A Review on the Effect of Solid Waste on Soil Stabilization: Towards Sustainability

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Abstract - *Developing countries like India with industrial backgrounds contribute to a significant portion of the waste produced on the earth. Because of the rapid growth and expansion of various industries in the country, the different types of waste materials are being generated and dumped in lands and water bodies, creating a significant impact on the environment. Some industrial wastes such as fly ash, plastic, glass, GGBS, cement kiln dust, quarry dust, etc., can be used as soil stabilizers. India is a developing country stepping towards "Digital India" and transforming into a digitally empowered society and generating electronic waste. To tackle the expanding problem of e-waste and the general lack of awareness about it leading towards environmental impact. These industrial waste materials are converted into engineering material to stabilize the expansive soil as part of waste management. This review paper's objective is to study the effect of solid waste in improving index properties and the engineering properties of expansive soils and finding its optimum quantity of percentage to be mixed with soil to get higher strength.*

Key Words: **Industrial waste, E-waste, Environmental impact, Soil stabilization, Index & Engineering properties.**

1.INTRODUCTION

The term Sustainability represents the development that meets the needs of the present without compromising the ability of future generations to meet their own needs [1]. (WCED 1987a: 43). The concept of Sustainability majorly includes three factors economy, environment, society. As concerning the engineering perspective, these factors will include using human and natural resources wisely, economic growth, restoring the ecosystem, and meeting basic needs such as safety, health, education & employment, and equality.

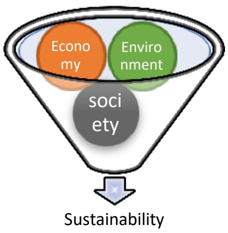


Fig -1: Sustainability

As part of the development, the rapid growth & expansion of industrialization is also causing significant environmental impact by generating waste material. Towards Sustainability, waste management also got attention to protect the environment and reduce the usage of natural resources. Industrialization plays a significant role in developing countries like India, but on the other hand, its waste generation creates eco problems. With the substantial increase in the harmful effects of industrial pollution, many researchers invest their time utilizing these waste materials in an eco-friendly manner to reduce pollution. The utilization of waste materials could reduce contamination and spaces for disposal. Therefore, recycling waste material into green material for application in construction industries is a prime concern among current researchers.

The substantial increase in population has led to considerable growth of infrastructure and construction activities. Connectivity plays a significant role in civilization by reaching every corner of the country. So the transportation & pavement roads are continuous construction activities to meet the need of the growing population. Sometimes this connectivity has to be laid through the unacceptable soil strata having more clay minerals like illite, montmorillonite, which gives swelling properties to the soil when it absorbs the moisture. Soil plays a vital role in the construction industry, being the foundation that must be strong enough to bear the loads coming from the whole structure. This reason takes forward to improve the properties of swelling soils to construct stable and durable pavements.

1.1 Soil stabilization

The process of soil stabilization involves the development of index & engineering properties of poor soils. Soil can stabilize either mechanically or chemically. In the case of chemical stabilization, different materials are used, such as cement, lime. The researchers are found by using the other waste materials generated from agriculture (rise husk ash, coir fiber, jute, bagasse, etc.), industrial (fly ash, GGBS, quarry dust, construction & demolition waste, copper slag, steel slag, etc.), municipal solid waste (plastic, glass, etc.), E-waste the properties of soil can be altered. Usage of these waste materials will be the alternate method of waste management that avoids landfilling, burning which causes land and air pollution [2].

2. SOLID WASTE

The concept of utilization of solid waste in the construction industry solves the environmental issue and makes the construction economic. A considerable depletion in carbon emission will be achieved by reusing the solid waste material as construction material and becomes effective waste management towards Sustainability of material as eco-friendly. This review presents the effect of plastic waste, fly ash, bagasse ash, E-waste as a soil stabilizer, various tests conducted, result discussion, and their optimum percentage mix.

