Compressive Strength of Concrete using Ceramic Tiles in Partial Replacement of Cement and Coarse Aggregates

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Abstract

A significant unit of shattered ceramic tiles used on a construction site for finishes becomes waste and mostly abandoned though sometimes re-use in tiling of shop outlets. The purpose of this experiment is to re-use ceramic tiles in concrete as material to partially replace cement and coarse aggregates. Ceramic tiles were broken into coarse and ground into powdery forms to replace both coarse aggregates and cement respectively in proportions of 0 to 30% at interval of 5%. Concrete cubes with a water cement ratio (W/C) of 0.4 were cast for each replacement (0-30%) and cured for 7, 14, and 28 days, respectively. This study focused on compressive strength of both conventional and ceramic modified concrete and was carried out in accordance to British Standard.. At 28 days, the compressive strengths of the modified concrete (5-30%) were 22.38N/mm^2, 21.38N/mm^2, 23.69N/mm^2, 19.71N/mm^2, 17.51N/mm^2, and 14.82N/mm^2 respectively, compared to control (25.77 N/mm^2). It can be concluded that the combined cement and coarse aggregates can be substituted with ceramic tiles in powdery and coarse forms respectively up to 15 % in concrete with the resultant concrete possessing properties similar to conventional concrete.

Keywords: Aggregate, Compressive Strength, Concrete, Ceramic tiles, Reuse

Introduction

Concrete, after water, is the second most widely utilized substance on the planet, and it helps to shape the built environment. It can also be repurposed as aggregate. Every year, an estimated 33 billion tons of concrete are manufactured around the world. This translates to more than 1.7 billion truckloads every year, or about 6.4 million truckloads per day, or more than 3.8 tons per person per year. Concrete is utilized in construction twice as much as all other building materials combined, including wood, steel, plastic, and aluminum. The need to utilize these wastes has become one of the most pressing issues of our time, necessitating specific actions aimed at reducing waste generation, such as the promotion of resource recovery systems (reuse, recycling, and waste-to-energy systems) as a means of utilizing the resources contained within waste that would otherwise be lost, thereby reducing environmental impact.
Binici, H.2007 used crushed ceramic waste and pumice stone as partial fine aggregate substitutes in mortar and concrete production. According to the findings, the finished product showed good compressive strength and abrasion resistance, as well as strong resistance to chloride attack. The goal of this research is to observe the effect on compressive strength when coarse aggregate and cement are replaced in the production of concrete with ceramic waste. The parameters to be studied are physical properties, workability, compressive strength, and tensile strength. Understanding the combined behavior of ceramic materials with partial replacement of coarse aggregate and cement at various compositions is also investigated in order to assess the suitability of these crushed waste tiles and tile powder in concrete mixes. Workability tests, ultrasonic tests, and compressive strength tests are carried out for all mixes after 28 days. Aruna *et al* (2015) Tile waste-based concrete, coarse aggregates were substituted with 20mm downsize, tile wastes with 0%, 5%, 10%, 15%, 20%, and 25%, and cement was partially replaced with fly-ash. At a 25% replacement rate, the average maximum compressive strength of roof tile aggregate concrete is achieved. At 25% roof tile aggregate replacement, a 10-15% drop in strength is found when compared to standard concrete. The workability of scrap concrete made from roof tiles is medium. For modest structures, the replacement of tiles with concrete is sufficient.

Batriti, M. R& Marwein M.S (2016) Broken tiles were used as the ceramic waste. 0 percent, 15 percent, 20 percent, 25 percent, and 30 percent ceramic waste concrete (CWC) manufactured with these tiles. All concrete mixes are made with M20 grade concrete and a constant water cement ratio of 0.48. At 3, 7, and 28 days, the distinctive qualities of concrete such as workability for fresh concrete, as well as Compressive Strength and Split Tensile

Strength, are found. The replacement of waste tile aggregate should be in the range of 5-30%, according to the study, and it is also good for standard mixes such as M15 and M20. Topçu B. and Canbaz M. (2010) The amount of tile debris generated is sufficient to utilize as a coarse aggregate substitute in concrete. The usage of ceramic tile waste benefits the environment as well as the bottom line. The self-weight of concrete is lowered by around 4% when tile aggregate is used, making the building more cost-effective. When it comes to concrete strength, tile aggregate replacement has a detrimental impact on both compressive and split tensile strength. However, this study looked at the highest percentages of tile waste that may be broken into smaller percentages and used in concrete with desirable qualities.

