Sustainability,Agri,FoodandEnvironmentalResearch,(ISSN:0719-3726),12(X),2024:
http://dx.doi.org/10.7770/safer.v12i1.2878

Use of recycled concrete aggregates in stabilization of black cotton soil.

Uso de agregados de concreto reciclado en la estabilización de suelos de algodón negro.

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ABSTRACT

The long-term performance of a pavement structure depends on its structural integrity and the stability of its underlying soils. The properties of black cotton (BC) soils are known to adversely affect the performance of pavement. BC soil is creating a lot of problems in constructing the pavements on it because of its low California bearing ratio (CBR) and high swelling potential behavior. Black cotton soil possesses poor strength, high swelling and shrinkage behavior on exposure to moisture. Pavements on BC soil require stabilization. Soil stabilization is a process utilized for improving the properties of undesirable weak soil. Stabilization of subgrade soil by chemical, thermal or mechanical techniques is very common practice and too expensive. Therefore, in this study, an attempt has been made to stabilize the BC soil subgrade by recycled concrete aggregate (RCA). The RCA are the waste aggregates obtained from demolition of concrete structure buildings, road, and bridges. The main aim of this study is to know the suitability of RCA waste as a stabilizer for BC soil in the construction of flexible pavements. In this investigation, properties of RCA and BC soil are evaluated, RCA is mixed in different proportions with the BC soil, and their influence on the CBR value and compaction curve are studied. Seven mixes (100% BC soil, 90% BC soil + 10% RCA, 80% BC soil + 20% RCA, 70% BC soil + 30% RCA, 60% BC soil + 40% RCA, 50% BC soil + 50% RCA, 40% BC soil + 60% RCA) are tested for CBR value in order to find the proportion which gives maximum CBR value. Based on the results, it is observed that for the BC soil used in this study, mix containing 60% BC soil and 40% RCA is the suitable mix proportion for the stabilization. For this proportion of mix, the CBR value increased from 3.53% to 11.2%. This accounts to 3.2 times increase in the CBR value, whereas the optimum moisture content (OMC) decreased from 27% to 22% and maximum dry density (MDD) increased from 1.22 gm/cm3 to 1.45 gm/cm3. Hence 60% BC soil and 40% RCA can be used to stabilize the given soil.

Keywords— Black cotton soil, Recycled concrete aggregate, Soil stabilization

RESUMEN

El desempeño a largo plazo de una estructura de pavimento depende de su integridad estructural y la estabilidad de los suelos subyacentes. Se sabe que las propiedades de los suelos de algodón negro (BC) afectan negativamente el desempeño del pavimento. El suelo de BC está creando muchos problemas en la construcción de pavimentos sobre él debido a su bajo índice de carga de California (CBR) y su alto comportamiento potencial de hinchazón. La tierra de algodón negro posee poca resistencia y un alto comportamiento de hinchazón y contracción al exponerse a la humedad. Los pavimentos en suelo BC requieren estabilización. La estabilización del suelo es un proceso utilizado para mejorar las propiedades de suelos débiles indeseables. La estabilización del suelo de subrasante mediante técnicas químicas, térmicas o mecánicas es una práctica muy común y demasiado costosa. Por lo tanto, en este estudio, se ha intentado estabilizar la subrasante del suelo de BC mediante agregado de hormigón reciclado (RCA). Los RCA son los áridos residuales obtenidos de la demolición de edificios con estructura de hormigón, carreteras y puentes. El objetivo principal de este estudio es conocer la idoneidad de los residuos de RCA como estabilizador de suelos de BC en la construcción de pavimentos flexibles. En esta investigación se evalúan las propiedades del suelo RCA y BC, se mezcla RCA en diferentes proporciones con el suelo BC y se estudia su influencia en el valor de CBR y la curva de compactación. Siete mezclas (100% suelo BC, 90% suelo BC + 10% RCA, 80% suelo BC + 20% RCA, 70% suelo BC + 30% RCA, 60% suelo BC + 40% RCA, 50% suelo BC + 50 % RCA, 40% suelo BC + 60% RCA) se prueban para determinar el valor CBR para encontrar la proporción que proporciona el valor CBR máximo. Con base en los resultados, se observa que para el suelo BC utilizado en este estudio, la mezcla que contiene 60% de suelo BC y 40% RCA es la proporción de mezcla adecuada para la estabilización. Para esta proporción de mezcla, el valor CBR aumentó del 3,53% al 11,2%. Esto representa un aumento de 3,2 veces en el valor CBR, mientras que el contenido de humedad óptimo (OMC) disminuyó del 27% al 22% y la densidad seca máxima (MDD) aumentó de 1,22 gm/cm3 a 1,45 gm/cm3. Por lo tanto, se puede utilizar un 60% de suelo BC y un 40% de RCA para estabilizar el suelo determinado.

