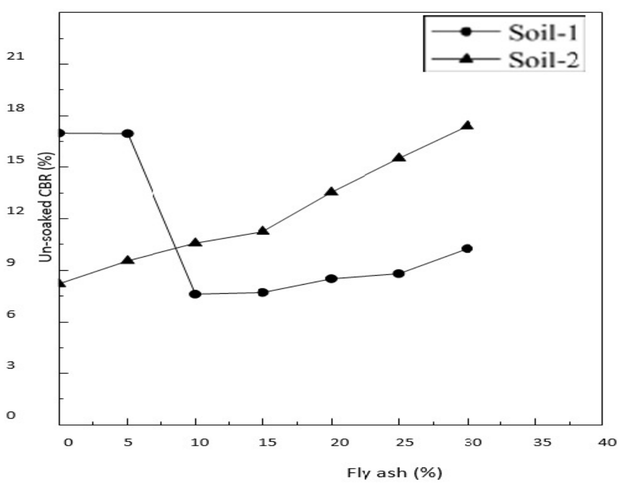

Figure 1: Effect of fly ash on soaked CBR of soils

G. Unconfined Compressive Strength (UCS)

Soil fly ash mixes are removed under their respective OMC and MDD conditions and then healed by capillary action over a period of 9 days. After the curing phase is over, specimens are examined for the unconfined compressive strength. The major reason for the treatment of the specimen in water for 9 days was to offer enough time to generate a better pozzolanic interaction of fly ash to soils. The UCS test results are shown in Table 3. The influence of fly ash on the unconfined compressive strength of soils may be seen in Figure 2. The UCS of soil-fly ash samples diminishes as the quantity of fly ash increases. The reduction of UCS may be caused by the development of unbound granular particles by the pozzolanic response of fly ash to soil owing to water treatment. By increasing the fly ash concentration in soil, the percentage of granular particles rises.

Table 3: UCS test results

Sample Reference	Soil 1	Soil 2
	UCS (kPa)	UCS (kPa)
Soil	149.0	110.0
95% soil + 10% fly ash	137.0	105.0
90% soil +10 fly ash	130.0	92.0
85% soil + 15% fly ash	122.8	80.4
80% soil + 20% fly ash	107.1	55.5
75% soil + 25% fly ash	86.8	48.4

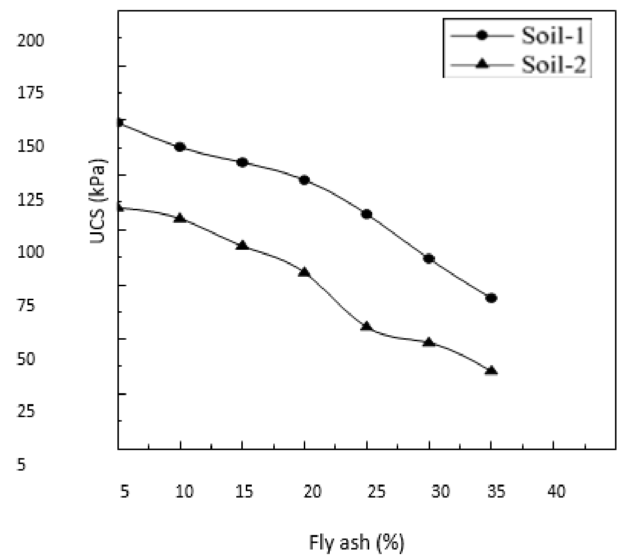

Figure 2: Effect of fly ash on UCS of soils

H. Shear Strength (Triaxial Compression Test)

The triaxial compression tests (UU) are conducted for soil and soil fly ash mix and results are presented in Table 4, Figs. 3 and 4 show the effect of fly ash on the shear strength parameters i.e., cohesion (c) and angle of shearing resistance (Φ) respectively.

