A Study on Use of Ceramic Waste & Granite Waste in Concrete

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Abstract – *The natural resources are depleting and construction & demolition wastes are increasing day-by-day. Researchers and governments of many countries trying to find out best solution to deal with this situation. Ceramic waste and granite waste from construction industry needed effective utilization. Many researchers have found its use for making concrete with partially or fully replacement of aggregates. In this study, we found out the optimum level of replacement of such wastes by studying various previous researches and reached to conduct a detailed experimental investigation using Indian Standards. In the proposed experimental investigation, the ceramic & granite waste will be used as coarse aggregate replacement up to 30% as individual or in combination of both to study their effect on M40 grade concrete for properties such as compressive, splitting, and flexural strength at 7 & 28 days.*

Key Words: Ceramic Waste, Granite Waste, Non-Conventional Aggregates, Non-Conventional Concrete, Construction & Demolition Waste

1. Introduction

With a size of $1 trillion by 2025, India is now the third-largest construction market in the world, behind the United States, China, and Japan (FE Bureau 2016). [1]. The construction industry makes up 10% of India's GDP and is expanding at a rate of roughly 9%, which is higher than the global average of 5.5% [2]. Building construction and building destruction have both grown as a result of growing urbanization and rising infrastructural activity. Thus, this led to an increase in the demand for concrete and the production of construction and demolition debris [3]. Significant environmental harm is being caused by the widespread depletion of natural aggregates and there is rise in building and demolition waste which is going to landfilling [4]. The necessity for sustainable and financially viable structural concrete has drawn the attention of both researchers and various construction businesses as a result of the ever-increasing demand for concrete [5]. Therefore, using alternative aggregates is a logical step towards resolving a portion of the depletion of natural aggregates; alternative aggregate produced from waste materials would seem to be an even more logical option [6].

2. Literature Review

Numerous industrial waste materials, including class F type ash, waste foundry sand, copper slag, imperial smelting furnace slag, blast furnace slag, ferrochrome slag and palm oil clinker, have been used as partially or entirely fine aggregate replacement materials in concrete production and their properties have been compared with control concrete [7].

Recycled concrete aggregates were used as coarse aggregates in concrete at rates of 30%, 60%, and 100% by K. Usha Nandhini, S. Jayakumari, and S. Kothandaraman (2017) to evaluate its mechanical and structural qualities. A water-cement ratio of 0.52 and 0.39 were used to create two sets of mixes with respective strengths of 20 MPa and 40 MPa. We examined the structural behaviour as well as the compressive strength, split tensile strength, flexural strength, and young's modulus. The findings indicate that recycled concrete aggregate increased the compressive strength of concrete over ordinary concrete. Higher strength of 12% for M20 concrete and 15% for M40 grade concrete were obtained by replacing the aggregate with recycled concrete up to 60%. Full replacement of recycled concrete aggregate produced concrete that was stronger than conventional concrete for M20 and M40 grade [8].

Waste glass was incorporated into concrete in a 2019 study by T. S. Thulasidhar Naidu, M. V. Deepthi, Shrihari K. Naik, and S. D. Anitha Kumari. Fly ash and GGBS were used to replace roughly 30% of the cement, while 0 to 25% of the fine aggregate was made up of recycled glass. Tests for flexural strength, split tensile strength, and compressive strength were conducted. According to research, 15% of leftover glass is the ideal amount to substitute fine aggregate in concrete [9].

Recycled tyre rubber was used to a Portland cement concrete mix by Zaher K. Khatib and Fouad M. Bayomy in 1999. In mixes, they employed two different types of tyre rubber: fine crumb rubber and coarse tyre chips. According to ASTM standards, the compressive and flexural strength of mixtures was evaluated. According to the findings, the amount of rubber in the aggregate should not be more than 20%. They came to the further conclusion that rubberized concrete mixtures would be appropriate for non-structural uses including lightweight concrete walls, building facades, and architectural components. Additionally, they might be utilized as cement aggregate bases for flexible pavements [10].