Palabras clave— Suelo de algodón negro, Agregado de hormigón reciclado, Estabilización de suelos

INTRODUCTION

The long-term performance of a pavement structure depends on its structural integrity and the stability of its underlying soils. The properties of BC soils are known to adversely affect the performance of the pavement. Weak soil and BC soil is creating a lot of problems in constructing the pavements on it because of its low CBR and high swelling potential behavior. This results in development of premature cracks in the pavement. Available subgrade earth materials such as BC soil are soft, weak and low strength soil. Therefore, it does not always meet the desirable requirements and need stabilization to improve its properties. Central and western part of India is mostly cover with BC soil and due to high swelling potential, it has been a challenge for pavement engineer to construct pavement on it. Soil stabilization is a process utilized for improving the properties of weak soil. This procedure involves applying various methods to stabilize the soil. Some of these include the use of chemicals, mechanical methods, and soil replacement (Justo et al., 2015). These methods of soil stabilization are very common and at the same time too expensive. Due to increase in cost of soil stabilization by these traditional methods, use of new types of recycled materials in soil stabilization is increasing (Hashemiet al., 2019). Therefore, many researchers are now trying to utilize construction and demolition (C&D) waste in soil stabilization (Bindu., 2015). As per 11th year plan, construction industry in India is the second largest economic activity after agriculture. The construction and demolition industry in India contributes to the country's economic activity. It generates around 5.14 million tons of waste annually. The increasing disposal cost and the scarcity of natural resources are the reasons why the urgent need for recycling

C&D waste is global concern. Recycled concrete aggregates (RCA) are one of the C&D waste widely available in India. The RCA are the waste aggregates obtained from demolition of concrete structure buildings, road, and bridges. Stabilization of soil with RCA helps to improve the characteristics of weak soil and reduce its adverse effect on environment.It also helps to increase the design life of pavement and reduce the cost of construction of pavement structure on weak soil. Stabilization of weak soil with proper suitable waste material can be an effective and economic method.

Soil stabilization is a process utilized for improving the properties of weak soil (Yoder, and Witczak). Complexity in pavement construction exists when itis to be constructed on clay soil or BC soil.Long-term performance of pavement structure is known to be influenced by the features of BC soils. BC soil cause a lot of challenges when it comes to constructing pavements on it because of their low CBR and high swelling potential (Aryaet al.,2014). Therefore, pavements on the BC soil requires stabilization. Soil stabilization is used to decrease the porosity and to increase the shear strength or load carrying capacity of natural soil (Kerniet al., 2015). In comparison with natural soil, stabilized soil has high strength, high stability, high density and low permeability (Fang et al., 2001). Soil stabilization methods can be broadly classified as mechanical, chemical, or thermal method. Various factors such as soil type, soil structure, soil composition, soil gradation, economic benefits of the project, and available fund affects the selection of compatible soil stabilization method. Mechanical method of soil stabilization work on the principle of achieving proper gradation and compaction of soil mass. Correctly proportioned soil and adequate compaction improve the properties of existing soil. In chemical stabilization, selected chemicals or stabilizer are added to the soil to improve or modify its property (Yinet al., 2022). Thermal stabilization requires heating or cooling of soil mass to cause improvement in the soil properties (Hashemiet al., 2019). Stabilization of subgrade soil by these traditional methods is very common practice and at the same time too expensive. Due to increase in cost of soil stabilization by traditional methods, use of new types of recycled materials in soil stabilization is increasing (Afrin., 2017). Lime klin dust, cement klin dust and flyash are some of the widely used recycled materials for soil stabilization (Ramaji., 2019). In a study, clay tile waste is used to stabilized the subgrade soil of flexible pavement construction. Clay tile waste was used in various proportions and found that with the addition of 45% of clay tile waste, the CBR

