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Slope Stability Analysis of Recycled Concrete Fine Aggregate Stabilized and Blended Soils

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Abstract*: Recycled concrete aggregate (RCA) is one of the major material generated from municipal soild waste industry. In the current study, recycled concrete aggregates are collected from the demolished building. The index and engineering properties of crushed concrete and locally available soil are determined. The study aims at effective reuse of demolition concrete waste as backfill of earth retaining walls. RCA passing through 4.75mm is stabilized by using Cement kiln dust (CKD) and Fly Ash (FA) in various proportions. Red soil is partially replaced by 30%, 50%, and 70% with recycled concrete fine aggregates. A numerical model is developed using limit equilibrium software i.e GeoStudio Slope/w. It is found that 15% CKD and 15% FA is optimum to stabilize the material. In case of blended soils, 30% replacement with RC-FA is found to be optimum

Keywords: Recycled concrete; Retaining walls; Slope stability

I. INTRODUCTION

The recycling and reuse of materials are the keywords for sustainable development. The economy growth of a nation is directly related to the growth of Infrastructure. Over a decade India has witnessed significant growth in the construction industry and it is expected to increase even further due to the vision of Government of India i.e. "Housing for all by 2022". Rapid growth in urbanization leads to an increase in the construction of residential buildings. In order to provide the ease of travel to the people, there is a significant increase in the development of transportation which includes Metro rails, bullet trains, widening of existing road networks, construction of flyovers, underpasses and expressways. The Ministry of Roads Transport and Highways (MORTH) is focusing on a lot of these major sectors. In order to complete these projects, a large amount of natural aggregate is required. Due to the shortage of natural resources, and excessive costs for transportation, there is a necessity of an alternative material used for construction. On the other hand, the renovation and demolition of infrastructure generate a lot of waste which is termed as Construction and demolition waste (C&D waste). According to the Ministry of Environment, Forestry and Climate change, construction and demolition waste is estimated to be about 530 million tons annually in India. Ashokan et al. (2007) discussed the generation of solid wastes in India and its reusing potential as construction materials.

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However, this material does not meet the requirements for the usage as backfill of retaining walls. In order to fulfill the requirements to use it as an alternative for conventional material, RCA has to be stabilized.

Naturally available granular materials are made into well-graded materials and these materials are conventionally used as a filler material for various geotechnical applications. Due to the rapid increase in construction activities, there is a high demand for granular materials which eventually leads to illegal dredging of sands from the river beds, which results in the depletion of natural resources.

Santos *et al.* (2014) used construction and destruction waste as backfill for retaining walls and found its performance as satisfactory. Viera *et al. (2018)* had seen the improvement in mechanical properties of long-term CKD stabilized wastes. Shiva Bhushan et al. (2019) characterized the construction and demolition waste and the investigation shows it can be used as backfill for MSE walls.

The objective of the present study is to assess the potentiality of recycled aggregate waste as a backfill material for earth retaining structures. In connection to the above, the index properties of recycled fine aggregates like pH, water absorption, specific gravity, particle size distribution are obtained. Recycled concrete fine aggregate (RC-FA) is partially replaced by 30%, 50%, 70% with the locally available soil. The sample from same source is been stabilized by using CKD and FA

For backfill, the properties of the material are been used to model the retaining structure. Firstly with stabilized materials and other with partially replaced soils were used. It is analyzed in GeoStudio Slope/w software to check their stability patterns.

II. MATERIALS

Material retained on 75µ and passing through 4.75mm was considered. The material so obtained was mixed with red soil. RCA was collected from a demolished building near Hyderabad (as shown in Figure 1). The material is crushed using mechanical crusher and we had also tested further material for particle breakage with proctor rammer. Material passing through 4.75mm sieve is taken for further tests.

Alireza et al. (2017) stabilised construction and demolition material with cement and seen reasonable properties to be utilized in base and subbase application.

Fig. 1. Location of Recycled concrete aggregates collected

The recycled concrete fine aggregate (RCA-FA) which obtained from the above process was mixed with the virgin red soil. It was oven dried to remove the total moisture in it. The gradation was considered to match with the requirements of well-graded sand, so that it can be used as a backfill material. The red soil is taken from Bachupally area, Hyderabad.

