Improvement of Soil using Construction and Demolition Waste for Pavement Application

Prajapati, A. R.[1]; Shah, A. U.[2]; Jain, P. H.[3]; Rangwala, H. M.[4]

[1] Research scholar, Nirma University, Ahmedabad 382481, India
20ftphde50@nirmauni.ac.in
[2,3] U.G. student, Nirma University, Ahmedabad 382481, India
[2] 18bcl006@nirmauni.ac.in
[3] 18bcl088@nirmauni.ac.in
[4]Assistant Professor, Nirma University, Ahmedabad 382481, India
Hasan.rangwala@nirmauni.ac.in

Abstract. India is in desperate need of landfill space for the disposal of construction and demolition waste (C&DW). Construction waste or debris resulting from the construction, maintenance, renovation, and demolition of residential buildings, large building structures, roadways, bridges, and dams. India produces around 150 million tonnes of C&DW every year. However, the recycling capacity is about 1.5% which is nearly 6,500 tonnes per day. So, it is important to implement a strategy for reducing, reusing, and recycling C&DW in India. This study presents the efficacy of C&DW for use as a reinforced material mixed with soil in pavement applications. Various index and engineering properties of soil and C&DW including compaction characteristics are ascertained and compared with different proportions of C&DW and soil mixture. Standard proctor test and California bearing ratio (CBR) test were performed on soil, C&DW and their different mix proportions like 0%, 25%, 50%, and 75% of soil replaced by C&DW. The compaction tests showed that the best results are achieved with 50% replacement of soil by C&DW. The CBR values were observed to be increased by 33% in unsoaked condition and 82% in soaked condition considering 50% replacement of soil by C&DW. The paper emphasizes the potential application of C&DW as a sustainable material in subgrade for pavement application.

Keywords*:* Construction & Demolition Waste; Sustainable material; CBR; Pavement

1 Introduction

Construction and demolition waste (C&DW) is any kind of debris from the construction process. C&DW resulting from the construction, maintenance, renovation, and demolition of residential buildings, large building structures, roadways, bridges, and dams. C&DW materials consist of non-biodegradable materials such as concrete, bricks, wood, metals, asphalt, and recovered building components. India produces an estimated 150 million tonnes of C&DW each year, but its official recycling capability is only 6,500 tonnes per day, according to the Building Material and Technology Promotion Council [1].

It is a challenge to handle the C&DW because it is a bulky, heavy, and inert material with a combination of numerous materials with diverse properties. It is also challenging to pick a proper disposal strategy; for instance, due to its high density and inertness, it cannot be incinerated [2]. Nowadays, an issue with the proper disposal of construction and demolition waste due to the quick growth of the construction industry in emerging nations like India [3-5]. C&DW generation and handling difficulties have come to attention with the introduction of sustainable practices in the building sector to accomplish the sustainable goals for our shared future. When treating C&DW, the reduce, reuse, and recycle mindset is quite helpful.

In recent years, C&DW has been widely employed in new road building, minimizing its potential environmental effect, and promoting sustainability on a global scale. It has been stated that similar materials are utilized in a variety of compositions in every stage of road construction, from the foundation to the surface layer. Therefore, to overcome methods for designing and building with such aggregates for the purpose of geotechnical constructions as well as transportation infrastructures, a rigorous experimental study is unavoidably needed.

In some areas, finding adequate foundation soils that can sustain new facilities might be difficult in some places. It is forced to come up with new ways to make use of the available sites to overcome the land shortage issue and the development of green environments. It is not just necessary to stabilize soft soils, but it is required to enhance the subgrade soil strength allowing for the reduction of base and subbase thicknesses, which might be cost-effective for road projects. Additionally, stabilizing soils using C&DW might help to create a green environment. [6].

The processed C&DW is frequently utilized as an alternative material in pavement engineering, recycled aggregates in concrete, to form bricks and blocks [7,8]. When C&DW are used in place of traditional pavement materials, they are often used in the base course or subbase course. As base and subbase materials for concrete pavement, Taesoon Park investigated the characteristics and performance of dry and wet C&DW [9]. According to Arulrajah, compacted C&DW aggregates had minimal effective friction angles that made them suitable as pavement materials [10]. The recycled C&DW aggregates function well when appropriately compacted [11,12]. Comprehensive research must be done on construction technologies and the application of subgrades filled with C&DW.