Crushed stone dust was examined by Sarvesh P.S. Rajput in cement concrete at rates of 20%, 40%, 60%, 80%, and 100%.

According to Indian Standards, M20 and M30 of cement concrete were manufactured in various ratios. The following tests were carried out: compressive strength test, compaction factor test, slump cone test, and ultrasonic pulse velocity test. The findings demonstrated the effectiveness of crushed stone dust as an alternative fine aggregate to natural sand in cement concrete [11].

E-waste plastics were utilised as coarse aggregate in concrete along with manufactured sand by Santhanam Needhidasan, B. Ramesh, and S. Joshua Richard Prabu (2020). In this investigation, manufactured sand was used to make M20 grade concrete, and e-waste plastic was used to substitute coarse aggregate from 0% to 12.5%. As a result, concrete replacing e-waste has higher compressive strength than conventional concrete with 10% replacement, higher flexural strength than conventional concrete with 10% replacement, and higher split tensile test than conventional concrete with 12.5% replacement, according to the results [12].

Coconut shell was utilised as coarse aggregate in concrete by Apeksha Kanojia and Sarvesh K. Jain (2017) up to a 40% replacement level in multiples of 10%. Different water-cement ratios of 0.55, 0.53, 0.492, 0.475, and 0.45 were designed for M20 grade concrete. They concluded that using scrap coconut shell in place of traditional aggregate made the concrete lighter and reduced its compressive strength. The 28-day strength was reduced by around 22% and the concrete density decreased by about 7.5% for 40% replacement, respectively [13].

Crushed, granular coconut and palm kernel shells were used as an alternative for traditional coarse aggregate in concrete made by E.A. Olanipekun, K.O. Olusola, and O. Ata (2006) in gradations of 0%, 25%, 50%, 75%, and 100%. 1:1:2 and 1:2:4 mix ratios were employed. In the two mix proportions, concrete made from coconut shells had a greater compressive strength than palm kernel shell concrete. For concrete made from coconut and palm kernel shells, respectively, the results likewise showed cost reductions of 30% and 42%. When employed as a replacement for traditional aggregates in the manufacturing of concrete, it was found that coconut shells were more suited than palm kernel shells [14].

2.1 Construction & Demolition Waste

Only 5% of the Construction & Demolition (C&D) waste produced in India each year gets treated, which is around 25–30 million tons [15]. Aggregates may be made from C&D waste, which is a step towards effective waste management and use. The processed aggregates can be divided into two categories: recycled aggregates (RA) and recycled concrete aggregate (RCA). Brick, tiles, granite, stone, and other materials can be used to make RA, and RCA contains hydrated cement paste with the original aggregate. Up to 25% in plain concrete, 20% in M25 or lower reinforced cement concrete, and 100% in lean concrete (less than M15 grade) can contain recycled aggregates as coarse aggregates [16].

2.2 Ceramic Waste

In the ceramics sector, around 30% of output is wasted and not currently recycled. This trash is durable, hard, and extremely resistant to factors that would cause it to degrade biologically, chemically, or physically. It has been claimed that the qualities of this trash can be utilized to create usable coarse aggregate [17]. Concrete can employ the ceramic electrical insulator trash as coarse aggregate [18].

In order to evaluate the impact on fresh characteristics and compressive strength, Salman Siddique, Sandeep Shrivastava, and Sandeep Chaudhary (2016) employed bone china ceramic waste as fine aggregates. Comparable values for compressive strength were achieved when bone china aggregate was used as fine aggregate. In the creation of concrete, ceramic bone china aggregates can be employed as fine aggregates [19].

In place of coarse aggregate in concrete, Zahra Keshavarz and Davood Mostofinejad (2019) utilised red ceramic and porcelain trash. In order to evaluate the compressive, tensile, flexural, and water absorption strengths, 65 specimens were cast. It was discovered that red ceramic waste enhanced concrete compressive strength by up to 29% and porcelain tile trash raised it by up to 41%. Additionally, it was discovered that porcelain might boost tensile and flexural strengths by as much as 41% and 67%, respectively. According to experiments on water absorption, red ceramic waste boosted water absorption by concrete by 91% whereas porcelain increased it by up to 54% [20].