Materials:

Cement Kiln Dust (CKD) is calcium-rich obtained as a byproduct from cement. Fly ash (FA) is silica-rich material obtained on burning the natural coal (mainly from thermal power plants). These two materials were been utilized as stabilizers for C&D materials by Arulrajah *et al.* (2018). Shiva Bhushan and Rajkumar (2019) studied the settlements for recycled concrete fine aggregate mixed soils using GeoStudio.

III. METHODOLOGY

Various laboratory tests were conducted on the virgin soil and the RCA-FA. The tests include pH test, specific gravity sieve analysis, compaction test and direct shear test were perfomed as per IS-2720- Part XXVI, Part-III, Part-IV, Part-VIII, Part-XIII respectively.

Recylced concrete gives a wide range of friction angles and cohesion (Arulrajah et al. 2015). Compaction test and direct shear test for various proportions i.e., 70% CC and 30% Red soil, 50% CC and 50% Red soil, 30% CC and 70% was performed. Red soil was tested to obtain the OMC & MDD and shear parameters.

Samples were prepared by mixing the CKD and FA with RC-FA in various percentages. The overall CKD + FA percent for stabilization was maintained to be 30 % in all the samples. Hence, the percentage of CKD and FA were changed simulataneously to make the sum percent to be 30.

Modeling in Slope/w:

A retaining wall of 5m height was considered for modelling. The model was simulated in limit equilibrium software (Slope/w). The material is chosen as Mohr-coulomb model and entry and exit method is chosen for as in Fig. 2. For the reuse of C&D waste for the backfilling material for retaining walls. The inputs for the Foundation soil and retaining wall were kept constant and the backfill material properties were changed and analyzed as shown in Fig. 2. The values which were taken as constant is shown in Table I. Slope stability analysis was done to analyze the factor of Safety for

a. Stabilised RC-FA using CKD and FA

b. Red sand blended with RC-FA in various percentages.

Table-I: Backfill and foundation soil properties used

	Unit weight (kN/m^3)	Cohesion (kPa)	Angle of shearing resistance
Foundation Soil	14	0	25^0
Backfill	24	500	0^0

The unit weight of soils were taken as 90% of its MDD. For backfill materials both blended soils and stabilized RC-FA are been considered whose shear parameters are shown in Table III and Fig. 6.

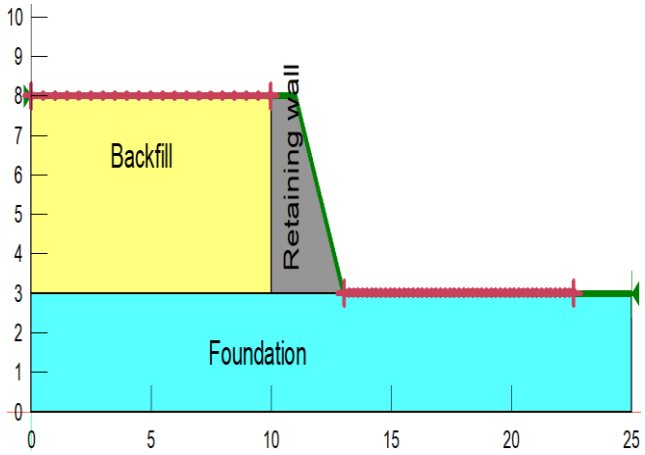


Fig. 2. Retaining wall considered in slope/w model

IV. RESULTS AND DISCUSSIONS

4.1 Red soil blended with RC-FA(a)

Specific gravity of RC-FA (2.76) is higher than red soil (2.66). Mixture of red soil and RC-FA can be classified as Well graded sand (SW). pH of RC-FA (11.39) was more alkaline in nature in comparison with red soil (7.37). The gradation parameters are shown in Table- II

Table II: Index geotechnical properties of the material

Geotechnical properties	Values obtained for	
	Red soil	RC-FA
D_{10} (mm)	0.2	0.23
D_{30}(mm)	0.8	1.3
D_{60}(mm)	1.85	2.5
C_c	9.25	10.86
C_u	1.72	2.9