Tavakoli D. et al. (2013) The potential of utilizing ceramic tile in concrete was studied. In the range of 0-40 percent, coarse aggregate is substituted. With 10% substitution, compressive strength increases by 5.13 percent, while slump, water absorption, and unit weight drop by 10%, 0.1 percent, and 2.29 percent, respectively. In Spain, a research was conducted on the concentration of ceramic waste from companies. The recycled ceramic aggregates met all of the technical standards imposed by current Spanish regulations, and the concrete was designed according to the Spanish concrete code. Ceramic aggregates are used to substitute coarse aggregate up to 100 percent. Appropriate tests were carried out to compare the mechanical properties of the new concrete to those of traditional concrete. The ceramic ware aggregate concrete had concrete characteristics that were comparable to typical gravel concrete.
Naveen Prasad *et al* (2016) used waste tiles and Granite powder were employed as substitute for coarse and fine aggregates at replacement level of , 10%, 20%, 30%, and 40% of waste crushed tiles were used in place of coarse aggregates, while 10%, 20%, 30%, and 40% of granite powder were used in lieu of fine aggregate. The M25 concrete grade was created to prepare the traditional mix. Varied types of mixes were created by replacing coarse and fine aggregates with crushed tiles and granite powder at different percentages without modifying the mix design. An investigation is carried out in the form of an experiment. The workability of concrete improved as the proportion of granite powder rose, and the compressive strength was found to be highest at 30% coarse aggregate substitution. Parminder S and Rakesh Kumar S (2015): A research paper on the use of industrial waste ceramic tiles. A partial substitute for coarse aggregate has been investigated. Concrete in three distinct grades has been made and tested. Although the findings do not match the conventional, given the strength properties, it is recommended that ceramic tile aggregate be used in concrete. Finally, it was determined that using roughly 20% ceramic tile in M20 grade concrete is ideal. Awoyera *et al* (2016) examined the use of ceramic tiles in concrete. Both coarse and fine aggregates are substituted in varied percentages with ceramic fine and coarse aggregates acquired from construction sites in Ota, Lagos, and Nigeria. The strength properties of conventional concrete are tested when ceramic fine and coarse particles are replaced. Finally, it claims that using ceramic waste in concrete increases the strength of the concrete significantly when compared to regular concrete. Rajalakshmi P *et al* (2016) The use of ceramic waste will offer an effective step in environmental preservation and concrete property improvement. The use of ceramic wastes instead of aggregates in concrete will have significant environmental benefits. In the ceramics business, roughly 30% of the output is discarded. Ceramic waste aggregate is a more hardy and long-lasting material than traditional coarse aggregate. It has a high level of thermal resistance. The durability of ceramic waste aggregate is very excellent. This study looked at fine aggregate replacement by ceramic tiles in the range of 10% and coarse aggregate replacement in the range of 30%, 60%, and 100% by weight of M-30 grade concrete. This research suggests that waste ceramic tiles can be utilized as an alternative to coarse and fine aggregate in concrete, regardless of the kind of concrete employed. Waste ceramic tiles have good strength properties, with a maximum strength of 10% CFA and 60% CCA.

Shruthi H. *et al.* (2016) observed that Ceramic tiles were taken from manufacturing plants, building sites, and demolition sites, resulting in pollution. The use of crushed tile as a coarse aggregate in concrete would be beneficial to the economy as well. Ceramic tile waste was employed as a replacement for natural coarse aggregate in concrete with 0 percent, 10%, 20%, and 30% substitutions, and M20 grade concrete was used in the study. After 3, 7, and 28 days of cure, the concrete molds were cast and evaluated for compressive and split tensile strength. The results show that a 30 percent replacement of ceramic tile aggregate with natural coarse aggregate yields the highest compressive strength. Saswat, H and Vikas, S.(2016) In stiff pavement, ceramic and demolition waste were used to partially replace fine aggregate. They discovered that utilizing ceramic and demolition trash to make rigid pavement can save 40% of natural fine aggregate. It was also discovered that the compressive strength of demolition waste and ceramic waste is higher than that of referral concrete up to 20% demolition debris and 20% ceramic waste. Saswat, H and Vikas, S.2016 had discovered through testing that using ceramic waste powder in cement concrete In cement

concrete, 30% ceramic waste powder can replace fine aggregate without reducing compressive strength. They also discovered that when compared to standard concrete, only about 1% of the split tensile strength is lost.