The objective of this study was therefore to identify the optimum quantity of C&DW which is replacing materials in pavement subgrade soil. The compaction and CBR tests were carried out to analyze the response to the replacement of locally available soil with C&DW at various proportions (0%, 25%, 50% and 75%).

2 Methodology

Following is an explanation of the methodology used for the current study it includes material procurement and different testing on soil, C&DW, and soil - C&DW mixtures.

2.1 Material

This study made use of locally available soil (Fig. 1) that was collected from an ongoing excavation for the hostel building at the Nirma University (NU) Campus. The natural moisture content of soil was observed to be 18.89%. The soil was investigated included specific gravity, particle size distribution, consistency limits, compaction characteristics and California bearing ratio (CBR).

The C&DW acquired from Ahmedabad Enviro Projects Pvt. Ltd., Piplaj, Ahmedabad, Gujarat, India utilized in this study. The C&DW was processed into crushing plants by crushing, reducing size, and grouping into different sizes. The processed C&DW with sizes of particles ranging from 4.75mm to 75 microns was used for this study. Fig. 2 shows the C&DW used in the current study. The C&DW investigated included particle size distribution, specific gravity, and compaction characteristics.

Fig. 1 Soil

Fig. 2 construction and demolition waste

2.2 Material characterization

Particle-size distribution of soil and C&DW and materials were classified as per Indian standard IS:2720 - IV and IS:1498, respectively [13,14]. According to the guidelines laid by IS: 2720 – III, the pycnometer technique was used to determine the specific gravity of the materials [15]. Similarly, in accordance with IS:2720 – VII, the Standard proctor tests were carried out to access the compaction parameters on the samples with various mix proportions of soil and C&DW [16]. The CBR tests were performed on different proportions of C&DW – soil samples. The findings of the CBR and compaction tests will be utilized to establish the optimum quantity of C&DW to replace the soil without sacrificing strength and to obtain enhanced subgrade qualities.

Properties of soil

The particle-size distribution curve for soil is shown in Fig. 3 which was created using the method laid in IS:2720-IV [13]. The guidelines set forth by IS: 2720 - V for the liquid and plastic limit as well as IS: 2720 - VI is to determine the shrinkage limit of soil [17,18]. The index properties, which include specific gravity, fine percentage, and consistency limit are listed in Table 1. According to IS classification, the soil was identified as clay with low compressibility (CL) based on the data in Table 1.

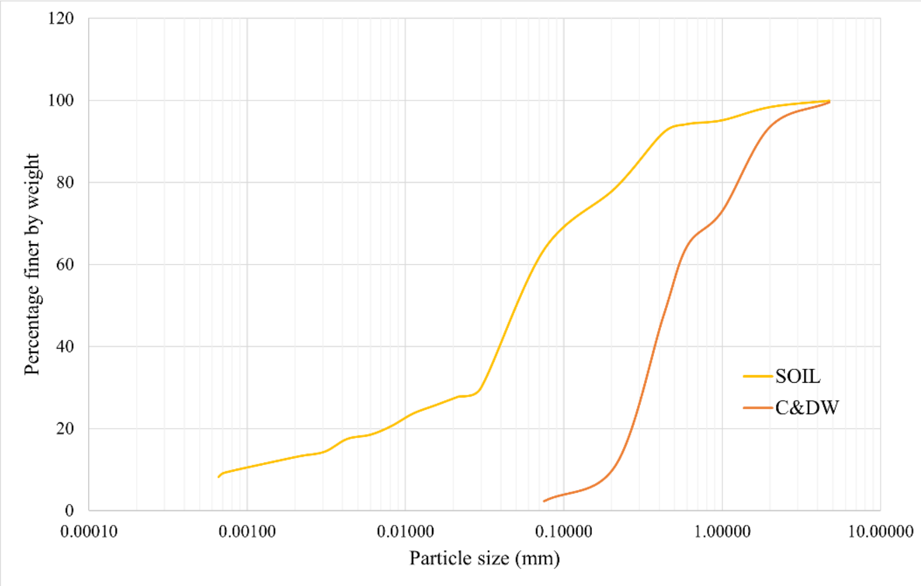

Fig. 3 Particle size distribution of soil and C&DW

Table 1 Properties of soil

Properties	Obtained Value
Natural Water Content	18.89%
Specific Gravity	2.614
Percentage Finer	63.66 %
Liquid Limit (%)	33.00
Plastic Limit (%)	18.89
Plasticity Index (%)	14.11
Shrinkage Limit (%)	11.38
Classification as per IS	CL

