EXPEMETNAL RESEARCH ON THE PARTIAL REPLACEMENT OF COARSE AGGREGATE IN CONCRETE WITH CERAMIC TILE WASTE

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ABSTRACT

The increasing demand for concrete in construction has led to the depletion of natural aggregates, necessitating the search for sustainable alternatives. This study investigates the feasibility of partially replacing coarse aggregates with ceramic tile waste in concrete production. The experimental research evaluates the mechanical and durability properties of concrete mixtures containing varying percentages (10%, 20%, and 30%) of ceramic tile waste as a substitute for conventional coarse aggregates.Compressive strength, tensile strength, and workability tests were conducted to assess the performance of the modified concrete. The results indicate that replacing up to 20% of the coarse aggregate with ceramic tile waste improves compressive strength while maintaining acceptable workability and durability characteristics. Beyond 20%, a reduction in strength and workability was observed due to the increased porosity of the ceramic waste material.The findings suggest that ceramic tile waste can be effectively utilized as a partial replacement for coarse aggregate, contributing to sustainable construction practices by reducing waste and conserving natural resources. This study highlights the potential of incorporating recycled materials in concrete to enhance environmental sustainability without compromising structural integrity.

Keywords:

Ceramic tile waste, coarse aggregate replacement, sustainable concrete, compressive strength, recycled materials, durability.

1.INTRODUCTION

Concrete is the most widely used construction material due to its high compressive strength, durability, and versatility. However, the continuous extraction of natural aggregates for concrete production has led to environmental concerns, including resource depletion and ecological imbalance. As a result, researchers and engineers are exploring alternative materials to replace conventional aggregates while maintaining or improving the performance of concrete.

Ceramic tile waste, a byproduct of the construction and demolition industry, presents a viable alternative to natural coarse aggregates. Large quantities of ceramic waste are generated globally due to the rejection of defective tiles during manufacturing, as well as the demolition and renovation of buildings. Disposing of this waste in landfills contributes to environmental pollution and waste management challenges. Therefore, incorporating ceramic tile waste as a partial replacement for coarse aggregate in concrete can serve as an eco-friendly solution to these issues.Several studies have explored the use of recycled materials in concrete, demonstrating that ceramic waste possesses suitable physical and mechanical properties for structural applications. The irregular shape and porous nature of ceramic aggregates can influence concrete's workability, strength, and durability. However, further experimental research is needed to determine the optimal replacement levels and assess the long-term performance of ceramic waste-based concrete.This study aims to evaluate the effects of partially replacing coarse aggregate with ceramic tile waste on the mechanical and durability properties of concrete. The research focuses on compressive strength, tensile strength, and workability tests for different replacement ratios (10%, 20%, and 30%). By analyzing the results, this study seeks to determine the feasibility of using ceramic tile waste as a sustainable alternative in concrete production.

Objectives of the Study

1. To investigate the physical and mechanical properties of ceramic tile waste as a replacement for coarse aggregate.
2. To assess the impact of ceramic tile waste on the compressive and tensile strength of concrete.
3. To evaluate the workability and durability characteristics of concrete containing ceramic tile waste.
4. To determine the optimal percentage of coarse aggregate replacement for structural applications.

Significance of the Study

This research contributes to sustainable construction practices by promoting waste recycling and reducing the environmental impact of concrete production. By utilizing ceramic tile waste in concrete, this study helps conserve natural resources, minimize construction waste, and reduce carbon emissions associated with aggregate extraction. The findings will be valuable for engineers, researchers, and policymakers in advancing sustainable building materials.

2.LITERATURE REVIEW

2.1 Literature Review of Crushed Ceramic Tile Waste

R.M. Senthamarai et al. (2015) substituted conventional crushed stone aggregate with ceramic electrical insulator. Different water cement ratio of 0.35, 0.40, 0.45, 0.50, 0.55 and 0.60 were adopted. Compressive strength, split tensile strength, flexural strength and Modulus of elasticity were found out. It is found that the compressive, split tensile and flexure strength of ceramic coarse aggregate are lower by 3.8%, 18.2% and 6% respectively when compared to conventional concrete.

A.Mohd Mustafa et al. (2018) studied on various types of ceramic waste like flower pots, tiles and clay bricks. Different water cement ratios were adopted such as 0.4, 0.5 and 0.7 with concrete of characteristics strength of 20 MPa. Flower pots gave the best results for compressive strength of about 2.50% lesser than that of conventional concrete.