Khuram Rashid, Afia Razzaq, Madiha Ahmad, Tabasam Rashid, and Samia Tariq (2017) used ceramic waste aggregate as partial substitution of coarse aggregate at rate of 10%, 20% and 30%. Compressive strength is predicted by using ACI model and very close correspondence is observed between experimental and analytical values at different ages. Both techniques, analytical hierarchy process and technique for order preference by similarity to ideal solution are applied to select the most sustainable concrete. Application of both techniques justifies the results by selecting similar mixtures as the most sustainable concrete. And concluded that concrete made by replacing 30% of conventional aggregate by ceramic waste is the best sustainable concrete at age of 63 days whereas the worst case from both techniques is conventional aggregate at both ages, 28 and 63 days [21].

2.3 Granite Waste

A significant amount of waste granite powder, also known as granite industry by-product (GIB), is produced by the granite processing industry as a result of its sawing and polishing operations. Since GIB is a dangerous pollutant that threatens ecosystems, there is an urgent need to discover a sustainable and technologically feasible approach to use it, therefore reducing its hazards. The positive findings demonstrated the viability of GIB concrete as a sustainable building material. 25% was found to be the ideal level for GIB to replace river sand [35].

Granite powder was utilized as a partial substitute for fine aggregate at rates of 5%, 10%, 15%, 20%, and 25% by M. Vijayalakshmi, A.S.S. Sekar, and G. Ganesh Prabhu (2013) to create concrete with a strength of 30 MPa and a water-cement ratio of 0.40. There were tests for slump, compressive strength, splitting tensile strength, flexural strength, elastic modulus, chloride permeability, water permeability, carbonation depth, sulphate resistance, and electrical resistivity. However, it is advised that the GP waste be subjected to a chemical bleaching process prior to blend in the concrete to increase the durability and strength of the concrete. The obtained test results indicated that the replacement of natural sand by GP waste up to 15% of any formulation is favorable for the concrete making [22].

Crushed limestone was combined with river sand, granulated blast furnace slag, and granite and marble as coarse aggregate by Hanifi Binici, Tahir Shah, Orhan Aksogan, and Hasan Kaplan (2008). This research included testing for fresh and hardened density, slump, setting time, compressive strength at different ages, flexural strength, splitting tensile strength, young's modulus, abrasion resistance, sulphate resistance, and chloride penetration. According to the findings of this investigation, discarded marble and granite aggregates may be employed to enhance the mechanical characteristics, usability, and chemical resistance of typical concrete mixes [23].

In concrete of M25 grade, Sarbjeet Singh, Shahrukh Khan, Ravindra Khandelwal, Arun Chugh, and Ravindra Nagar (2016) substituted granite cutting waste for fine aggregate at rates of 10%, 20%, 30%, and 50%. In addition to SEM analysis and XRD analysis, workability, compressive strength, flexural strength, abrasion resistance, water permeability, and other tests were performed. The study demonstrates that concrete produced by partially substituting granite cutting debris for sand has stronger and more durable properties than control mix. Concrete's compressive strength was at its peak at 30% replacement while at 50% replacement, it was equivalent to the strength of the control mix. Concrete's flexural strength likewise rises when GCW (%) increases [24].

Waste granite and glass powder were employed by Kishan Lal Jain, Gaurav Sancheti, and Lalit Kumar Gupta (2020) to investigate the impact on concrete durability. Glass powder was utilized as a partial replacement for cement and waste granite powder was used as a partial replacement for sand. In order to partially supplement the cement and sand in the concrete mixtures, glass powder was added in amounts of 5%, 10%, 15%, 20%, and 25%, and granite powder in 10%, 20%, 30%, 40%, and 50%, respectively. The combined impact of glass and granite suggested improved durability performance of concrete [25].