Properties of construction and demolition waste

The method outlined in IS:2720 - IV was used to obtain the particle-size distribution curve for the C&DW [13], which is displayed in Fig. 3. Table 2 list the properties, which includes the parameters like the coefficient of uniformity (C_u), coefficient of curvature (C_c), and specific gravity. According to IS classification, the C&DW was categorized as SP (Poorly graded sand) based on the grading characteristic data in Table 2.

Table 2 Properties of C&DW

Parameters	Obtained Value
Specific Gravity	2.508
D10	0.150 mm
D30	0.280 mm
D60	0.534 mm
C_u	3.56

C_C	0.979
Classification as per IS	SP

3 Results and discussions

In order to establish the optimum quantity of C&DW to use as reinforcing material in the subgrade soil, the study is carried out to examine, perform, and compare the experimental results for different combinations of C&DW and soil. The physical tests such as specific gravity, sieve analysis, hydrometer analysis, consistency limit, compaction tests and CBR tests were carried out.

3.1 Compaction test

The compaction test was performed to determine the optimum quantity of C&DW that may be advised for the best proportion among all the Mixes. The compaction test, the Standard proctor test was carried out to determine optimum moisture content and maximum dry density in accordance with IS 2720 – VII [16].
The relationship between moisture content and dry density to know OMC and MDD for different proportions of C&DW and soil is shown in Fig. 5. It was found that the addition of C&DW to soil increases the value of OMC, while the value of OMC decreases when soil is replaced by more than 25% C&DW. The results show that the value of OMC for uncontaminated soil is 11.75%, while a sample with 75% soil and 25% C&DW has a value of 12.78%, a sample with 50% soil and 50% C&DW has a value of 11.70%, which is almost equal to the value of uncontaminated soil, and a sample with 25% soil and 75% C&DW has a value of 9.63%. The results show that increasing the percentage of C&DW increases the value of MDD, while it decreases for the sample with 25% soil and 75% construction debris. The maximum value of MDD is 18.91 kN/m^3 and was found for the sample with 50% soil and 50% C&DW.

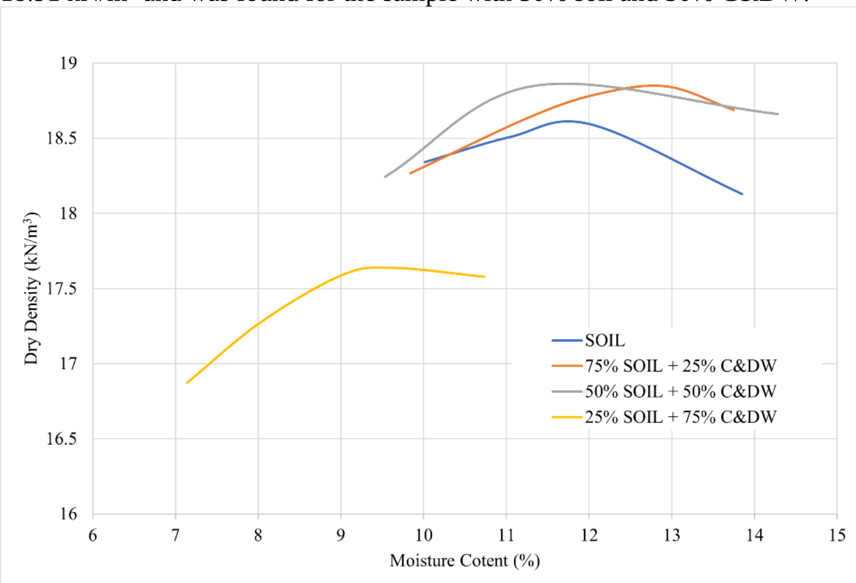

Fig. 4 Relationship between moisture content and dry density for the different proportions of soil and C&DW

3.2 California Bearing Ratio test

The California bearing ratio tests were performed on the uncontaminated soil and mixture with a higher value of MDD. The CBR tests were carried out to determine CBR value in both unsoaked and 4-day-soaked conditions according to IS 2720 – XVI [19].