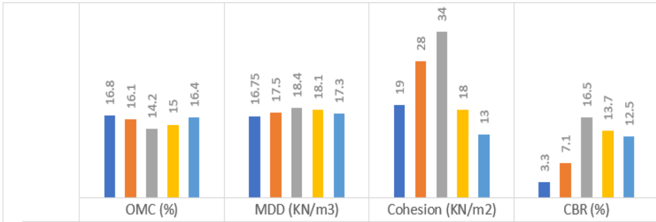
2.1 Plastic waste

The plastic product became a basic need in daily human life because it has attractive qualities (such as its lightweight, water retainer and resistance, expandable, strong, and very cheap to produce), which leads to overconsumption of plastic-based products [3]. This overconsumption has a large amount of waste as a deposit, which must be recycled or reused to diminish the environmental impact. Mostly the plastic is made up of non-biodegradable sources. Landfilling using plastic is nothing but burying the toxic material over a period until it naturally degrades. Its rate of decomposition and bulk nature in the filling will create an environmental problem.

Several experimental studies have utilized plastic waste as an engineering material in the construction industry as an alternate method of landfilling. The different types of plastic waste are used in different ways, i.e., to replace some aggregate in concrete production, as a binder material for aggregates in asphalt pavements. It also can be used in soil stabilization to control the shrink-swell properties of soil and improve the shear strength properties and the capacity of soil to support the loads.

Plastic wastes generally include Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE), Low-Density Polyethylene (LDPE), Poly Vinyl Chloride (PVC), Poly Propylene (PP), and Polystyrene (PS). All these kinds of wastes are using in soil reinforcement; in this paper, we tried to discuss the effectiveness of PET plastic bottle strips as reinforcement to improve the engineering properties of soil.

The improvement of soil properties such as shear strength, maximum dry density (MDD), and CBR values have been investigated by adding strips cut from plastic bottles by conducting various laboratory tests on disturbed soil samples collected from the plain of Bihar (Patna) is covered by Gangetic alluvium [4]. The sample was soil classified as silty sand and conducted tests on natural soil without adding plastic content & they added plastic content in percentage by weight of natural soil, i.e., 0.2%, 0.4%, 0.6%,0.8% & aspect ratios of 15x15mm, 15x25mm, 15x35mm.



	OMC (%)	MDD (KN/m3)	Cohesion (KN/m2)	CBR (%)
0%	16.8	16.75	19	3.3
0.20%	16.1	17.5	28	7.1
0.40%	14.2	18.4	34	16.5
0.60%	15	18.1	18	13.7
0.80%	16.4	17.3	13	12.5

Chart -1: Test results for different % of plastic content

The researcher found the optimum plastic content and aspect ratio in this study as 0.4% & 15x15mm, respectively. The results of different tests conducted are shown in the chart-1. Here we can compare the parameters CBR, cohesion, MDD are higher for 0.4% of plastic content & they are reducing for more and less % plastic content of 0.4%, so we can conclude that 0.4% of plastic content is optimized to improve the soil properties. The strip size & its nature also has influence in improving soil properties as shown in the chart-2 15x15mm size strips are showing better results compared to other.

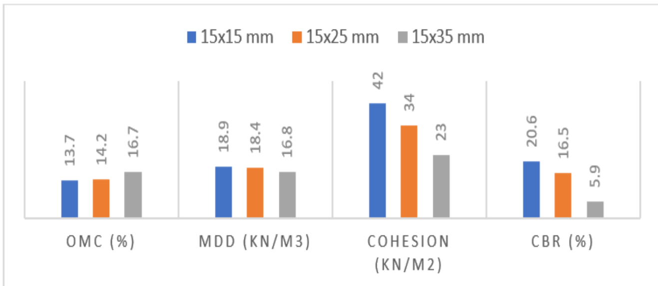


Chart -2: Test results for different plastic strip size

From this research, we can conclude that for getting the best results of engineering properties of soil reinforced with plastic strips, using 0.4% plastic content and plastic strip size of (15x 15 mm) with natural soil is recommended.

2.2 Fly ash

Fly ash is a byproduct produced as waste material during coal combustion in massive volume for the thermal generation of electricity. There are different types of fly ash, including Class F and Class C, generated by burning black coal and brown coal, respectively [5].

