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Evaluating the Feasibility of using Construction and Demolition Waste in Subgrade

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Abstract: ***The expansion in infrastructure due to the building and demolition operations, more construction and demolition waste are produced and this waste must be properly disposed of and managed. This paper proposes to evaluate the feasibility of using construction and demolition waste (CDW) for the subgrade of roads. The subgrade material is fully replaced by the finer portions of CDW and its practicality is analysed. The properties were identified by conducting compaction, direct shear, CBR etc. The properties of finer portions of CDW were compared with the basic requirements of subgrade material. The results indicated that the subgrade material can be fully replaced by finer portions only after suitable modification of CDW.***
Keywords: California Bearing Ratio (CBR), Construction and Demolition Waste (CDW), Subgrade of Pavement.

I. INTRODUCTION

In India, the construction sector produces 10–12 million tonnes of different wastes per year. Pavement construction is the primary application for construction-demolition waste (CDW). The consumption of natural aggregate and the quantity of waste dumped in landfills are both decreased by the use of CDW in pavement building. The usage of CDW as an alternative to natural aggregate for road subgrade depends on its characteristics, accessibility, effectiveness, etc. Waste material generated during the construction, renovation, and demolition of buildings, roads, and bridges is referred to as construction and demolition trash. The natural material that lies beneath a pavement construction is called subgrade. The thickness of the subgrade required is 150mm to 300mm and on highways, it should be a minimum of 500 mm. It means that numerous fillers are required while building the subgrade to accommodate such depths. Hence, reusing CDW as an alternative to fine soils and gravels in the pavement subgrade would be a useful technique.

II. LITERATURE REVIEW

Population expansion and rapid urbanisation had raised a demand for additional housing, and infrastructure. A large amount of construction and demolition debris are produced worldwide as roads, buildings, and bridges are renovated and replaced. The government have begun to implement new environmental restrictions encouraging the use of recycled materials rather than natural resources in order to deal with both growing waste dumps and the concurrently growing need for raw materials. Multiple economically valuable materials, including reusable aggregate, bitumen, brick, cardboard, concrete, metal, and wood, are included in construction and demolition waste. Many of these materials could be used directly or indirectly to create new products and construction materials. Around 130 million tonnes of CDW were produced in India in 2012, and by 2050, that number is anticipated to reach over 750 million tonnes annually [8]. Managing demolition waste has various benefits, including improving health and safety conditions, lowering airborne pollutants caused by garbage unloading operations, and minimizing the likelihood of heavy metals and hazardous materials in the waste stream. The properties of construction and demolition waste were noted to help in the stabilization of sandy soil as well as clayey soil. For sandy soil, the values of the internal friction angle and soil cohesiveness were increased by 1.11 and 26.69 times, respectively, by the addition of CDW. The highest strength value was obtained at 16% ratio for just CDW addition which was selected to be the optimum ratio. Bearing capacity values increased up to 40% as CMT increased up to 6% [4]. In clayey soil, it was suggested that the optimum CDW ratio should be 14%, and the optimum curing time should be 14 days in clay soil. The Bearing capacity increased approximately 2.41 times [3].

In most of the studies, the basic requirement of subgrade material is sufficient CBR value as per the standards of the specific location. Since CDW created in Almera is a granular material with a very high CBR, it may be utilised as sub-bases or esplanades of roads and highways as earthworks. Sand (56.9 wt%) and gravel (38.4 wt%) were the two most prevalent components, with silt (4.7 wt%) making up the remainder. The CBR was 36, which made it a selected soil (CBR $\geq$ 20) for the formation of esplanades [6]. Compaction of CDW also played a vital role in bearing strength. The effect of compaction was best when the moisture content of CDW was controlled at 15%-16% [10].

