

Engineering Applications of Concrete Demolition Waste in Stabilizing Expansive Soils

¹Radityaraj Goud, ²Vaibhav Singh

¹M.Tech Scholar, Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore, Madhya Pradesh, "India"

²Assistant Professor, Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore, Madhya Pradesh, "India"

Abstract

One of the most significant issues engineers face when working on any kind of construction project is expansive soil. For many engineering applications, on-site soil treatment is one of the most economical options. Thus, in order to increase the stability of black cotton soil for use in building, stabilization is essential. Research is still ongoing on the use of construction and demolition waste for soil stabilization. Black cotton soil is the fourth largest soil group in India. Black cotton soil has low strength compared to the other type of the soil. Expansive soils have notable volume variations in response to moisture changes which is an indication of considerable building issues, especially for foundations and embankments. Wet-dry cycles can cause structural stresses, cracks, and settling issues in these soils, which boosts the expense of the maintenance and repairs. A number of stabilization strategies, such as incorporating construction and industrial wastes, are employed to minimize these problems. Among these, concrete destroyed waste (CDW) demonstrated potential as a soil stabilizing addition because of its accessibility, affordability, and environmental advantages. Because CDW is mostly made up of small particles that are high in calcium compounds, it may be useful for modulating the expansive soils' engineering characteristics. The techniques by which CDW interacts with increasing soil particles and the ideal mixing ratios for the greatest stabilization outcomes are covered in the review. It also explains about how employing CDW has an impact on the environment because it preserves natural resources by lowering the need for standard stabilizing materials while also reducing the amount of debris that ends up in landfills. According to the results, adding CDW to expansive soils increases their strength and durability, decreases their flexibility, and increases their capacity to support loads, making it an excellent alternative for conventional soil stabilization methods. Recommendations for more study on the long-term performance of CDW-stabilized soils and their possible uses in civil engineering projects are included in the review's conclusion.

Keywords: Expansive soil (Black soil), Concrete Demolished waste, Soil Stabilization, Compressive strength, Geotechnical properties.

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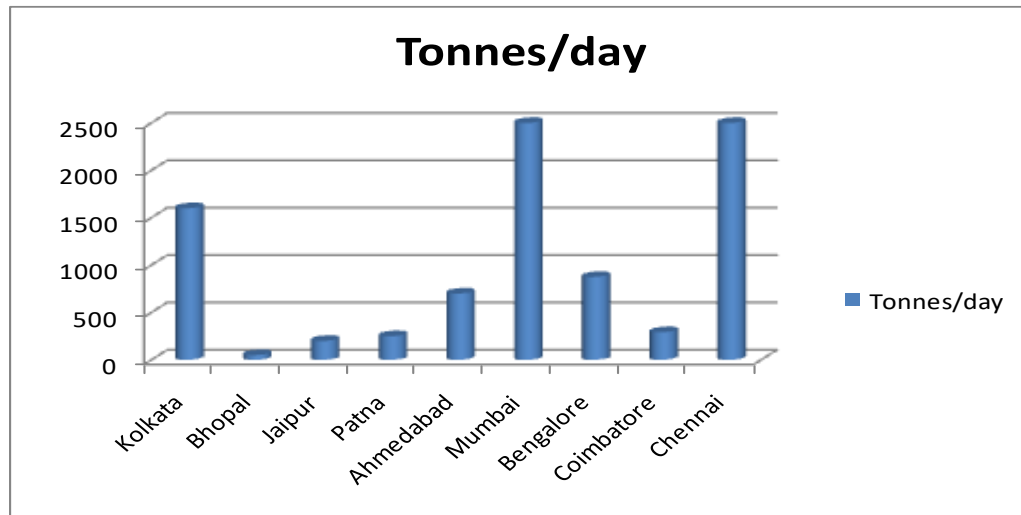
I. Introduction