Class F fly ash contains low lime content, less than 15%, and includes a more significant amount of silica, alumina, and iron (more than 70%) compared to Class C fly ash. In comparison, Class C fly ash contains a large amount of lime content, nearly 15%-30%. Fly ash contains more fine particles than cement & process pozzolanic properties, and it gives rapid hardening strength to concrete by using as an admixture in concrete production. The expansive soils can be stabilized with fly ash using a chemical stabilizer which will show an abrupt change in soil properties like density, water content, plasticity, strength and compressibility performance of soils, hydraulic conductivity, etc.

The soil properties can be improved by adding definite % of fly ash with respect to weight of natural soil [6]. The researcher conducted laboratory experiments on black cotton soil by adding fly ash and found that 10% fly ash content giving higher CBR value as well as UCS and the values are decreasing for more or less % of fly ash as per the table -1.

Table -1: Test results for different % of fly ash content

Fly ash (%)	**CBR (%)**	**UCS (N/mm²)**	**Cohesion (N/mm²)**
0%	2.189	168.8	84.4
5%	2.043	125.0	62.5
10%	2.335	333.0	166.5
15%	2.265	177.9	88.5
20%	1.265	169.2	84.6

The unconfined compressive strength of natural soil is 168.8 N/mm^2; it increased to 333 N/mm^2 by adding 10% fly ash. Almost 50% strength increased; the California bearing ratio value improved by just 6% for the same percentage. For better improvement, fly ash can blend with other materials as reinforcement like plastic strips, fibers.

2.3 Bagasse ash

Recently most of the studies are concentrating on the utilization of agriculture-based waste products as engineering resources. The different wastes generated in agriculture-industries like rice husk, bagasse from sugar industries, sawdust, coconut husk, etc., these waste materials will convert into ash form by burning them in controlled conditions at high temperatures for a prolonger time. This bagasse ash acts as cementitious material having pozzolanic properties, which improves the properties of weak soils [7].

Bagasse is a fibrous waste product produced from sugar factories. It can be used as biofuel in paper production—the burning of bagasse results in bagasse ash which shows pozzolanic properties due to the presence of silica. The quality of ash can be developed by controlling the burning temperature and rate of heating, etc. The pozzolanic property will hold the soil particle together and improve shear strength. Gave an attempt to stabilize the block cotton soil by using bagasse ash alone as a cementitious material. They added the ash content in 3%, 6%, 9%, 12% to find the optimum % of bagasse ash and conducted the laboratory tests [8].

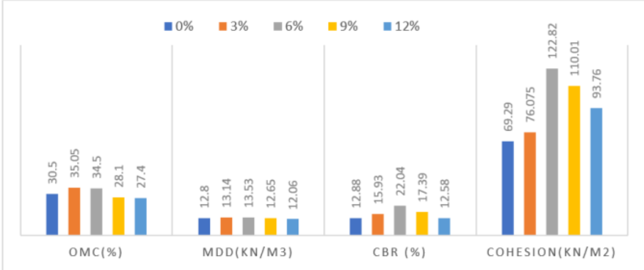


Chart -3: Test results for different % of bagasse ash

All the test results are shown in a single chart-3 to correlate soil improvement for different % of bagasse ash content. As the % of ash increases, optimum moisture content (OMC) decreases, which is essential, but soil bearing strength decreases after adding ash content more than 6%. The reason might be the less availability of moisture content for the hydration process. The cohesion will be only the shear strength parameter for clay soils which is maximum at 6% of ash content; after that, it was decreased due to low specific gravity of ash replacing the high specific gravity of soil.

From this experimental investigation, we can conclude that 6% bagasse ash content is optimum to get higher soil strength properties. The CBR & cohesion values are increased by 40% by adding 6% bagasse ash without any other binding material.

2.4 E-waste

Towards the advancement in technology, a variety of electronic devices (such as computers, mobile phones, televisions, refrigerators, etc.) have increased substantially. As the utilization increases, its scrap deposition also increases after the end of its life. The composition of E-waste is shown in the chart-4 burning in an open atmosphere or landfilling the products. Having this complex composition in large quantity is more dangerous in the environmental aspect [9].