The comparison of unsoaked and soaked CBR values for different proportions of C&DW and soil is shown in Fig.6. It is found that an increase in the amount of C&DW for replacing the soil increased the value of CBR. The results show that the value of unsoaked and soaked CBR for virgin soil is 14.54% and 9.39%, respectively. The sample with 75% soil and 25% C&DW has a value of unsoaked and soaked CBR is 16.31% and 12.36%, respectively while the sample with 50% soil and 50% C&DW has a value of unsoaked and soaked CBR is 19.44% and 17.16%, respectively.

The CBR value gradually increased as the sand size C&DW increased. The possible reason for this was the higher particle strength of C&DW, which led to an increase in the overall strength of the materials used in the pavement. Mixing the soil with C&DW resulted in higher interlocking, which increased the load transfer capability of the pavement material.

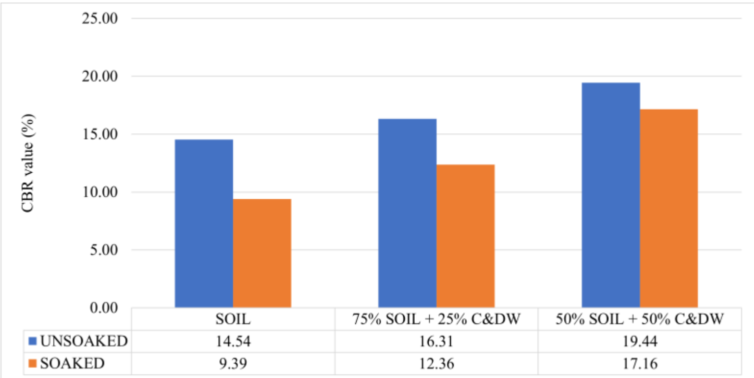

Fig. 5 Unsoaked and soaked CBR value for the different proportions

The compaction test was carried out with soil and soil mixed with C&DW. It was found that as the percentage of C&DW increases, the value of MDD increases, and the maximum value of MDD is 18.91% for the sample with 50% soil and 50% C&DW. Moreover, the MDD value of the sample with 25% soil and 75% C&DW is much lower than the other mixes. This is the reason for conducting the CBR test with the virgin soil and the mixture of 75% soil and 25% C&DW & 50% soil and 50% C&DW. The results show that the MDD and CBR value for the mixture of 50 % soil and 50 % C&DW is more meaningful for use in the pavement than that of soil and other mixtures. As shown in Fig. 3, the particle size of C&DW is greater than the particle size of soil, which means that as the particle size increases in the mixture of 50% soil and 50% C&DW, the CBR value is much higher than that of virgin soil.

4 Conclusions

An attempt is made to recommend the optimum quantity of C&DW that can be replaced in the soil to be used as subgrade material. The important conclusions are summarized below.

- The study included the replacement of soil with C&DW by evaluating the properties of different soil - C&DW mixes. This led to the identification of an optimum mix proportion, which will utilize the maximum amount of waste with the maximum potential improvement in the road subgrade.
- It is observed that when C&DW replaces 50% of the soil, the maximum dry density increases by 1.61% and the optimum moisture content is almost identical to that of virgin soil.
- The CBR value was observed to be improved after mixing C&DW into the soil. In a sample where C&DW was used to replace 50% of the soil, the CBR value was increased by 33.70% in unsoaked conditions while the CBR value increased by 82.75% in soaked conditions when compared to the virgin soil sample.
- The C&DW employed in this study has the potential to be used in road subgrade. It is concluded that using an optimised replacement of soil with C&DW would produce better outcomes than using other replacements. It must be taken into account that different parts of the world may have different composition of C&DW.