Hemanth, K.C. *et al*. (2015) The effect of waste ceramic tiles as a partial replacement for coarse and fine aggregate in concrete was also explored. Waste crushed tiles were used to partially substitute fine and coarse aggregate in the study (10 percent and 20 percent). The optimum percentage of coarse aggregate that can be replaced with shattered tiles, they discovered, is 10%. Shruti, H.G., *et al* (2016) Ceramic tile waste (CWT) was also investigated as an aggregate in concrete. In their investigation, ceramic tile waste was employed as a replacement for natural coarse aggregate in concrete at several levels of substitution (0, 10%, 20%, and 30%) and M20 grade concrete was used. After 3, 7, and 28 days of cure, the concrete molds were cast and evaluated for compressive and split tensile strength. The results show that a 30% substitution of ceramic tile aggregate with natural coarse aggregate yields the highest compressive strength.

Topcu, I.B and Canbaz, M. (2007) The effect of replacing crushed tile as a coarse aggregate in concrete with partial replacements of natural aggregate (0 percent, 50%, and 100%) was investigated. Mechanical and physical tests have been completed. Crushed tile aggregate concrete's strength and unit weight were lower than control concrete's. In comparison to the control concrete, the absorption and capillary coefficients were higher. Ikponmwosa, E.E. and Ehikhuenmen. (2017) The influence of ceramic waste as coarse aggregate on concrete strength qualities was explored. The study determined that ceramic waste might be used for both structural and non-structural purposes, but that ceramic waste material should not be used in concrete constructions where high strength is a primary factor, according to 130 American Journal of Civil Engineering and Architecture.Reddy, M.V. and Reddy, C.N.V.S. (2007) It was also shown that ceramic scrap can be used to partially replace typical coarse aggregates (10% and 20%) without compromising structural integrity.

Adeala A.J and L.A Omisande (2016) also discovered that the genuine slump of all the adjusted new concrete was between 1mm and 2mm. The compressive strengths of modified concrete ranging from 5% to 20% substitute were greater than 25N/mm^2, indicating that such concrete with broken tiles has greater potential than conventional concrete with the same 1:2:4 mix design ratio for 28 days compressive strength. Broken ceramic concrete comes within the statutory allowable range of conventional concrete, which is 2300-2500 kg/m^3 and behaves similarly to regular concrete. According to the Concrete Society of the United Kingdom, the modified concrete meets the requirements of a good concrete, with water absorption ranging from 0.89 to 3%. Finally, in both developing and developed countries, recycling of broken ceramic waste tiles can be used to substitute coarse aggregates in concrete production up to 20%..

MATERIALS & METHODS

The materials used in this study were broken waste ceramic tiles recovered during renovation in the Federal Polytechnic Ilaro (Fig.1) and were further broken down into smaller usable sizes using hand held hammer. Some of the broken ceramic tiles were milled fine into powdery form as shown in (Fig.2) using power milling machine.



Figure 1: Broken Ceramic Tiles



Figure 2: Crushed Powdery Ceramic Tiles

Broken ceramic tiles were allowed to pass through 20mm sieve down to 150µm sieve as aggregate to replace coarse aggregates and powdery ceramic tiles were passed through 75µm sieve (Fig.3). Coarse aggregates with maximum size of 19mm and fine aggregates were bought in Ilaro, Ogun state and cement was also procured from a Dangote cement retail outlet in Ilaro. Portable water was obtained from the Material Testing Laboratory of the Federal Polytechnic Ilaro. Sieve analysis was carried out on both coarse and aggregate sizes. Powdery ceramic tiles and crushed ceramic tiles were substituted at 5%, 10%, 15%, 20%, 25% and 30% for cement and coarse aggregates respectively. Total number of Seventy-two (72) cubes were mixed at water cement ratio of 0.4, cast and cured in water for 7,14, 21 and 28 days as shown in Fig. 4 and thereafter crushed.