value of subgrade soil 3% to 7.3%. Excessive addition of clay tile waste resulted in decreased CBR value of soil (Bindu., 2015). Similarly lime klin dust (LKD) is used to stabilize soft clay and found LKD significantly improved the properties of soft clay (Bandaraet al., 2012). In another study, 0%, 5%, and 10% demolished concrete coarse and fines are used for clay soil stabilization and found that for the soil stabilized with demolished concrete, specific gravity, MDD and CBR value of the mix increases. For mix having 10% demolished concrete, CBR value increased by around 82% (Nikrazet al., 1998). Jain et al., (2016) investigated the use of demolished concrete aggregate in stabilization of kaolinitic soil. Result indicated that use of demolished concrete aggregates up to 40% increases the CBR value from 3.4% to 11.2% and MDD from 1.24 gm/cm^3 to 1.46 gm/cm^3. Further increase in demolished concrete content decreases the CBR value. Therefore, in this study, an attempt has been made to stabilize the BC soil by RCA.

MATERIALS AND METHODS

The main objective of this study is to know the suitability of RCA waste for the stabilization of BCsoil in the construction of flexible pavement. The subgrade soil used in the study is BC soil collected from Agriculture College, Nagpur, and Maharashtra. Figure 1 show the BC soil sample collected from the site. RCA waste was collected from pavement demolition sites in and around Shankar Nagar, Nagpur. The collected concrete waste materials then crushed using a jaw crusher to obtained different size of RCA. Figure 2 shows the concrete waste collected from the site. The particle size distribution of BC soil and RCA obtained from the site is shown in figure 3.

Fig. 1. BC soil sample collected from the site.

Fig. 2. RCA sample collected from site.

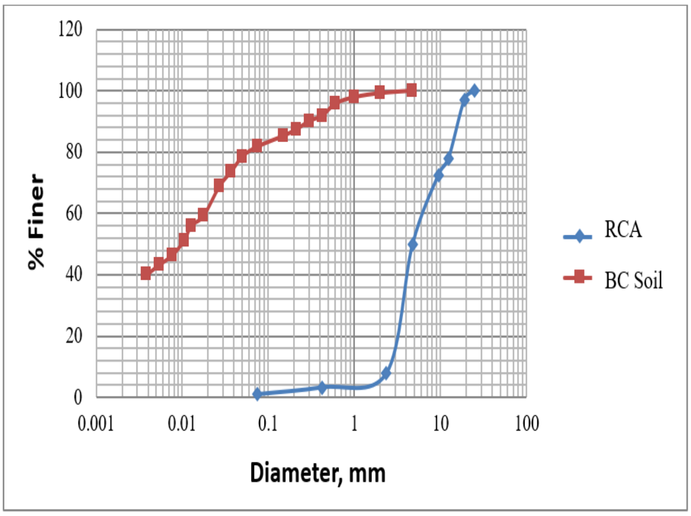


Figure 3: Particle Size Distribution of BC soil and RCA.