Acknowledgement

The authors would like to thank Nirma University for providing facilities and infrastructure support.

References

1. Centre for Science and Environment "India manages to recover and recycle only about 1% of construction and demolition (C&D) waste" (2020).
2. Shrivastava, S., Chini, A.: Construction Materials and C&D waste in India. Lifecycle Design of Buildings, Systems and Materials. 72. (2009).
3. Sharma, R. K., Bhardwaj, A.: Effect of construction demolition and glass waste on stabilization of clayey soil. International Conference on Sustainable Waste Management through Design (pp. 87–94). Springer. http://doi.org/10.1007/978-3-030-02707-0_12 (2018).
4. Sharma, A., Sharma, R. K.: An experimental study on uplift behaviour of granular anchor pile in stabilized expansive soil. International Journal of Geotechnical Engineering, 1–14. http://doi.org/10.1080/1938636.2.2019.1597481 (2019).
5. Sharma, A., Sharma, R. K.: Effect of addition of construction–demolition waste on strength characteristics of high plastic clays. Innovative Infrastructure Solutions, 4(1), 1–11. http://doi.org/10.1007/s41062-019-0216-1. (2020).
6. Kumaran, G. S., Twagirimana, E., Banzibaganye, G.: Concrete Demolition Waste as an Alternative for Pavement Subgrade Stabilisation. (2017).

7. Kourmpanis, B., Papadopoulos, A., Moustakas, K., Stylianou, M., Haralambous, K. J., Loizidou, M.: Preliminary study for the management of construction and demolition waste. Waste Manag Res, 26(3). 267-275, http://doi.org/10.1177/0734242X07083344 (2008).
8. Ossa, A., García, J. L., Botero, E.: Use of recycled construction and demolition waste (CDW) aggregates_ A sustainable alternative for the pavement construction industry. Journal of Cleaner Production, 2016(135). 379-386, http://doi.org/10.1016/j.jclepro.2016.06.088 (2016).
9. Park, T.: Application of Construction and Building Debris as Base and Subbase Materials in Rigid Pavement. Journal of Transportation Engineering, 129(5). 558-563, http://doi.org/10.1061(ASCE)0733-947X2003129:5(558) (2003).
10. Arulrajah, A., Piratheepan, J., Disfani, M. M., Bo, M. W.: Geotechnical and geoenvironmental properties of recycled construction and demolition materials in pavement subbase applications. Journal of Materials in Civil Engineering, 25(8). 1077-1088, http://doi.org/10.1061/(asce)mt.1943-5533.0000652 (2013).
11. Del Rey, I., Ayuso, J., Galvin, A. P., Jimenez, J. R., Barbudo, A.: Feasibility of using unbound mixed recycled aggregates from CDW over expansive clay subgrade in unpaved rural roads. Materials, 9(11). http://doi.org/10.3390/ma9110931 (2016).
12. Sangiorgi, C., Lantieri, C., Dondi, G.: Construction and demolition waste recycling: an application for road construction. International Journal of Pavement Engineering, 16(6). 530-537, http://doi.org/10.1080/10298436.2014.943134 (2014).
13. IS 2720-part IV: Methods of Test for Soils: Grain Size Analysis, Bureau of Indian Standards, New Delhi, India. (1983).
14. IS 1498: Classification and identification of soils for general engineering purposes, Bureau of Indian Standards, New Delhi, India. (1970).
15. IS 2720-part III: Sec 1: Methods of test for soils: Determination of specific gravity Section 1 fine grained soils, Bureau of Indian Standards, New Delhi, India. (1980).
16. IS 2720-part VII: Methods of Test for Soils: Determination of water content-dry density relation using light compaction, Bureau of Indian Standards, New Delhi, India. (1980).
17. IS 2720-part V: Methods of test for soils: Determination of liquid and plastic limit, Bureau of Indian Standards, New Delhi, India. (1985).
18. IS 2720-part VI: Methods of test for soils: Determination of shrinkage factors, Bureau of Indian Standards, New Delhi, India. (1972).
19. IS 2720-part XVI: Methods of test for soils: Laboratory determination of CBR, Bureau of Indian Standards, New Delhi, India. (1987).