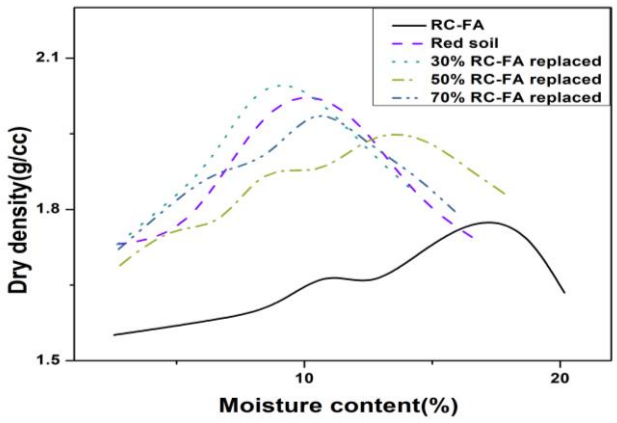


Fig. 3. Modified Compaction characteristics of blended soils

The modified compaction characteristics of red soil and RC-FA and are shown in Fig 3. From the experiments, it was observed that 30% replacement sample had the least OMC and highest MDD. The combination behaves more like RC-FA than the red soil with further increase in replacement.

The shear strength parameters of blended soils are shown in Fig. 3. It was found that cohesion reaches peak at 30% and angle of shearing resistance attains peak at 50% replacement of RC-FA. The shear strength envelopes of blended soils shows that the shear strength increases upto 30% of replacement of RC-FA and then decreases.

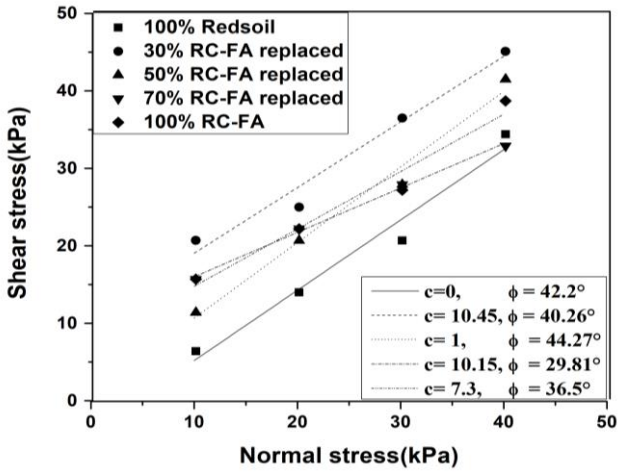


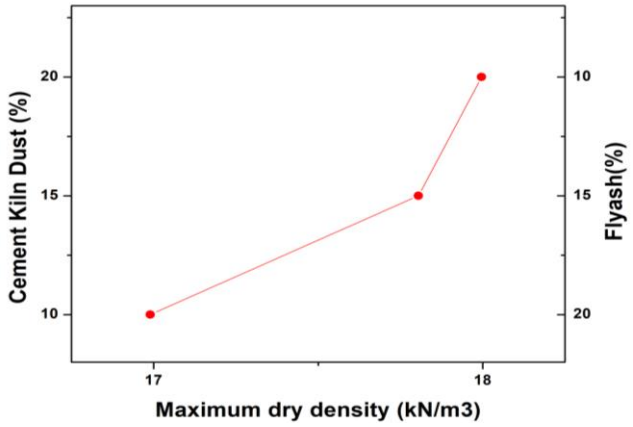
Fig. 4. Shear strength envelopes of blended soils

The factor of safety from the model was calculated from the Slope/W software. The factor of safety was found to be highest for the 30 % replacement case as the shear parameters were high for it.

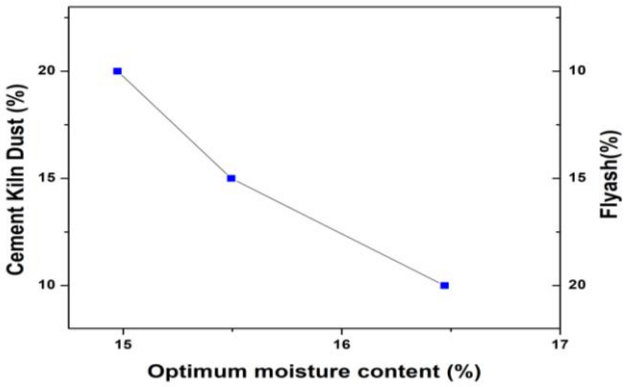
Table- IV: Factor of safety of blended soils

Sl.No	RCA	Red soil	FOS
1	100	0	1.565
2	70	30	1.504
3	50	50	1.526
4	30	70	1.602

4.2 Stabilized RC-FA with CKD and Flyash



(a)



(b)

Fig. 4. (a) Maximum Dry density and (b) Optimum Moisture Content in stabilized RC-FA with CKD and FA compaction characteristics

The material which is used for stabilization of RC-FA had OMC and MDD of 17% and 1.78g/cc respectively. It is observed by adding CKD & FA (overall percentage of addition of stabilizer is 30%) together, the values of OMC and MDD decreases and increases respectively. Fig. 4 shows the pattern of compaction curves of stabilized RC-FA.