There is an increase of construction concrete and demolished waste (CDW) in major Indian cities due to increasing need of technology in construction, which is having a negative impact on the ecosystem. CDW is now one of the main sources of atmospheric CO₂ emissions. Particularly in construction and civil engineering projects, concrete demolition waste can play an important role in soil stabilization. By crushing them into rubble, concrete and brickwork can be recycled. Reclaimed brick or concrete can be used as wrap, road base, fill, or concrete aggregate after it has been analyzed screened, and pollutants have been eliminated. On-site concrete recycling is also made possible by mobile concrete crushers. Since 150 MT of construction waste are generated in India each year, which represents 35 - 40% of all C&D waste

globally, construction waste management (CWM) has emerged as a significant environmental concern in a large number of Indian municipalities. It is shown how much C&D waste is produced in different Indian cities in fig. 1. Construction, repair, and restoration, as well as the development and demolition of small and large buildings, bridges, piers, highways, dams, and other structures, produce solid waste, either destructive or non-damaging. As per the Environment Protection Agency's (EPA) 2018 data sheet, which was released in December 2020, 90% of the total CDW generated came from demolition, whilst only 10% came from new construction operations. [17] Due to the fact that the construction industry is expanding and historic buildings are being demolished to give them a more contemporary aesthetic appeal, a significant amount of waste is produced, mandating management and

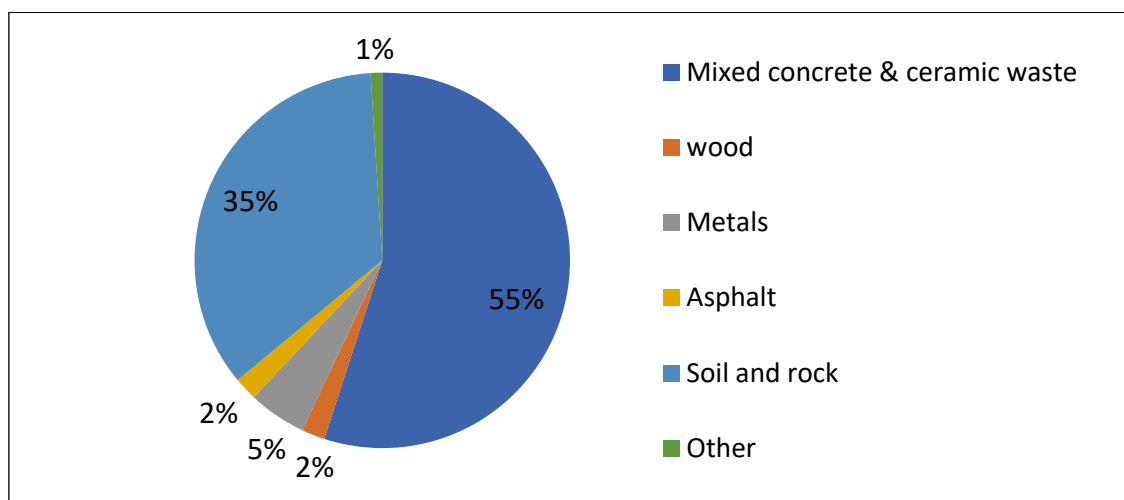
disposal. It is challenging to dispose of this waste because there isn't much available land. Nearly 2.2 billion tons of construction and demolition trash is

generated globally, and by 2025, that number is projected to rise, as per Transparency Industry Analysis.[16]



Solid waste products from industrial and commercial operations, as well as from construction and demolition (C&D), are known as demolished concrete waste materials. These materials include items and building materials such as fiber, steel, recovered asphalt, concrete, bricks, and wood. The Center for Science and Environment (2020) report

has a wealth of survey data, which shows that bulky materials. The remaining 10% of the demolished C&D waste materials are made up of bitumen, wood, paper, plastic, and other elements. Figure 2 shows the composition of the demolished C&D garbage (according to the CSE report 2020).



Critiques

Various studies had been conducted for feasibility of using CDW as stabilizing material in expansive soil, but still there are certain research gaps that have been identified which are as follows -

- Limited studies focus on the influence of specific particle size ranges of CDW on expansive soils, particularly for optimizing gradation for stabilization.