Table 4: Soil and soil fly ash mix and results

Sample reference	Soil – 1		Soil – 2	
	c (kPa)	ϕ (degree)	c (kPa)	ϕ (degree)
Soil	56	6	44	10
Fly ash	7	44	7	44
95% soil + 5% fly ash	52	7	40	12
90% soil + 10% fly ash	50	9	38	14
85% soil + 15% fly ash	45	10	35	15
80% soil + 20% fly ash	38	10	31	18
75% soil + 25% fly ash	30	14	28	18
70% soil + 30% fly ash	24	15	18	24

Figure 3 shows that the cohesiveness of fly-ash samples decreases with the rise in the quantity of the fly-ash samples, while the angle of shear resistance of soil-fly ash samples rises. This may be because the pozzolanic reaction results in the creation of granular particles. Since soil-1 has a greater percentage of clay, less silt than soil-2, soil-fly-ash mixture cohesiveness in the case of soil-1 is higher than soil-2 samples, but the angle of shearing resistance is lower for the soil-1-fly ash mix samples than the soil-2 - fly ash samples. Fig. 4 shows that the cohesiveness of fly-ash samples decreases with the rise in the quantity of the fly-ash samples, while the angle of shear resistance of soil-fly ash samples rises. This may be because the pozzolanic reaction results in the creation of granular particles. Since soil-1 has a greater percentage of clay, less silt than soil-2, soil-fly-ash mixture cohesiveness in the case of soil-1 is higher than soil-2 samples, but the angle of shearing resistance is lower for the soil-1 fly ash mix sample than the soil-2 fly ash mix samples.

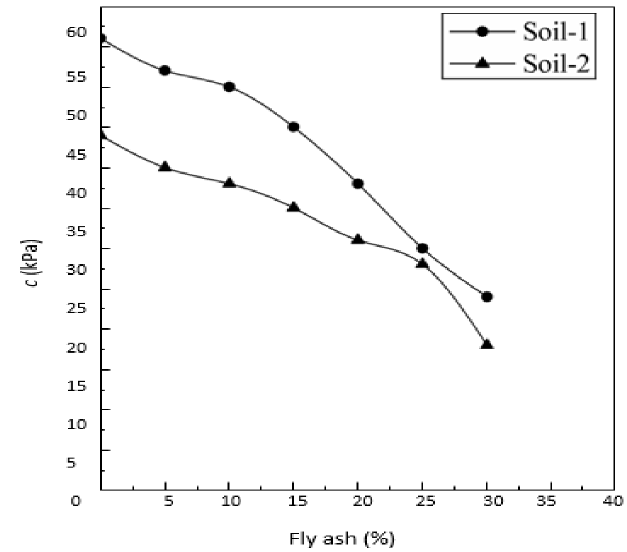

Figure 3: Effect of fly ash on the cohesion of soils

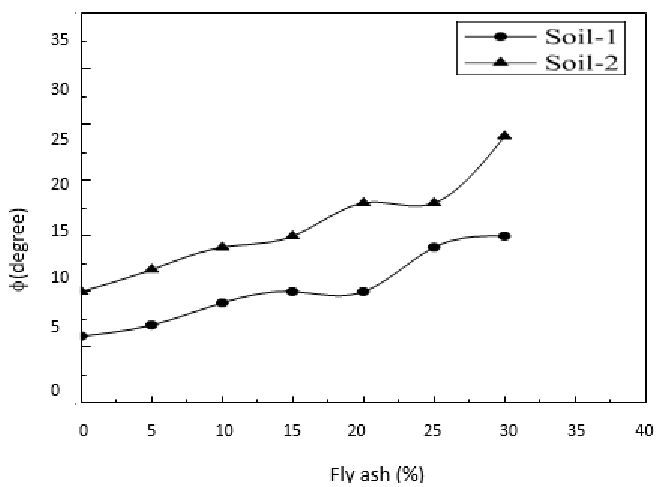

Figure 4: Effect of fly ash on the angle of shearing resistance of soils

I. *Effect of wool waste on various soil parameters*

- *Compaction Characteristics*

Table 5: Compaction characteristics of soil & wool waste

Sample reference	Soil – 1		Soil – 2	
	OMC (%)	MDD (kN/m^3)	OMC (%)	MDD (kN/m^3)
Soil	16.10	17.80	11.50	18.80
Wool waste	6.70	26.34	6.70	26.34
95% soil + 5% Wool waste	15.50	18.20	11.20	19.20
90% soil + 10% Wool waste	16.00	18.50	10.80	19.40
85% soil + 15% Wool waste	15.00	19.00	10.50	19.70
80% soil + 20% Wool waste	14.40	19.40	10.20	19.82
75% soil + 25% Wool waste	12.37	19.95	9.80	20.30
70% soil + 30% Wool waste	11.20	20.50	9.30	21.05

