Geo technical Laboratory Evaluation of Construction Demolition Recycled Material for Road Embankments

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Abstract: The recycling of construction demolition waste material has already become a prime focus under sustainable technologies and innovations across the globe. A report announced by the Centre for Science and Environment (CSE), Delhi, in August 2020 stated, India generates approximately 150 million tons of construction demolition waste every year and recycles only 1%. The rest remains strewn across, in landfills causing air contamination and water tainting. Whereas "The United States Environment Protection Agency (USEPA)" approximated that 600 million tons of construction waste had been generated in 2016 in the USA, around 75% of the waste was recycled and also used effectively. The present paper focuses on predicting the suitability of recycled construction demolition waste material for road embankment and comparing its characteristics with conventional embankment materials. The Guidelines given by IRC and BIS were following to predict the feasibility of recycled construction demolition waste as fill material for road embankment. Laboratory results indicated the suitability of recycled construction demolition waste material for road embankments. This study probed a single source of construction demolition waste with one particular gradation as it can significantly alter the properties and suitability requirements.

Keywords: Construction demolition waste, Gradation, Recycled material, Road embankments.

1. Introduction:

The recycling of building-related demolition waste is now emerging and is also a prime focus under sustainable technologies and innovations across the globe. A report announced by Delhi Centre for Science and Environment (CSE) in August 2020 has shown, India generates approximately 150 million tons of construction demolition waste each year and recycles only 1% of the rest that remains strewn across in landfills or open areas everywhere causes air contamination and water tainting, on the authority of Building Material Promotion Council. Whereas United States Environment Protection Agency (USEPA) approximated that 0.55 billion tons of construction waste was collected in 2015-16 in the USA, around 75% of the waste had been recovered and reused effectively. The construction-related demolition wastes include debris from construction activities, demolition of buildings, and renovation works with concrete, brick, timber, metals such steel reinforcement, glass, and geosynthetic materials such as geotextiles geo-grids, and geocomposites as its main constituents. The infrastructure developments across the globe have been rapid in recent decades, especially in developing and developed nations demanding amounts of conventional construction materials and generating enormous construction demolition debris. To meet this necessity, recycling and reusing demolition wastes in various civil infrastructures such as embankments, concrete production, road works, and filling material in retaining structures are in practice nowadays [10-12]. The higher probability for salvageable and retrievability of construction wastes is one of the major driving forces
for the researchers in the construction industry to develop new technologies and methods for efficient utilization and achieve sustainability by reducing the consumption of conventional resources [13, 14]. Meanwhile, issues related to environmental safety associated with the safe ejection of construction wastes such as air contamination due to increased dust content in the atmosphere and water pollution resulting from unorganized landfills can be addressed by effective use of construction demolition recycled materials [4, 5]. The brick mortar waste as shown in Figure 1.

![Brick mortar waste](image)

**Figure 1.** Brick mortar waste.

Zhang [6] performed laboratory and field evaluation of road embankment constructed using 100% recycled materials derived from building-related demolition wastes. Results depicted the suitability of demolition recycled materials as a highway embankment. The laboratory tests executed on selected demolition recycled material were carried similar to this work. Cristallo [1] studied the Geotechnical and Geoenvironmental characteristics for the construction demolition-related recycled materials. The fundamental physical and mechanical properties to be determined for assessing the suitability of recycled material for road embankment were executed similarly to this research paper. Zhu [2] suggested using liquid silicone resin for pre-treatment of recycled construction wastes to improve the characteristics of building-related demolition recovered materials in terms of strength and moisture absorption resistance and to bring the deformations of recycled demolition derbies within the permissible limits. Silva et al. (2018) examined the viability of recycled demolition wastes as a substitute for conventional filling material in retaining structures and embankments. Investigations revealed that the shear strength at the contact between recovered material and geosynthetic material has reduced with the rise in moisture content of recovered demolition debris, and improved interface shear strength has been achieved with the enlargement in the degree of compaction. The probability for recycled material derived from construction demolition for engineering applications such as road embankments fundamentally relies on laboratory evaluation, recycled material constituents, and gradation patterns. The basic requirements such as adequate shear strength,
good trainability characteristics, and limited settlements within the embankment must be evaluated before field applications.

2. Methodology:

Assessing the suitability of construction demolition recycled material owing to its availability in large quantities, cost-effectiveness, and eco-friendly characteristics as a substitute to conventional materials used in civil engineering infrastructures were explained in this study. The present investigations are aimed at studying the collected material from various construction demolition sites located in Hyderabad. The separation and recycling process for the collected waste was complex due to the heterogeneity of the waste materials. Among the different constituents of demolition wastes brick with cement, the motor has been selected for laboratory evaluation purposes as brickwork holds the majority portion of waste generated from demolition activities. The performance of tests on selected brick waste revealed the influence of heterogeneity characteristics in brick waste on the properties. IRC gives the guidelines: 75-2015 [8] are in use to design high embankments. The details of the tests performed on the selected brick waste and tests procedures were explained in the following sections.