- Insufficient research on the balance between mechanical improvement and economic feasibility when using CDW for stabilization.
- Insufficient exploration of how CDW composition and gradation influence critical parameters such as swell pressure, free swell index, and shrinkage limit.

Objective of Study

The objectives of the study are -

1. To investigate the effect of different CDW particle sizes on the geotechnical properties of expansive soils and identify the best particle size range for stabilization.
2. To identify the most effective proportions of CDW to be mixed with expansive soils to achieve maximum stabilization benefits while maintaining cost-effectiveness.
3. To evaluate the effect of concrete demolition waste (CDW) on the engineering properties of expansive soil.
4. To investigate the impact of CDW on the swelling and shrinkage behavior of expansive soils.

II. Experimental Methods

Materials and Their Testing

Expensive soil:- The materials required for this study include expansive soil samples, which will serve as the base material for stabilization experiments. The soil should be characterized for its

natural geotechnical properties, such as Atterberg limits, swell index, and shrinkage behaviour. Concrete demolition waste (CDW), sourced from construction and demolition sites, will be the primary stabilizing agent. The CDW needs to be processed into varying particle sizes through crushing and sieving to evaluate the influence of particle size on soil properties. A range of CDW proportions, measured by weight or volume, will be prepared for mixing with the soil to identify the optimal mix ratios. Standard laboratory equipment like sieves, compaction moulds, swelling test apparatus, and tools for testing soil strength and shrinkage properties will support the experimental work.

Concrete demolition waste (CDW):- Solid waste products from industrial and commercial operations, as well as from construction and demolition (C&D), are known as demolished concrete waste materials. These materials include items and building materials such as fiber, steel, recovered asphalt, concrete, bricks, and wood.



Fig-3 Concrete demolished waste

Process of Concrete demolished waste (CDW):- Creating Concrete demolished waste involves processing Concrete demolished waste into fine particles. Different percentage of the obtained Concrete demolished waste (CDW) were mixed with the black cotton soil, the prepared specimens were cured for 1, 7 and 28 Days. The Optimum moisture content (OMC) and Maximum dry density (MDD) were used for all specimens to deduce comparative data.



Fig-4. Process of concrete demolished waste (CDW)

Laboratory Tests

A series of laboratory tests were conducted for the natural and soil admixture combination; the tests were conducted according to the ASTM standards. The tests consisted of:

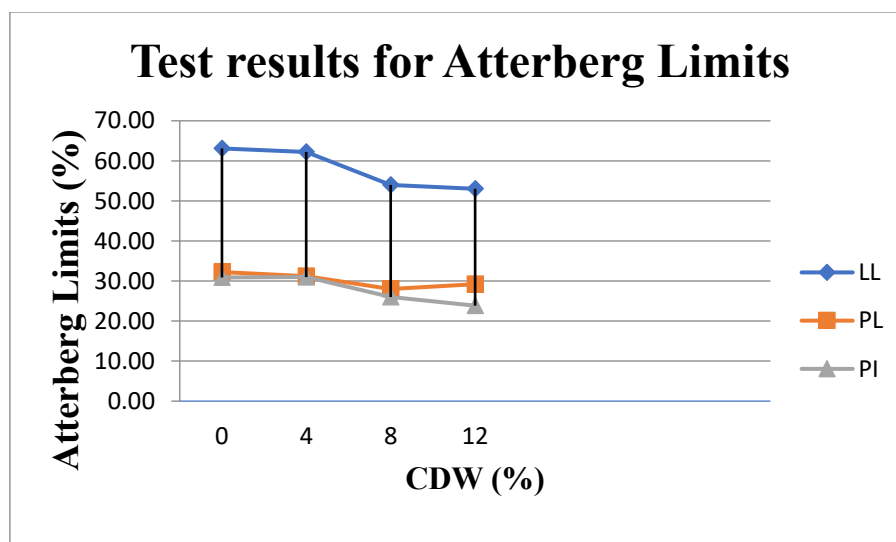
1. Atterberg limits (IS 2720 Part-5).
2. Compaction test (IS 2720 Part-7).
3. Unconfined Compressive strength test (IS 2720 Part-10)
4. Californian bearing ratio test (IS 2720 Part-16)
5. Free Swelling Index (IS 2720 Part-40)