The OMC of soil-1, soil-2 and Wool waste are 16.1, 11.5 and 6.7% respectively, whereas the MDD of soil-1, soil-2 and Wool waste are 17.8, 18.8 and 26.34 kN/m3 respectively.

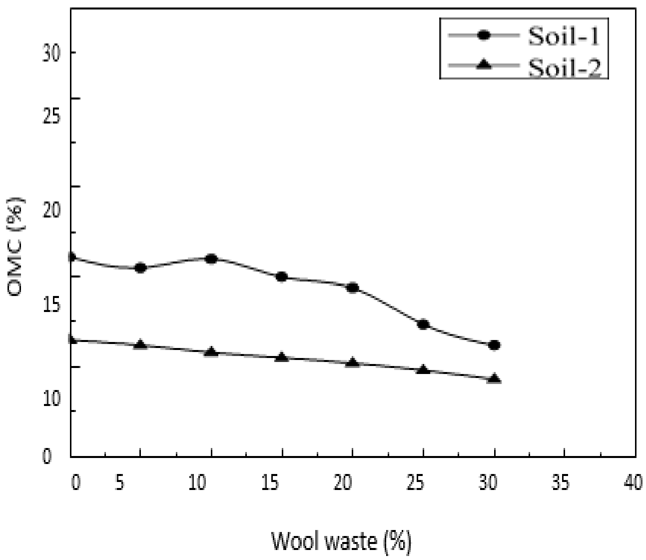

Figure 5: Effect of wool waste on OMC of soils

The OMC of soil-waste samples fell steadily as the Wool waste concentration increased. But the MDD for soil-waste samples rose steadily with an increase in the proportion of wool-waste.This kind of change may be caused by the following causes;
(i) The OMC of wool waste is less than that of the soils. (ii) The specific gravity of wool waste is higher than that of the soils.

J. California Bearing Ratio (CBR)

Table 6, presents the results of the CBR testing. The untreated CBR of the waste combination for soil-1 is much higher than the mixture for soil-2. But the proportion of unsoaked CBR growth in soil-1 is lower than the soil-2 regardless of the proportion of wool waste in the mixed soil. The unwashed CBR of soil-1 is enhanced by 52 percent at 30 per cent of wool waste, but the unwashed CBR of soil-2 is enhanced by 177 per cent. This might be owing to the presence in soil 1 of more clay than soil 2.

Table 6: CBR of soil and wool waste mixture

Sample reference	Soil – 1		Soil – 2	
	Un-soaked CBR (%)	Soaked CBR (%)	Un-soaked CBR (%)	Soaked CBR (%)
Soil	16.99	3.61	8.22	5.25
Wool waste	40.05	38.40	40.05	38.40
95% soil + 5% Wool waste	16.79	3.94	10.50	6.10
90% soil + 10% Wool waste	17.77	4.17	13.40	7.20
85% soil + 15% Wool waste	18.56	4.44	15.60	8.30
80% soil + 20% Wool waste	19.29	5.39	17.05	8.89
75% soil + 25% Wool waste	23.07	5.74	19.42	11.40
70% soil + 30% Wool waste	25.76	9.17	22.80	13.80

CBR rise may be attributed to the following factors: (i) Increases in specific gravity and MDD by increasing the Wool waste content of the soil-Wool waste mixes. (ii) Formation of granular particles in the soil- Wool waste combination owing to flocculation and agglomeration. At 30 percent wool waste, soil-1 and soil-2 wet CBR rose by 154 per cent, compared to their soaked CBR without wool waste by 163 per cent.