Following the collection of samples from the respective sites, the properties of the BC soil were evaluated using IS Codes, including specific gravity, liquid limit, plastic limit, plasticity index, free swell index, CBR, maximum dry density (MDD), and optimum moisture content (OMC). The properties ofBC soil investigated in this study are listed inTable 1. Specific gravity, aggregate impact, aggregate crushing, aggregate abrasion, and water absorption tests were performed on RCA aggregates to determine their suitability for use in the construction of flexible pavements. The properties of RCA employed in the investigation are listed in Table 2.

Table 1. Properties of BC soil used in the study.

Parameter	Value	Reference code
Specific Gravity	2.65	IS: 2720 (Part 3)
Liquid limit (%)	58.31	IS: 2720 (Part V)
Plastic limit (%)	29.62	IS: 2720 (Part V)
Plasticity Index (%)	28.70	IS: 2720 (Part V)
Free Swell Index	51%	IS: 2720 (Part XL)

Table 2. Properties of RCA used in the study.

Property	RCA	MoRTH
Specific Gravity	2.79	2.5 - 3.0
Aggregate Impact Value	17.45	10 - 30
Aggregate Crushing Value (%)	30.53	Max 45
Aggregate Abrasion Value (%)	32	Max 40
Water Absorption (%)	3.27	4

Selected blends of RCA and BC soil used in the study.

Different proportions of RCA and BC soil are taken in this study. The proportions of RCA were varied from 0% to 60% with an increment of 10% in each blend. Standard Proctor test as per [20] and CBR test as per [21] were performed on each blend to evaluate its compaction characteristics. Table 4 shows the different blends of RCA and BC soil used in the study.

Table 4. Blends of RCA and BC soil used in the study

Blend	BC Soil (%)	RCA (%)
1	100	0
2	90	10
3	80	20
4	70	30
5	60	40
6	50	50
7	40	60

RESULT AND DISCUSSION

RCA are used in this study for stabilization of BC soil. Various test on RCA and BC soil are performed to evaluate their properties. Test on RCA were includes specific gravity, aggregate impact test, aggregate crushing test, aggregate abrasion test and water absorption test, whereas test on BC soil were includes specific gravity,Atterbergconsistency test, and free swell index test. The properties ofblended mix was also evaluated by standard proctor test and CBR test.

A. Standard Proctor Test:

The standard proctor compaction test is used to determine the moisture content of soil at which it will attain most dense state and achieve maximum dry density. This test was performed on all the blended mix. Figure 4 shows the compaction curve obtained from standard proctor test. For each blend, as the water content in the mix increases, its dry density also increases. The water content at which, the dry density is maximum is known as OMC and the corresponding density is known as MDD. Figure 5 shows the variation of MDD with RCA % in the blend and figure 6 shows the variation of OMC with RCA % in the blend. The MDD increases as the RCA content in the blend increases. This may be attributed to the high specific gravity of RCA used in the blend. Similarly, the OMC value decreases as RCA content increases in the blend. This may be attributed due to the low water absorption and good quality of RCA used in the study. By the addition of 40% RCA, MDD of the sample was increased from 1.22 gm/cm^3 to 1.45 gm/cm^3. Further addition of RCA resulted in decrease in value of the MDD.

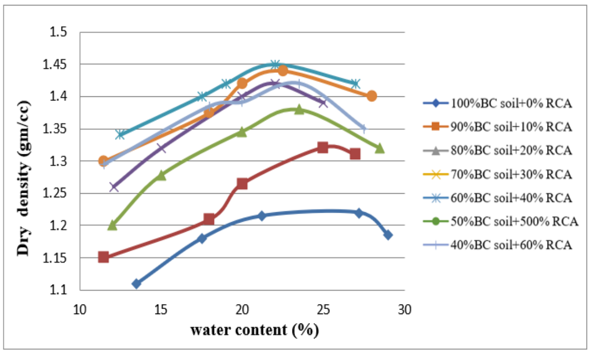
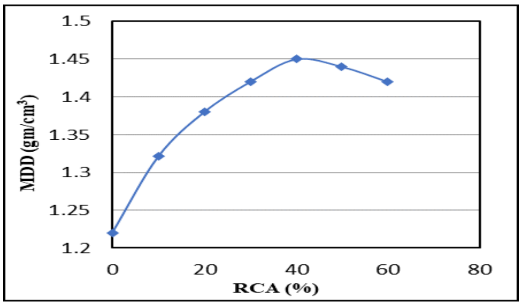


Fig. 4. Compaction curves of BC soil mixed with RCA.