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The partial crushing and breaking that was permitted during the compaction process modified the grain-size distribution and increased the proportion of cubic grains. Better densification was produced by this physical alteration, and this enhanced bearing capacity, resilient modulus, and resistance to permanent deformations. The results indicated an average CBR of 73% and 117% for intermediate effort and modified effort, respectively. When the compaction effort is increased, the bearing capacity of the recycled CDW aggregate increases. Research suggested that recovered aggregate from building and demolition waste might be used as a coarse base and sub-base layer for low-traffic roadways [9]. The CBR analysis showed a 75% decrease in the performance of recycled concrete aggregate, with 50% clay addition [5]. When comparing [6] & [9], recycled construction and demolition waste was much more effective than unrecycled material. After cement stabilisation was applied, the CDW from Fooladshahr had CBR values that were below the norm, making them appropriate for use as the bases and sub-base of roadways. The results show that the maximum dry density of without-cement wastes after stabilization with 12 percent cement (by weight), increased from 1.83 to 2.10 g/cm^3, and their CBR value increased from 65.8% to 88.6% [7]. Sinop-MT (Brazil) soil stabilised by adding 50% and 25% sand fractions of CDW produced CBR of 74% and 20%, justifying its application to subgrade layers. Even with 100 percent construction waste, CBR outperformed natural soil [1]. In some studies, the construction and demolition wastes were separated from the clay masonry work and the recycled clay masonry and construction and demolition waste were added in different proportions. The resilient modulus significantly increased for various ratios of the C&D/RCM (Recycled Clay Masonry) blends, including 100/0, 90/10, 80/20, 70/30, 55/45, 40/60, 20/80, and 0/100% of the total aggregate mass. The C&D/RCM mixes showed soaked CBR values ranged from 70% to 153%. The CBR value for the 100% C&D mix was the highest; this could be because C&D materials still include some free lime, which could promote more cementation. In general, the relative CBR dropped as the RCM content improved [2]. UCS under the optimal moisture content of 15%-16% were in the range of 0.85 MPa to 0.62 MPa, and the mean value was 0.74 MPa. The average CBR value was at least 34.7%, the Field deflection of the embankment was 0.66 mm, and the resilient modulus was 162.7 MPa, which meets the requirements of subgrade [10]. In most of the studies, it was found that CDW can be reused as the subgrade of roads. Usage of CDW in subgrade increased the strength characteristics and reduced the compressibility. In cases where CDW was not suitable, stabilisation methods were adopted. Moreover, the properties of CDW depend on the nature and source of the waste, materials present in the CDW etc. The CDW were widely effective after recycling. In India the recycling process is tedious. So, the study was concentrated on the effectiveness of using the fine-grained portions of CDW as a subgrade material. This helps in the effective management of CDW as well as cost reduction in the construction of pavement.

III. MATERIALS AND METHODOLOGY

Construction and demolition waste used in the study were collected from the Nalanchira location at Trivandrum, Kerala, India. The sample was the demolition waste of a single-storey residential building. The finer portions of CDW were separated from the CDW. That is the particles passing through IS sieve 4.75 mm were taken for the study. The finer fractions were taken due to the limitation in crushing the large concrete and masonry waste. The CDW samples collected were tested in the laboratory to determine their geotechnical properties as per the Indian Standards. The CDW samples were dried before conducting the tests. The laboratory test conducted were sieve analysis, specific gravity, compaction, soaked CBR and direct shear test. Four different trials were conducted for the CBR test and the average was taken into consideration.

IV. RESULT AND DISCUSSION

The geotechnical properties of sample collected from the Nalanchira site are represented in Table 1. As per sieve analysis results, the percentage of clay in the given sample was 0.2 %, percentage of sand was 81.8 % and percentage of gravel was 18 %. Thus, the soil sample mostly consists of sand. Therefore, as per IS 2720: Part 4, the soil can be classified as poorly graded sandy soil.

Table 1 Geotechnical Properties of finer portions of CDW

Properties	Measured Value
Percentage of Sand (%)	81.8
Percentage of Clay & Silt (%)	0.2
Percentage of Gravel (%)	18
Specific Gravity, G	2.36
Angle of internal friction (degree)	36
Cohesion (kg/cm^2)	0.15
Maximum Dry Density (g/cc)	1.86
Optimum Moisture Content (%)	15
Soaked CBR (%)	4.62
Soil Type	SP

