Using Ceramic Wastes in Stabilization and Improving Soil Structures: A Review Study

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Abstract. The goal of this review study is to define the use of ceramic wastes as a raw material in soil structures and the construction of road pavement subgrades. The global output of ceramic waste powder (CWP) produced during the final polishing phase of ceramic tiles exceeds 22 billion tones. The application of (CWP) in landfill sites could create major environmental issues for soil, water and climate. It has been calculated that about 30% of the daily growth in the ceramic industry goes to waste. By trying to reduce this material, we can provide a big benefit of minimizing the use of natural products, decreasing the amount of money used and enhancing land conditions, based on the quantities we can use. Such wastes cannot be processed in any manner and thus create issues with the disposal and loss to the industry. Ceramic waste is strong, durable and resistant to all kind of declining powers, and these properties allow it to be substitute for replacements. Using various quantities of ceramic waste, we will obtain different results and characteristics of soil structures in different California bearing ratios, dry unit weight, unconfined soil density and optimum water content.

1. Introduction
Building and demolition waste accounts to cover 75% of pollution in the world. While ceramic products contribute the largest proportion around 54% of the waste. Due to unavailability of standards, lack of expertise and procedure for using ceramic in soil structures, the current ceramic waste disposal choice is landfill [1, 2]. Many waste materials have been found to be very useful and improving soil engineering properties to reach requirement properties and long lasting infrastructure, that is called soil stabilization, it is a treatment method to increase soil strength to be more desirable lasting for building purpose [3, 4]. However, we should not lose sight of reality of any engineering production process produces a byproduct and waste materials that affect human health and environment ,some of them occur during the initial phase ,some during transportation of the materials [5]. About 95% of earth surface is made of quartz and silicate rock forming. That has been used for manufacture of bricks, ceramics, and tiles [6]. Reuse of ceramic waste is a safe way to handle solid waste, as demolition waste is increasing due to house collapse and lack of adequate waste disposal and management technology [4]. Global production of ceramic tiles is more than 12 billion m², while ceramic production itself produce 19 kg/m² of ceramic waste powder (CWP) during final polishing process. The ceramic waste powder worldwide exceeds 22 billion tones [7]. Ceramics sector has been significant source for infrastructural growth and using it as national income. In processing, transporting, distribution, storage and reusing kinds of ceramic products. Studies found that
30% of world's ceramic goods are coming from industrial waste [8]. Tiles of ceramic are usually made from natural materials that contain a large percentage of clay minerals. Then they complete their dehydration cycle and firing from temperature of 700°C to 1000°C [9]. Crushing solid waste by mill for manufacture of solid wastes into powders, and using them in engineering foundations and below pavement can be useful [10]. Year by year volume waste has increased and recycling is becoming a major concern. Ceramics in the past were pottery artifacts containing clay, hardened by burning in high temperature, either by them or combined with other ingredients [11]. Ceramic wastes have large amount of silica, iron oxide and aluminum oxide, it is estimated about 89.1% of its composition [12]. Solid waste products are collected from dumpsites at different sites, separated, washed then crushed into varying size and textures. Their characterization can be conducted through particle size analysis and UV-VSA spectrophotometer analysis. The XRD is used to evaluate the gradation and micro property of crushed materials by plotting diffractograph. It can also show the efficiency of soil blend materials [10]. A ceramic waste has been proven to be used for partial replacement of fine and coarse aggregates [1]. Expansive soil has the propensity to expand its volume and cause danger for the constructed system. This expansion in volume is attributed to presence of montmorillonite mineral, that are distinguished by high cation exchange power, large surface and low particle size [13]. Ceramic solidified bodies have benefit of low expansion rate, good mechanic and strong chemical ability [14]. There is mullite ceramics that have gained significant attention for their efficiency, better properties, low conductivity and thermal expansion with strong creep resistance, such as powder and porous forms [15].