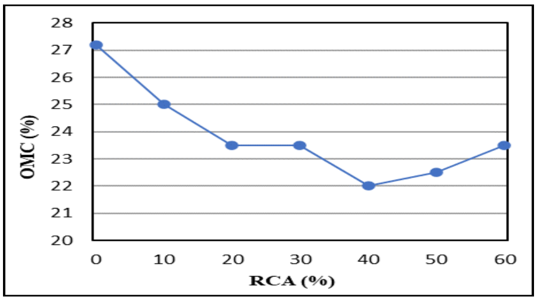


Fig. 5. Variation of MDD with RCA in the blend. Fig. 6. Variation of OMC with RCA in the blend.

B. California Bearing Ratio Test:

The CBR value of each blend can be obtained by conducting CBR test on it. A series of soaked CBR test were performed on each blend by varying the RCA content from 0% to 60%. The variation in CBR value with RCA percent in the blend is shown in Figure 7. The CBR value of BC soil is found to be 3.53. The low CBR value of BC soil is due to the presence of clay fractions and low strength of clayey soil. The CBR value increases as the

RCA content in the mix increases. The CBR value of the sample was increased from 3.53% to 11.2% by adding 40% RCA. The value of the CBR decreased when the RCA was added more. With the addition of 40% RCA to the blend, the maximum soaking CBR value for BC soil is 11.2%.

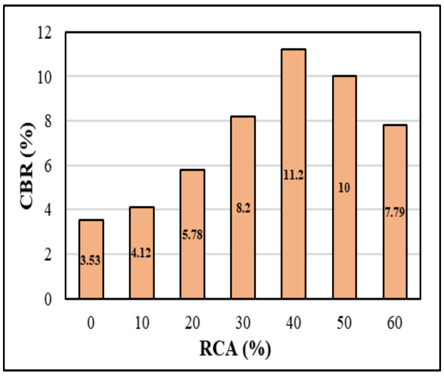


Fig7. Variation of CBR value with RCA in the blend

CONCLUSION

The main objective of this study was to know the suitability of RCA waste as a stabilizer for BC soil in the construction of flexible pavements. From this study and experimental investigation, it is observed that the properties BC soil can be effectively improved by use of different percentage of RCA in the mix. Based on the present study, the following conclusions can be drawn:

1. The RCA used in this study were satisfying all the permissible values as per MoRTH (2013) specifications and are suitable to use in the construction of flexible pavements.
2. The MDD value seems to increase with increase in the percentage of RCA in the blend. This may be due to high specific gravity of RCA used in the study.
3. The OMC value decreases as RCA content increases in the blend. This may be attributed due to the good quality of RCA used in the study.
4. In comparison to the blend having100% BC and 0% RCA, for the blend having 60% BC soil and 40% RCA, MDD value is increased from 1.22 gm/cm^3 to 1.45 gm/cm^3 and the OMC value is decreased from 27% to 22%.
5. In comparison to the blend having 100% BC and 0% RCA, the CBR value of the blend having 60% BC soil and 40% RCA is increased from 3.53% to 11.2%. This accounts to 3.2 times increase in the CBR value.
6. From this investigation, blend of 60% BC soil and 40% RCA can be effectively used to improve or stabilize the given soil.

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Received: 24th March 2023; Received: 03th August 2023; First distribution: 03th March 2023.