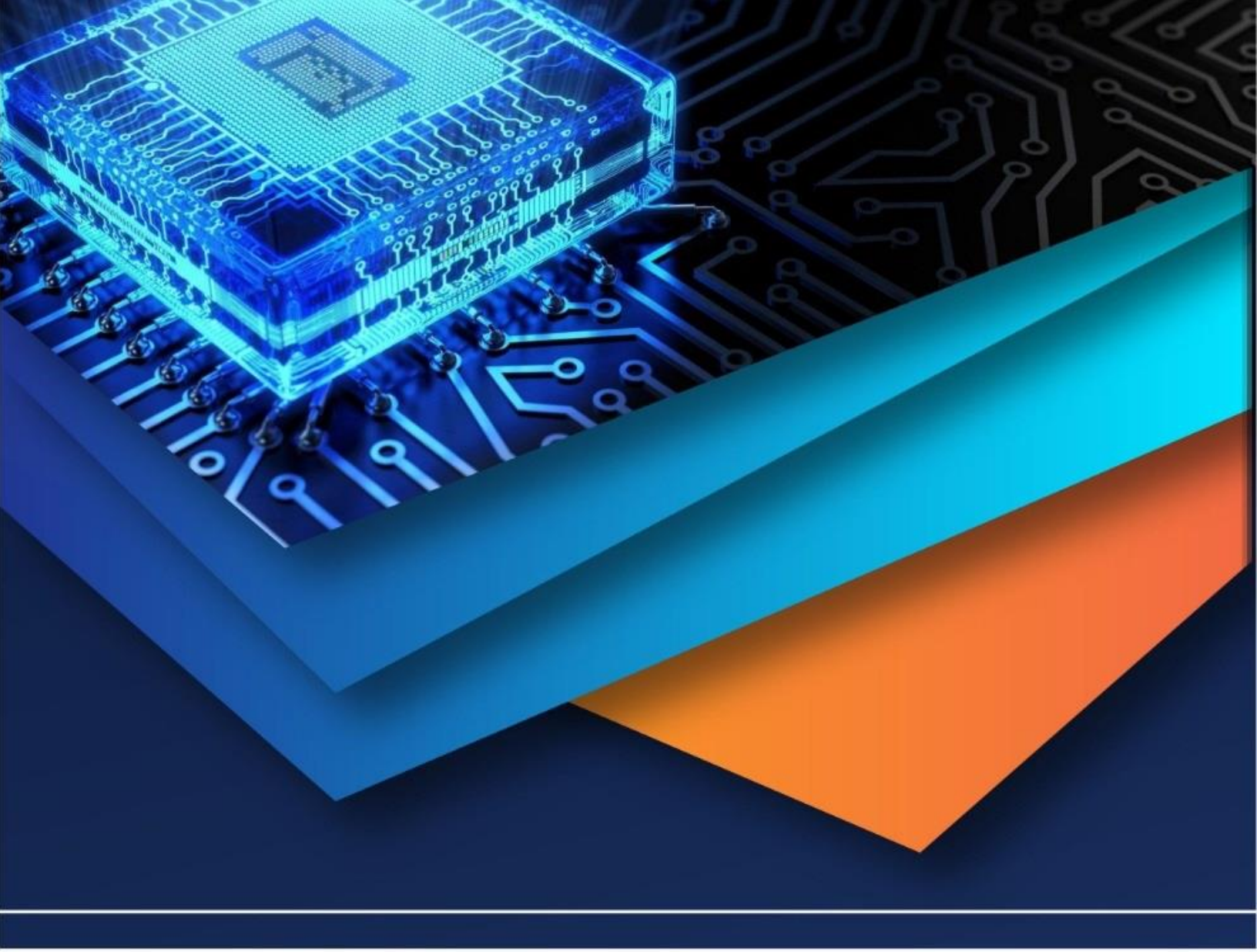
The cohesion was obtained as 0.15 kg/cm^2 & the angle of internal friction was obtained as 36^0. The maximum dry density was 1.86 g/cc and optimum moisture content was 15 %. The average soaked CBR value was obtained as 4.62 % after conducting four trials. For the design of subgrade, the CBR value of subgrade material should not be less than 10% as per AASHTO T-193 & AASHTO T-180. The soaked CBR value obtained is less than the specified requirement. So, the demolition waste sample could only be reused as a subgrade material after suitable modification. The reduction in CBR value may be due to the very low clay content present in the sample. So, it can be concluded that the sample of demolition waste will highly depend on the source and nature of demolition waste. As the CDW obtained from the site was the waste of a single-storey residential building, it was having a high amount of concrete waste and masonry rather than fine soil. If the CBR value is low it will cause failure when heavy traffic occurs. The traffic volume will be comparatively low in low volume roads. As an initial step, the CDW could be directly provided in low volume roads after suitable modification.

V. CONCLUSION

The debris gathered from construction and demolition projects in Trivandrum, India's Nalanchira neighborhood, was examined to determine whether it could be replenished in the subgrade. The finer portions of CDW were tested to analyse whether it is suitable to fully replace the subgrade material of pavement. The results show that the CBR values didn't reach the specified requirement. And hence the finer portions of CDW could only be used as a subgrade material only after adequate modification. The CDW obtained was having a large proportion of concrete waste and clay content present is very low. It may be the reason for the inadequacy of using CDW in pavement subgrade. But as an initiation, the direct usage of CDW could be adopted for low volume roads in India. Since the traffic volume occurring in these types of roads are low, the possibility of failure due to heavy traffic is minimum. So direct application of CDW could show better performance in low volume roads after suitable modification. The literatures are evident that the CDW could be effectively utilized in pavement subgrade construction directly or after recycling. However, some studies showed that the demolition waste could only be utilized after adopting suitable modification as it depends on the nature and the particles present in it. Also, the waste could only be replaced in pavements only after the confirmation that it satisfies the specific requirements of the pavement section as given in the Standards. The process of modifying the subgrade could be achieved under the condition that the values provided should not be adopted in the field as such, only the method should be adopted. So from this study it is clear that the clay content must be sufficiently available in the CDW samples to achieve better bonding and compactivity of subgrade. Then only the CBR value could reach the requirement of subgrade. Large amount of waste produced due to expansion in infrastructure could be efficiently managed by considering the above mentioned factors of CDW thus achieving economical improvement of the country and a credible way of waste management.

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