According to the study, using 25–40% of granite cutting waste (GCW) in place of river sand will improve the strength and durability of concrete. Compressive strength at 0.30 w/c is raised by GCW when 25% more river sand is substituted. Flexural strength is increased when GCW replaces 40% of river sand. Concrete's service life and durability may be considerably increased by using 55% GCW. In comparison to the control concrete, the use of GCW up to 25–40% as a partial substitute for natural sand resulted in comparable or superior corrosion resistance [36].

3. Methodology

By studying the literature review, the methodology for the future research work can be formed. The proposed methodology for the experimental work to be conducted has been described in this section. All the ingredients such as fine aggregate (river sand), coarse aggregates, cement, etc., used for making desired concrete mixes will be tested as per specifications of Indian Standards. IS 383: 2016 and IS 2386: 1963 will be used for specifications and testing of aggregates for various physical & mechanical properties to check their suitability as coarse aggregate. IS 4031: 1996 & IS 269: 2015 will be used for specifications and testing of cement for various properties to check suitability as cement. IS 456: 2000 & IS 10262: 2019 will be used for mix design of concrete as per specifications given in them. IS 9103: 1999 will be used for specifications of concrete admixtures and their suitable dosage in concrete. IS 1199: 2018 (Part 2) will be used for consistency determination of fresh concrete. IS 516: 1959 & IS 5816: 1999 will be used for casting, curing, and testing of hardened concrete at suitable age of curing.

The waste materials such as ceramic tiles waste and polished granite waste will be collected from tiles suppliers and construction sites. The received raw waste will get break down into pieces by manual hammering action. Then the processed material having the appearance of coarse aggregates will be subjected to sieving through 20 mm and 4.75 mm IS sieves. Now, this converted waste will be called as ceramic tiles waste aggregates (CTWA) and polished granite waste aggregates (GWA).

The experimental work will be done in three steps. First, NCA will get partially replaced by CTWA up to 30% in multiples of 10%. Second, NCA will get partially replaced by GWA up to 30% in multiples of 10%. Third, NCA will get partially replaced by both CTWA & GWA up to 30% in multiples of 10%. The mix design of M40 grade concrete is taken as reference concrete. The calculation of various ingredients to be used in concrete mixes will be kept constant for all mixes except coarse aggregates. The substitution of coarse aggregates will be done by volume.

The total of 10 concrete mixes must be prepared for this work. There will be 180 specimens to cast, cure, and test at 7 & 28 days for various strength properties such as workability, concrete density, compressive strength, splitting tensile strength, and flexural strength. Out of 180 specimens, 60 cubes of 100 mm X 100 mm X 100 mm size, 60 cylinders of 100 mm diameter & 200 mm height, and 60 beams of 100 mm X 100 mm X 500 mm size will be used to find hardened properties such compressive strength, splitting tensile strength, and flexural strength at 7 & 28 days to check the effect on partial substitution of NCA with CTWA and/or GWA.

Table 1

The composition of various concrete mixes.

Designation of Concrete Mix	Replacement (%)		
	NCA	CTWA	GWA
CM-I (Control Concrete Mix)	100	-	-
CM-II	90	10	-
CM-III	80	20	-
CM-IV	70	30	-
CM-V	90	-	10
CM-VI	80	-	20
CM-VII	70	-	30
CM-VIII	90	5	5
CM-IX	80	10	10
CM-X	70	15	15

4. Conclusion

Based on the above literature review and by studying various researches, it can be concluded that ceramic wastes and granite wastes are accumulating in huge quantities and there is no proper solution of disposal of such wastes other than land filling. Many researchers have studied their effect on partial or full replacement of such waste as coarse or fine aggregate to obtain their optimum levels. Based on this study, it can also be concluded that the ceramic tiles waste and polished granite can be transformed into useful coarse and fine aggregates to be use in concrete for desired strength Researchers studied ceramic and granite waste in lower grade of concrete (less than M30) for partially or fully substitution in concrete as coarse and/or fine aggregates and found even more better results as compared to conventional concrete mixes. The literature review suggested that the use of ceramic waste and granite waste can be found to be effective for making M40 grade concrete but only up to 30% replacement level.

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