2.1 Tests conducted

The following tests have been conducted in the test schedule to meet the objectives of the present investigations.

Sieve Analysis: IS 2720 (Part-IV)
Specific gravity test: IS 2720 (Part-III)
Atterberg’s Limits: IS 2720 (Part-V)
Compaction tests: IS 2720 (Part-VIII)
CBR: IS 2720 (Part-XVI)
Direct shear tests: IS 2720 (Part-XIII)

Sieve Analysis for determination of particles distribution within the brick waste by IS 2720 (Part-IV): 1985 [7] conducted on the crushed sample to classify the brick waste based on the specifications mentioned in IS 1498: 1970 Classification and identification of soils for general engineering purpose. Atterberg’s limits, along with the sieve analysis results, were used to classify the selected brick waste as per the guidelines given in the AASHTO Soil classification system. Specific gravity test helps determine the applicability of material for construction works; the high value of specific gravity designates high strength for material under consideration. The specific gravity range of the materials used in engineering applications is 2.60 to 2.80 as per the specifications given in the IS 2720 (Part-III): 1980 [7]. The compaction tests help determine the maximum dry density and desirable moisture content for any engineering materials; the amount of material must be compacted to ensure the structure's stability and prevent damage from excessive settlements can be studied by compaction tests. The shear parameters of the material govern the suitability for the engineering applications, and based on the characteristics of the material under consideration; relevant tests must be carried. Index properties of the brick waste particle size distribution, consistency limits also material composition recommended direct shear test as per the IS 2720 (Part-XIII): 1986 [7] to determine shear parameters of the brick waste. The CBR is a penetration test performed to find the strength of aggregates used for
road works and treated as an index for aggregate stability and bearing capacity as per the recommendations mentioned in IS 2720 (Part-XVI): 1987. The shear strength of aggregate declines as the water content rises. CBR test soaked (4 days) condition to stimulate the field conditions for the worst situation conducted on the brick waste to evaluate its strength characteristics.

The aggregate crushing test estimates the strength of aggregate in compression; low crushing value means strong aggregate. IRC and BIS specified the aggregate crushing value used for base layers should be lower than 45%. For materials used in coarse surface layers crushing value should not be more than 30%. The manual separation and mechanical sorting of demolition wastes using jaw crushers, hammers, conveyors, screening, and stockpiling are in practice nowadays to recycle the construction demolition wastes. The laboratory tests explained above can provide basic information about the selected recycled material extracted from construction demolition activities. Comparing the properties obtained from laboratory tests on selected recycled construction demolition material with the conventional embankment material can assess the feasibility of using recycled materials in road embankments. Precise estimation of properties in the laboratory and constituents of recycled construction demolition material governs the suitability characteristics of recycled material in different civil applications like roadways and production of the concrete matrix. Sharkawi [3] explained the effect of available other crushing methods on the properties of recycled construction demolition material and investigated the performance of different recycled construction materials in various engineering applications. The results of Sharkawi [3] suggested a jaw-crushing technique instead of hammer crushing for recycling construction demolition wastes. The brick waste collected from the demolition site in this study was processed into a uniform material by crushing the sample in a laboratory compression testing machine (CTM) as per the codal provisions given by IS 2386 (Part-IV): 1963.

3. Results and discussions:

3.1. Sieve Analysis: The sieve analysis results on the brick waste collected from a demolition site in terms of uniformity coefficient (Cu) and curvature coefficient (Cc) before compaction and after compaction on crushed sample classified the brick waste as poorly graded sand and well-graded sand, respectively. To determine the secondary breakage effect, compare the gradation of recycled brick waste before and after compaction as explained in figure 2. The recovered brick waste had a recognizable shift to a finer gradation after compaction. The Cu value reduced from 15.59 to 7.51, and the Cc value increased from 0.49 to 1.06. According to IS code provisions, the curvature coefficient (Cc) in the range of 1 and 3 describes the material as well graded. Hence, it is found that the compaction yielded a secondary breakage of recovered brick waste, which thereby resulted in denser with fine gradation. Table 1 illustrates the soil classification details.

| Parameters | Before Compaction | After Compaction | Soil Classification |
|------------|-------------------|------------------|---------------------|
| Cu         | 15.59             | 7.51             | poorly graded sand  |
| Cc         | 0.49              | 1.06             | Well graded sand    |

Table 1. Soil classification
Figure 2. Particle size distribution curve.