2. Literature Review

2.1 General approaches in using ceramic wastes

Ceramic waste usage has become essential concern today in building and manufacture of raw materials. Study on recyclable building material and demolition has the feature that provides benefit to waste management. Researchers suggest that ceramic waste has good degradation power and durability, but still more work is required due to obstacles in analyze and modeling of ceramic activity. They also have abrasion resistance and low density, which is useful to increase efficiency and effectiveness [1, 8]. Worldwide supply of ceramic tiles is around 8,500 million m² [13]. Most of the ceramic waste is created during production process of ceramic tiles, transport and installation [11]. Ceramic waste powder (CWP) contain high amount of silica and alumina, usually more than 80% [7]. The largest producer of ceramic tile is China that have (5,200 million m²) accounting for 47% of world's production, and about (4,300 million m²) accounting for 39% of world's consumption [16]. Ceramic tile is an inorganic, nonmetallic material produced from natural material include high amount containing clay by thermal action and cooling. Its composition contain 1.6% CaO and 59.1% silica. Waste tiles can be collected from building sites and brake them into smaller pieces, small parts can be placed into Los Angeles abrasion machine to make it even smaller [11, 5]. Ceramic tiles can be used as blend, according to the California bearing ratio (C.B.R) values of test findings to maximize the particle size of the sample. Various C.B.R value results in various mixtures; also seemed to be higher in unsoaked sample than in saturated condition sample. The angle of internal friction differs with size change of the tiles in mixture [13]. Expansive soil swelling poses large problems and issues for surrounding structures. The most problematic soil in the world is expansive clays related to their swelling-shrinkage behavior in various moisture [11, 17]. In America, more than 40% of ceramic waste will be processed; the remaining 40% will be made to ceramic powder to use it in other factories. Also in Japan due to lack of resources and good caring for climate change, industries pay attention to ceramic waste throughout focusing of manufacturing phase and recycling [18]. Ceramics include floor tiles, wall tiles, and household ceramic, sanitary ware. Made up of non metallic substance and by method of firing. Clay is heated with high temperature depending on form of ceramic needed. For instance, ceramic wall tiles are fired up to 1150 °C through complete cycle of firing. In South Africa, ceramic waste is listed as non-recyclable waste except for usage of filling products. That is due to the absence of rules and requirement regarding the use of it in building and other purpose. Their local building sector may not have skills and expertise to use the material [1]. Waste from paper industry has
been integrated into red ceramics. For ceramic production, fluxes are new raw materials with large volume of alkaline oxide. Which in reaction with alumina and silica simulate forming of liquid phase that allow densification [19]. Properties of ceramic are depending on bulk modulus, water absorption, linear shrinkage and flexural rupture is calculated. This suggests that addition slugs will improve accumulation of water and increase mechanical strength of ceramic clay [16].

2.2 Recent works done on using ceramic wastes

**Table 1. Works done by researcher with some of their test results**

| Test no. | Done by       | Used material                        | Purpose                                         | Amount of waste cement/Used material (%) | CBR | Compressibility | Swell | UCS (Kn/m²) | ydry Kn/m² | W.C | L.L., PL, PI % | 0 | Result |
|----------|---------------|--------------------------------------|-------------------------------------------------|-----------------------------------------|-----|-----------------|-------|-------------|------------|-----|----------------|---|--------|
| 1        | Cabalar et al. (2017) | Waste ceramic tiles and a low-plasticity clay (CL)-type soil | Use of waste ceramic tiles as a raw material in the design of road pavement for subgrade. | 9%, 15%, 20%, and 30% by dry weight of the specimens: for 30% results were | + 8-14 | - | 2.69-1.48% | 540 | 260 | 173 | 13 | - | - | Up to 30% ceramic tile can be alternative material to improve performance of CL-type soil |
| 2        | Agrawal (2017) | Crushed waste ceramic                | Effect of addition crushed waste ceramic tiles as a replacement for natural coarse aggregate. | 10%, 20%, 30%, and 50% of substitution: for 30% results were | + 5.43% | - | + | + | 15.6 | 18.3 | 20.4 | 17.6 | - | - | Optimum value of ceramic to be used as a replacement in mix is about 30% |
| 3        | Sabat (2012) | Waste ceramic powder with expansive soil | Stabilization of expansive soil using waste ceramic powder. | 0 to 30% | + 105 | - | 130 | 24 Kpa | 55 | 15.6 | 18.3 | 20.4 | 17.6 | - | - | Soil changes from CH to CL group |
| 4        | Upadhayay & Kaur (2016) | Clayey soil available locally was blended with tile waste | Analysing the effect of tile waste on claysy soil. | 0 to 30% at an increment of 10% for 20% result were | + 48% | - | + | - | - | - | - | - | up to 20% CW can be used to strengthen clay soil substrate of flexible pavement |
| 5        | James & Pandia (2018) | Micro ceramic powder and three different lime contents (below ICL, ICL and above ICL). | Use micro ceramic powder as an additive in lime in soil stabilization. | Increasing proportion to lime soil mix for 3.5 wt. % and 7 wt. % for 3 wt % result were. | + 12-14% | - | + | 130-150 | 1595-1900 | 20.4 | 17.6 | - | - | 0.5 wt. % CD dosage is optimal dosage for all three lime to gain 12-14% strength (28 day curing) |
| 6        | Chen & Iduhuyi (2012) | Waste ceramic powder and shrink-swell soil. | Effects of waste ceramic dust on engineering properties of shrink swell soil. | 0 to 30% at an increment of 15% | + 195 | 15.6 | 18.1 | - | - | - | - | - | Up to 30% can be used in strengthening of flexible pavement |
| 7        | Saini et al. (2018) | Ceramic waste tiles and black cotton soil. | Improve design properties of soil by treating it with clay and water. | 0 to 30% at 0 increment of 10% at 0.20% result were | + 105 | + | 15.5-16.31 Kpa | 104-54 | 15.6-18.1 | - | - | - | - | Solid materials to ceramic can be used for soil stabilization as lime |
| 8        | Okunola et al. (2019) | Latroct soil stabilized with ceramic waste dust. | Stabilization of Latroct soil from Agbowa Nigeria with ceramic waste dust. | 0 to 30% at incremental rate of 3% for 30% | + 4.55 | - | 17.5 | - | - | - | - | - | From standpoint of economy and strength, it is recommended up to 30% can be used for soil improvement |
Table 1 shows some works done by researcher, summary of applied tests and their effects are summarized, most of the results show that 30% of waste ceramic is the best amount to be used for soil stabilization. When positive sign (+) refers to increasing the value according to the origin sample and negative sign (-) refers to decreasing the value according to the origin sample.