Figure 3: Powdery Ceramic Tiles during sieving



Figure 4: Mixing and casting of concrete

Table 1: Batch weight of materials in (kg) with 0.4 water-cement ratio

Materials	0%	5%	10%	15%	20%	25%	30%
Cement	11.00	10.45	9.90	9.35	8.80	8.25	7.70
F.A	22.00	22.00	22.00	22.00	22.00	22.00	22.00
C.A	44	41.8	39.6	37.4	35.2	33.00	30.80
PCT	0	0.55	1.10	1.65	2.20	2.75	3.30
CCT	0	2.20	4.40	6.60	8.80	11.00	13.20

Table 1 above shows batch weights of materials used for the research work. The percentages of the substitutes both Powdery ceramic tiles (PCT) and crushed ceramic tiles (CCT) were as shown.

RESULTS & DISCUSSIONS

The result of the sieve analysis carried out in accordance to BS 1377 on the coarse aggregates is as depicted in Fig. 5. The Cu of the aggregates lies between 1 and 3 while the finesse moduli are between 2 and 4 for both coarse (conventional and modified) and fine aggregates as shown in fig.5 and fig.6 below.

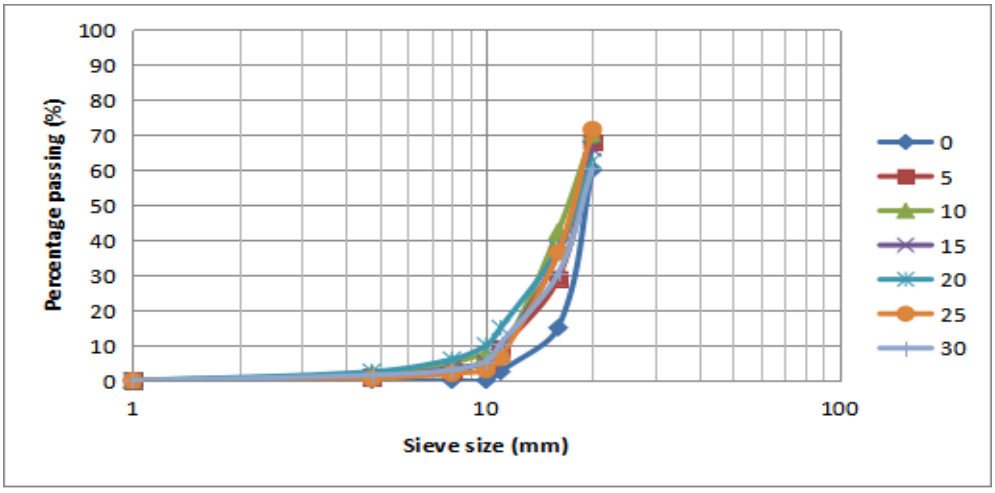


Figure 5: Grading Curves for conventional and modified coarse Aggregates

It was observed that both conventional and modified coarse aggregates are well graded in accordance with BS 1377, 2: 1990