3.2. Atterberg’s limits: The liquid limit and plastic limit water content of the recycled brick waste obtained from the laboratory Casagrande’s apparatus and plastic limit roller device according to the IS 2720 (Part-V): 1985 cod provisions was 38% and 29%, respectively. Corresponding plasticity index for the recycled brick waste equal to 9%. Based on the sieve analysis results, particle size distribution curve and Atterberg’s limits of the recycled brick waste material classified according to AASHTO soil classification system as “Silty or Clayey gravel sand (A-2-4)” with excellent to good rating as an embankment material.

- Moisture content at liquid limit = 38%
- Moisture content at plastic limit = 29%
- The Plasticity index (Ip) = 9%

3.3. Specific Gravity: The laboratory pycnometer test to determine the specific gravity of the recycled brick waste as per the guidelines mentioned in IS 2720 (Part-III): 1980 codal provisions was 2.65 indicate suitability as an embankment material.

3.4. Compaction tests: The optimum moisture content (OMC) and maximum dry density (MDD) characteristics for recovered brick waste were conducted in the laboratory using standard proctor test and modified proctor test as per specifications given in IS 2720 (Part-VIII): 1983 [9] codal provisions and depicts in Figure 3. The Table 2 illustrates the moisture density characteristics. The degree of compaction required and a suitable compaction technique for the embankment layers. Primarily depends upon the optimum moisture content and maximum dry density parameters for the material using in embankment constructions.

Table 2. Moisture-density characteristics

| Parameters | Standard proctor test | Modified proctor test |
|------------|-----------------------|-----------------------|
| OMC (%)    | 17.2                  | 15.5                  |
| MDD (g/cc) | 1.75                  | 1.85                  |
3.5. CBR test: The CBRat2.5mm value of recycled brick waste in soak condition from the laboratory was 3.59%. The requirement of CBR in soak condition for subgrade or fill materials should be more than 3%.

3.6. Direct shear test: The shear parameters obtained from the laboratory direct shear test and depicted in Figure 4. The suitability of recycled brick waste material for embankment constructions.

![Figure 3. Dry density vs Moisture content comparison.](image1)

![Figure 4. Determination of shear parameters](image2)
3.7. **Crushing test**: The crushing value of recycled brick waste obtained from the laboratory compression testing machine was 30.875% depicts the suitability of recycled brick waste for embankment fills.

3.8 **Comparison of recycled brick waste with conventional embankment material**:

3.8.1 **Gradation** – well-graded fill materials consist of a mixture of finer particles along with granular composition is desirable as a fill of embankment in road works. Due to more variations in soil, there are no universally specified boundaries for the gradation of fill materials. Crushed recycled brick waste particles size had a well-graded curve and after compaction yielded a secondary breakage, which formed a fine and dense gradation.

3.8.2 **Specific Gravity** – Embankment fills materials comparatively low in unit weight have the advantage of conveying lesser dead loads to underlying strata over which embankment is constructed. Recycled brick waste specific gravity attests to the suitability for embankment fill material.

3.8.3 **Moisture-Density Characteristics** – The compaction characteristics (OMC, MDD) of fill material are the important properties that affect the embankment structural functioning. The specifications for embankment construction demand the well-compacted fill material with in-situ density higher than 95% of the maximum dry density achieved in the laboratory at water content approximately equal to optimum moisture content. The laboratory results of standard and modified proctor tests on recycled brick waste material indicated satisfactory results to conventional embankment fill materials.

3.8.4 **Shear Strength** - The shear parameters (Cohesion, Angle of internal friction) are representatives of the ability of fill material to bear the loads imposed on it and are used to analyse the stability of an embankment. The conventional fill materials used in road embankments have cohesion in the range of 10-25 kPa, and the angle of internal friction lies between 22° to 26°. In contrast, the shear parameters for recycled brick waste from the direct shear test had cohesion of 25 kPa and an angle of internal friction 25°.

4. **Conclusions**

This paper focused on the suitability of recovered building-related demolition waste such as recycled brick wastes in road embankments. The required laboratory tests were carried out to evaluate the index properties and engineering properties of building-related demolition wastes.

- The recovered brick waste through manual processing and mechanical operations satisfied the guidelines given by Indian standards. The AASHTO Classification System classified recycled brick waste as an admirable embankment material.
- The direct shear test performed in the laboratory indicated acceptable shear parameters for the recycled brick waste to be used in road embankments.
- The crushing value of recycled brick waste to be used in road embankment fill material met the recommendations given by IRC and BIS.
• Compared to conventional embankment fill materials, recovered brick waste had better characteristics and depicted the substitution of recovered demolition wastes for the traditional fill of embankment materials.

5. Future Scope
The scope of the present investigation for the future can be the influence of material origin and induced gradation on the characteristics of construction demolition wastes. Also, stability analysis of embankment constructed with the 100% recycled demolition wastes and cost-effectiveness analysis should be determined for recycled demolition debris in road embankments.

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