3. Results and Discussions
Ceramic waste allows us to make advances and efficiency usage for modern structural materials [6]. In the result we can see that if we use ceramic waste properly, cost of manufacture will be minimized also environmental harms reduces, to solve massive environmental problem and rapid economic growth that is the main goal to address [8]. It has been shown that use of ceramic aggregate as partially replacement will result in longer foundation and structure life. Nevertheless, ceramic bricks have shown to have high water absorption. In fact, unfavorable findings were found when substituting fraction of 4.32 mm proportion of natural aggregate by ceramic aggregates [1]. Ceramic contain high clay minerals and 94% of component at atomic stage of silica, iron oxide, calcium oxide and aluminum. Clay firing at high temperature to give necessary mechanical property to be useful as replacement in soil foundations, road construction or as concrete aggregate. From point of view of energy and economy, ceramic waste dust can be useful tool for improving strength property of lateritic soil and soil stabilization [4]. It is clear that after improving productivity and recycling waste production to minimize the building expenses stabilization economy examined to improve soil subgrade of flexible pavement, it is not only increase surface property but also help in reusing ceramic waste at disposal sites. About 30% of ceramic waste used for road pavement subgrade will give better sustainability and lower construction cost [21, 5]. Ceramic aggregate used should be presaturated with waster due to its high absorption [7]. It was found that ceramic dust can be used in stabilization in addition to lime in expansive soil with soil sample currying and early appearance of cement waste can be resolved by using more lime content in stabilization [13]. In soil stabilization solid waste content will increase soil geotechnical characteristics. For various forms, various kind of waste product is ideal and they all have varying degree of change [21, 13]. It is observed that any work carried out on recyclable and waste materials, it will show how much expense can be saved by using such wastes. But still methods and machinery details are hardly mentioned, laboratory analysis could be a good way to begin to work more on such wastes and get benefit from them [3].

4. Conclusions
Ceramic waste can be used for soil stabilization, particularly in expansive soil. Following assumptions can be made according to the studies carried out by researchers:
- Studies show that ceramic waste up to 30% is useful for replace pavement subgrades, with major reduction in building costs.
• With using addition ceramic waste liquid limit LL, plastic limit PL and plasticity index PI of soil reduces.
• California bearing ratio CBR of clay soil increase with more amount of ceramic waste. There is 150% rise in soaked CBR performance of treated soil compared to untreated soil by increasing 30% in ceramic dust.
• Swelling pressure decrease if addition ceramic dust used. When 30% ceramic dust is added to the soil mix, 81.5% of swelling pressure reduction can be seen compared to untreated soil.
• The with improvement amount of ceramic dust MDD will continue to rise.
• The unconfined compressive strength of clay soil increase as ceramic waste dust increases.
• Stability factor begin to decline while angle of internal friction continues to rise with sufficient amount of ceramic dust applies.
• Amount of 30% addition in ceramic dust will change the soil from CH group to CL group.
• Mineralogy analysis of stabilized soil samples showed less quartz and montmorillonite peak in stabilization with lime and ceramic dust .it result in improved intensity due to the application of ceramic dust to saturated soil lime.
• Ceramic dust impacts more at lower lime content relative to higher lime content.

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