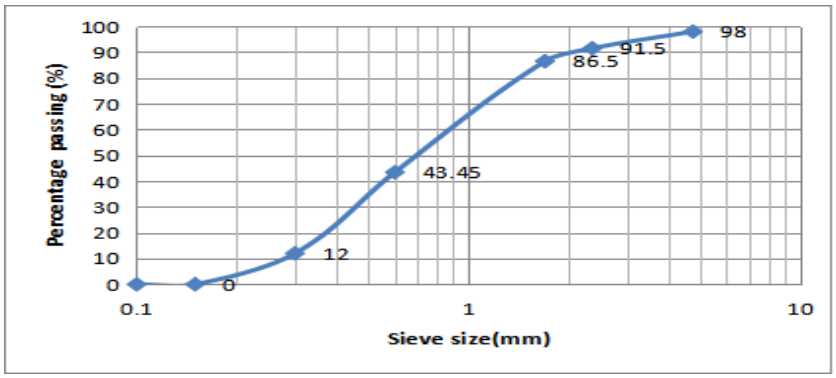


Figure 6: Grading Curve for fine Aggregates

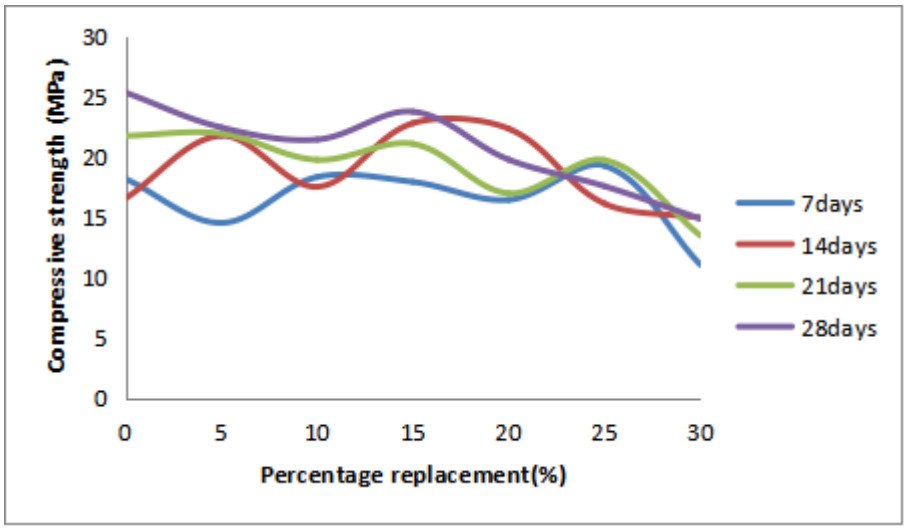


Figure 7: Compressive strength development against percentage substitution

15 % substitution of ceramic aggregate and for all curing days i.e. 7,14, 21 and 28 days with compressive strengths of 17.87,22.73,21.024 and 23.69N/mm^2 respectively, which in comparison to the control concrete, which has compressive strengths of 16.503,18.125,21.691 and 25.277 N/mm^2 for respective curing days which is higher and considered most desirable among all samples. The increase in strengths observed with 15 present substitution of ceramic aggregate may be due to increase in ceramic aggregates in comparison to natural aggregates.

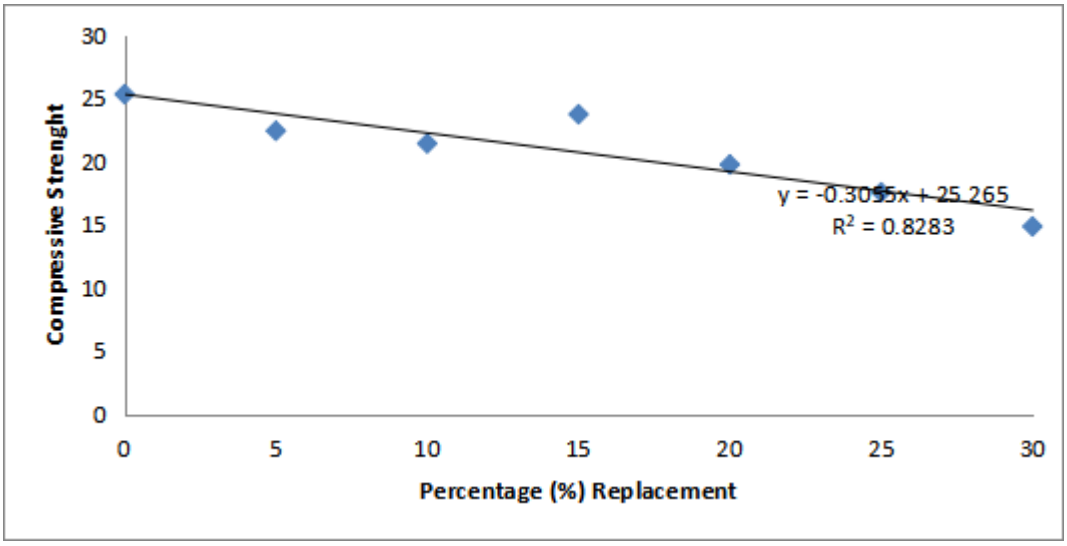


Figure 8: Regression Analysis showing relationship between compressive strength and substitution of broken ceramic and powdery ceramic tiles at 28 days.

There is a strong relationship between the compressive strength and the percentage replacement since R^2 = 0.828.

CONCLUSION

It was observed that 15% substitution of powdery ceramic tiles and broken ceramic tiles for 28 days can be used as partial replacement of cement and coarse aggregates respectively in the production of concrete. It was also observed that there was strong relationship between compressive strength and percentage substitution of powdery ceramic tiles (PCT) and broken ceramic tiles (BCT).

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