IV. RESULTS AND DISCUSSION

A. Shear Strength (Triaxial compression Test)

By performing a triaxial compression test, the shear strength parameters (c and s) of the waste soil wave blend are found (UU: unconsolidated undrained). The results of the tests for triaxial compression are shown in Table 7 and shows the changes of cohesiveness (c) and shearing resistance angles (also) of soils following Wool waste addition.

Table 7: Shear Strength of soil & wool waste mixture

Sample reference	Soil – 1		Soil – 2	
	c (kPa)	ϕ (degree)	c (kPa)	ϕ (degree)
Soil	56	6	44	10
Wool waste	1	42	1	42
95% soil + 5% Wool waste	50	6	42	13
90% soil + 10% Wool waste	48	7	38	15
85% soil + 15% Wool waste	45	7	32	16
80% soil + 20% Wool waste	40	9	30	16
75% soil + 25% Wool waste	37	12	26	20
70% soil + 30% Wool waste	30	15	21	25

V. CONCLUSION

Attempts have been undertaken, using industrial waste, with or without lime, to explore the engineering qualities after the stabilization of expansive soils. This review provided insight into existing information, its limitations/insufficiencies, and so allowed us to draw inspiration and scope for the current work. Literature analysis has shown that minimal study has been done to stabilise the local expansive soil using industrial waste from surrounding companies, whereas there has been minimal study into stabilising expansive soil utilising wool waste as an addition. With respect to the usage of wool, since all the local sources for fly ash have been thoroughly exhausted, the addition of wool as a strengthening addition might open up enormous new possibilities in the technical efforts to turn poor soils into effective (founding) building. Based on the aforementioned, efforts were undertaken to investigate the stabilisation of local expansive soils with or without lime utilizing local industrial waste, i.e., wool waste and additives. . The current study gives the ability to transform waste (fly ash and wool waste) into sustainable building material via a cautious and suitable combination and for the same, important final items are listed below:

- The L.L. and P.I. soils progressively decrease with an increase in fly ash or wool waste content by the addition of fly ash or wool waste. At 30 percent fly ash or 30 percent wool waste content, the maximum decline is seen. Adding lime to the combination of soil-fly ash or soil-wool waste significantly decreases L.L. and P.I.
- The addition of fly ash or wool waste reduces the free swell index (FSI) of soil, with a minimum decline of 30% for fly ash or wool waste. Adding lime to the aforementioned mixes considerably decreases FSI. Soil 1 FSI with 30% fly ash or a waste of wool content is lowered by 100% and soil-fly ash and soil-wool waste combination by 85% with 4% lime content accordingly. For soil-2, the FSI is lowered by 100 percent using 30 percent fly ash or wool and lime (4 percent).
- Rising the level of fly ash in soil improves OMC and reduces MDD. At 30%, the OMC content of fly ash rises by 52% & 37%, while MDD reduces accordingly by 10% & 7% for soil-1 and soil-2. However, the opposite tendency in soil-wool waste mixtures is found. At 30 percent the content of wool waste, OMC reduces by 30% and 19 percent and MDD rises by 15 percent and 12 percent correspondingly for soil 1 and soil 2.
- CBR rises in soil-fly ash or soil-wool waste with an increase in the content of fly ash or wool waste. The largest rise in ash or wool waste is found at 30%.
- UCS reduces in both soils when fly ash or wool waste content increases. The UCS of stabilised soils (ash-lime soil-flying and waste-lime soil-wool) is increasing by increasing the content and curing time. UCS values of soil-fly ash with a 4% lime content for soil-1 and soil-2 are 286 kPa and 192 kPa after 56-day wet curing Correspondingly.

VI. DISCUSSION

- The features of stabilised soil have been examined under OMC and MDD conditions with changed Proctor compaction in this inquiry. The same may be explored with the humidity content other than OMC as well as with the conventional Proctor compaction.
- The features of CBR and UCS of soil-fly-ash and sample soil-wool waste may be examined during soaking periods of 7, 14, 21, 28 and 56 days.
- The research may be carried out using stabilisers such as cement, bitumen and other chemical to stabilise mixesofsoil-flyashandsoil-woolwaste.
- Thecostanalysismaybeperformedforthe preferred design combination to analyse its economic aspect

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest

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