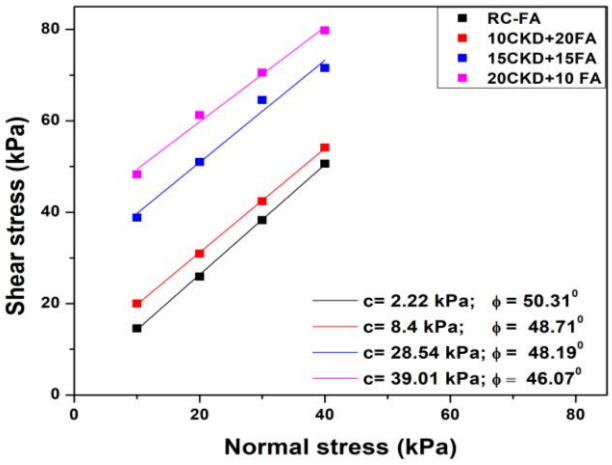


Fig. 5. Shear strength properties of stabilized RC-FA

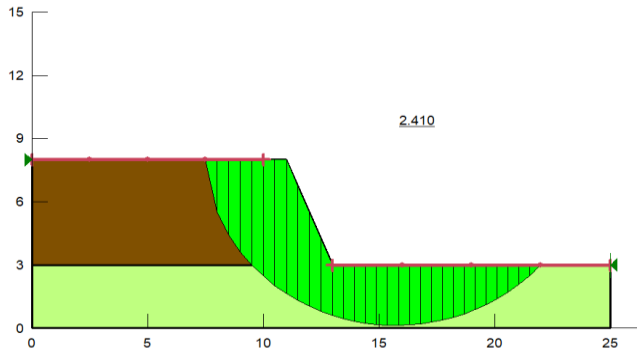


Fig. 6. Slope stability of stabilized RC-FA with 20% CKD and 10% FA

The shear strength properties of stabilized RC-FA is shown in Fig. 5. It was observed that cohesion component of the shear strength increases with the percentage increase of CKD. This is due to presence of Calcium oxide (CaO) which is acting as a binding agent in the mixture. However, there is slight decrease in the angle of shearing resistance. Overall the optimum percentage mixing was found to be 20% CKD and 10% FA with RC-FA. The factor of safety for modelling retaining structure with backfill material as stabilized RC-FA with 20% CKD and 10% FA is shown in Fig. 6.

Table- V: Factor of safety of stabilized RC-FA

Sl.No	% CKD	% FA	FOS
1	0	0	1.643
2	10	20	1.724
3	15	15	2.324
4	20	10	2.41

Table V shows the factor of safety of stabilized RC-FA. It shows a great variation in the values when RC-FA is stabilized using 20% CKD and 10% FA. The factor of safety for the RC-FA had increased by about 50% when it is stabilized with CKD and FA. As CKD has one-third of the amount of cement oxides, the high percent of CKD gives higher strength.

V.CONCLUSION

Recycled concrete fine aggregate RC-FA is been tested to check its potentiality as backfill material. Testing has been done on various percentages of RC-FA blended with soil. Properties obtained from the tests were used to model a retaining structure in Slope\W. RC-FA was also stabilized using 30 % of Cement Kiln Dust and Fly-Ash. The properties of the stabilized mixture was obtained. The following conclusions were drawn:

1. The shear strength of RC-FA blended soils was meeting the requirements of backfill material specified by MORTH and found to be optimum at 30% RC-FA substitution
2. For backfilling material for the retaining walls, it was observed Factor of Safety is found to be high at 30% Replacement of RC-FA.
4. Shear Strength of stabilized RC-FA was found to be higher when 20% CKD and 10% FA are used. Factor of safety was also found to be highest for same combination.

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