III. Test Results & Discussion

1. Atterberg limits (IS 2720 Part-5). The liquid limit (LL) and plastic limit (PL) of the natural soil

were 60% and 28.5%, respectively. A significant reduction in liquid limit observed on adding CDW to the soil and the results are presented in Fig. 6. From this figure, it can be observed that the liquid limit sharply dropped to only 50%. in contrast the plastic limit of the soil slightly increased by adding CDW, (see Fig. 6). Hence the plasticity index of the soil improved too and the results are presented in Fig. 6. Linear shrinkage test was conducted for the natural soil and the result was 15.9%. Also, the Linear shrinkage test was performed for the soil-stabilizer mix as it can be seen in Fig. 7. From the results, it is obvious that the Linear shrinkage limit of the soil reduced to 10.3% on adding 18% of CDW as the results are presented in Fig. 6.

Sr.No.	Percentage of Concrete demolished waste		0%	4%	8%	12%
1	Atterberg limits	Liquid limit (%)	63.1	61.20	54	53
		Plastic limit (%)	32.23	31.2	28	29
		Plasticity index (%)	30.87	30.00	26	24

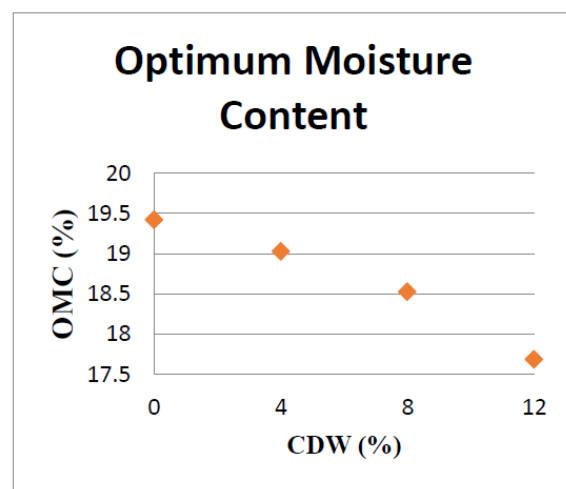
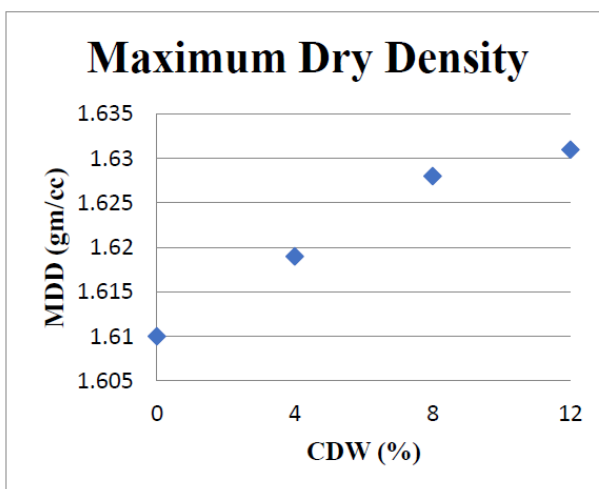


2. Compaction test (IS 2720 Part-7). The modified proctor test was employed for investigating the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of soil and soil-admixture. 12% of CDW was selected as an optimum mix based on the results from swelling percent and

swelling pressure tests. the soil-CDW combinations and their proportion for conducting the compaction tests were fixed as soil:CDW, 88:12 and the results are shown in Fig. 11. The addition of 12% CDW reduces MDD from 1.8 to 1.78 gm/cm³. Also, OMC decreased from 17.5% to 15.23%.