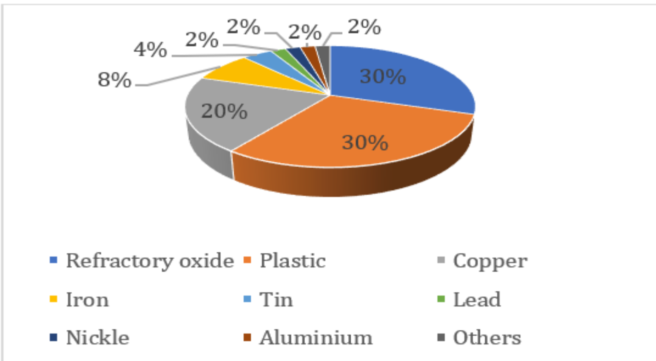


Chart -4: E-waste composition

The recycling or reuse of the E-waste is also part of disposal. The effect of E-waste in soil stabilization has been investigated [10]. The wastage is collected, shredded, and crushed into powder form and mixed with soil in a small percentage of 2%, 5%, 8%. Block cotton soil was opted to stabilize. The strength tests (Atterberg's Limit, Specific Gravity, Compaction Test, Unconfined Compressive Test, California Bearing Ratio) performed in the lab know the effect of E-waste as a soil stabilizer.

The test results obtained by the researcher are shown in the chart-5**;** by observing the chart data, the E-waste shows a moderate change in the strength of the soil. By adding 5% E-waste content to the soil, the OMC is minimum, and the MDD & UCS values are maximum. As the waste percentage increased more than 5%, the strength values decreased, but the CBR value still increased for 8% E-waste content. The test results indicate that the OMC and MDD for the soil sample mixed with E-waste are optimum at 5% and higher UCS values at the same percentage. The E-waste effect is moderate by adding it alone; E-waste can combine with other cementitious materials like fly ash, copper slag, etc.

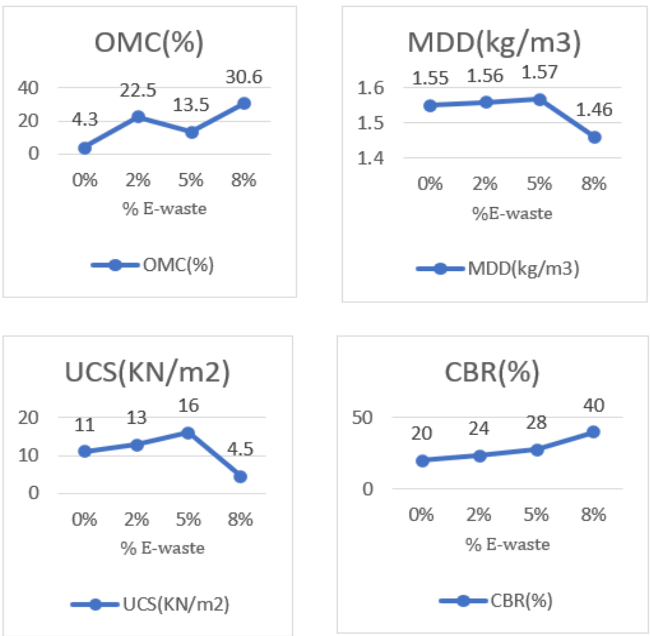


Chart -5: Test results for different % of E- waste

3. CONCLUSIONS

- The weak soils can be strengthened by using cement, lime, and other chemical admixtures, but the production cement will release CO_2 (0.95ton CO_2/ ton cement), which causes global warming.
- The landfilling or burning of waste material generated from industries will also create environmental pollution, so the utilization of waste material in soil stabilization will replace the cement usage. Then carbon emission will reduce, and the waste material disposal problem will also be resolved.
- Plastic reinforced soil acts as fiber reinforced soil; the aspect ratio and the surface texture also have a significant role in achieving better soil properties. The undulated surface will cause cohesion & angle of internal friction.
- The plastic strips and fly ash can be used combinedly for better improvement of soil properties. The fly ash will act as a bunding material that holds the soil particle together, and the plastic strips act as a reinforcement that increases the tensile strength of the soil.
- Towards sustainability, the effective utilization of solid waste material is more important to reduce the usage of natural resources & to avoid environmental pollution by avoiding improper disposal.

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