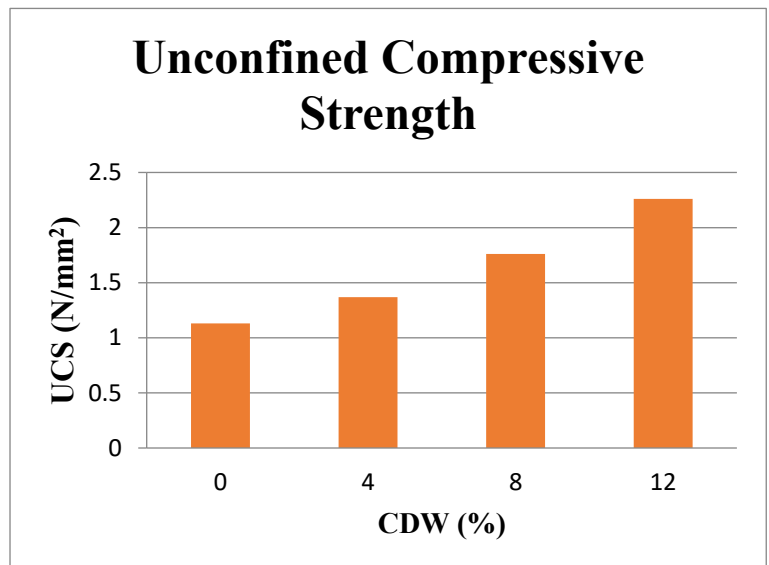
Sr.No.	Percentage of Concrete demolished waste		0%	4%	8%	12%
1	Compaction test	MDD (g/cc)	1.61	1.619	1.628	1.631
		OMC (%)	19.42	19.03	18.53	17.69



3. Unconfined Compressive strength test (IS 2720 Part-10). The unconfined compressive strength (UCS) test was conducted to investigate the improvement in compressive strength of the soil stabilized with CDW. Different soil-admixture combinations such as: soil:CDW, 90:10, 88:12, 86:14, 84:16, 82:18, 80:20 and 78:22 were used. The samples were prepared and wrapped with several layers of cling film and tested after a curing period of 1, 7, and 28 days (see Fig.12). The UCS

for untreated soil was 302 kPa. It was observed that the strength increases with the addition of CDW and strength increased with higher curing periods. The UCS value for stabilized samples with CDW and cured for 7days are 591.4 kPa for 10% CDW, 775.9 kPa for 12% CDW and 950.9 kPa for 20% CDW. The results of 28-days, UCS tests are: 735 kPa for 10% CDW, 962.68 kPa for 12% CDW and 1039.7 kPa for 20% CDW, the results are illustrated in Figs. 13, 14 and 15.

Sr.No.	Percentage of Concrete demolished waste	0%	4%	8%	12%
1	Unconfined Compressive strength (N/mm ²)	1.13	1.37	1.76	2.26

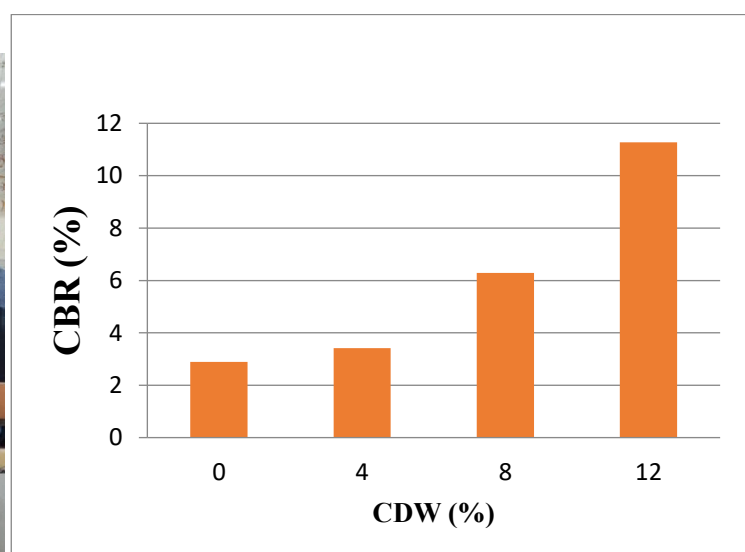


IV. Discussion:-

4. Californian bearing ratio test (IS 2720 Part-16). The California bearing ratio (CBR) test was conducted on soil and the soil-stabilizer mix (optimum mix) as soil:CDW; 88:12 which is selected based on swelling tests results. The addition

of 12% CDW to soil increases the soaked CBR value for 7 days from 4.27% to 24.14 % as shown in Fig. 19. The increase in CBR is due to the presence of sand and cement particles in the CDW which create bonds and mobilizes the angle of internal friction resulting in an increase in strength.

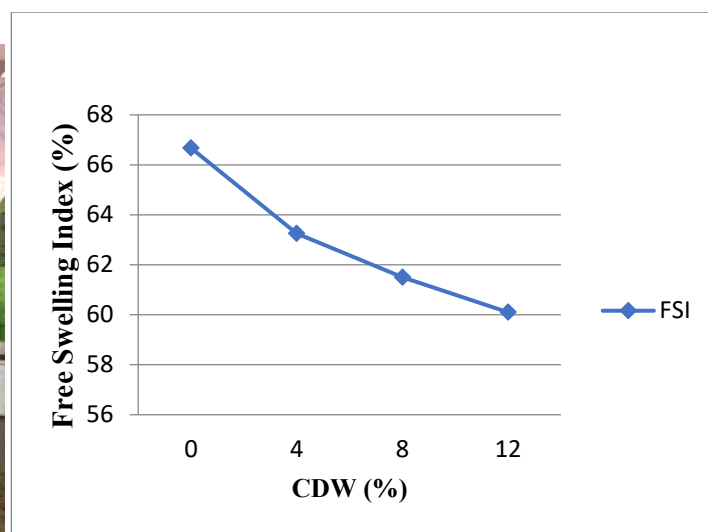
Sr.No.	Percentage of Concrete demolished waste	0%	4%	8%	12%
1	Californian bearing ratio test (%)	2.89	3.42	6.29	11.28



5. Free Swelling Index (IS 2720 Part-40). The effect of adding CDW on swelling percent of soil is illustrated in Fig. 8. The swelling percent of the untreated soil was 14 % which on the addition of CDW reduced drastically at 12 % of CDW content and becomes 4.28 % after 28 days of curing. Further addition of CDW results in a slight reduction in swelling percent. The addition of CDW to soil resulted in a decrease in soil swelling pressure. The swelling pressure of the soil decreases with the

addition of CDW content, at the binging the samples were compacted in the oedometer ring and the constant volume method were used to investigate the swelling pressure as shown in Fig. 9. an improvement of up to 55% in swelling pressure was obtained on adding 12% of CDW after 28 days of curing as shown in Fig. 10. Further addition of CDW results in a slight reduction in swelling pressure.

Sr.No.	Percentage of Concrete demolished waste	0%	4%	8%	12%
1	Free Swelling Index (%)	66.67	63.25	61.5	60.1



V. CONCLUSION:

The aim of this study was to identify the effect of concrete demolishing waste (CDW) on the geotechnical properties of the selected expansive soil and the results concluded as:

1. Liquid limit, plasticity index and linear shrinkage limit of the treated soil decreased with the increase in CDW for all soil-admixture percentage since CDW is non-cohesive material.
2. The swelling potential (swelling percent and swelling pressure) of the stabilized soil improved, as swelling percent decreased to one-third of its original value also the swelling pressure reduced to half of its original value after adding 12% of CDW. Adding further CDW caused insignificant change in the swelling potential of the soil.
3. Adding 12% of CDW caused reduction in Maximum dry density and Optimum moisture content. The decreases are due to the presence of fine sand in CDW.
4. UCS increased with the addition of CDW, the increases in strength, is more and significant on adding 12% of CDW cured for 28 days. It is reported that the soil behavior changes from flexible to brittle materials on adding CDW in increment.

5. Soaked CBR value of the soil Soaked for 7 days increased up to 6 times compare to virgin soil after adding 12% of CDW.

In conclusion, CDW is an economical and environmentally sustainable solution to improve expansive soils, especially for low expansive soils and adverse the unacceptable geotechnical properties of the soils.

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