C. Medina et al. (2022) investigated on the reuse of waste as recycled coarse aggregate in partial substitution of 15%, 20% and 25% in the manufacture of structural concrete. Compressive strength is found out t 7, 28 and 90 days. There is an increase in strength with increase of percentage replacement, the best results shown is at 25% with increase of 21.12%, 11.04% and 6.70% at 7, 28 and 90 days respectively.

R.M.Senthamarai et al. (2021) studied the durability properties of ceramic industry waste as coarse aggregate in concrete. Water cement ratios from 0.35- 0.60 were used and properties such as volume of voids, water absorption, chloride penetration and sorption were studied. Water absorption ranges from 3.74-7.21% whereas that of conventional concrete from 3.1 – 6.52%. Concrete with Ceramic shows higher results in all tests.

T. Sekar (2021) studied on strength characteristics of concrete utilizing waste materials viz: ceramic tiles, ceramic insulator waste and broken glass pieces. Ceramic tiles gave the best results when compared to the other two type of waste. The concrete produced by ceramic tile aggregate produced similar strength in compression, split tensile and flexure as conventional concrete.

Y. Tabak et al. (2022) studied on the mechanical and physical properties of concrete produced form Floor Tiles Waste Aggregate (FTWA). Two samples were made, the first one substitution by Floor Tile Waste Dust (FTDA) and the other a combination of Floor Tile Waste Dust (FTDA) and Floor Tile Waste Aggregate (FTWA).Best result is shown b FTWA substitution. Increase in compression strength is 13.53%, 16.70% and 2.91% for 2, 7 and 28 days. Similarly there is an increase of 23.21%, 0.1% and 19.47% respectively for flexure strength. There is a reduction of specific density and water absorption of 0.284Kg/m3 and 0.158% respectively when compared to conventional concrete.

Umapathy et al. (2024) studied on Rice Husk Ash(RHA) as cement at 10%, 15% and 20% and waste tiles as coarse aggregate at 20%, 30% and 50%. Compression strength is found out and the best results is with 20% tiles and 10%RHA of 80.60% to that of conventional concrete.

Daniel RJ et al. (2021) The extent of 35% coarse aggregate were partially substituted with ceramic waste based tile. Several studies indicate that between 20% to 30% of the raw materials handled in tile production facilities are lost as waste.

Mainkandan KP et al. (2023) This research paper explains an experimental study on the utilization of waste material extracted from the ceramic manufacturing.

3. EXPERIMENTAL METHODOLOGY

3.1 MATERIAL PROPERTIES

Concrete is an important element to create any structural elements. Before concreting of the structure we find out the physical properties of concrete raw materials (cement, fine aggregate, coarse aggregate) some of the physical properties of concrete raw materials are given below. This chapter deals with the mix design procedure adopted for control concrete and the studies carried out on properties of various materials used throughout the experimental work. Also, deals of casting and testing of specimens are explained.

Material Used

- Cement
- Fine Aggregate
- Coarse Aggregate
- Water
- Crushed Ceramic Tile Waste (Replacement of (0%, 5%, 10%, 15%, 20%, 25%, 30%& 35%)

3.2 CEMENT TEST

Table 1 Fineness Test of Cement

Sl.No	Total Wt. of Sample Taken (Gm)	Sample Retained on90µ Sieve	Fineness %	Average Fineness %
1	100	3.4	3.4	**3.85**
2	100	4.3	4.3	

Table 2 Physical Properties of Cement

Sl.No	Physical Properties OfOPC 53 Grade Cement	Results	Requirements As Per Is:8112-1989
1	Specific Gravity	3.15	3.10-3.15
2	Standard Consistency (%)	31.5	30-35
3	Initial Setting Time(Min)	55	30 Minimum
4	Final Setting Time(Min)	325	600 Maximum

3.3 AGGREGATE TEST

Table 3 Flakiness and Elongation Index of Natural coarse aggregate

Sieve size Range (mm)	Weight(gm)	Flaky Aggregate(gm)	Remaining Weight(gm)	Elongated Aggregate weight(gm)
25-20	-	-	-	-
20-16	1487	513	974	328
16-12.5	1008	222	786	394

12.5-10	485	112	373	166
10-6.3	265	27	238	19
Total weight	3245	874	2371	907

Table 4 Flakiness and Elongation Index of Crushed Tile aggregate

Sieve size Range (mm)	Weight(gm)	Flaky Aggregate(gm)	Remaining Weight(gm)	Elongated Aggregate weight(gm)
25-20	0	0	0	0
20-16	1338	0	1338	310
16-12.5	350	95	255	130
12.5-10	230	9.5	220.5	160
10-6.3	82	11.3	70.7	43.5
Total weight	2000	115.8	1884.20	643.5

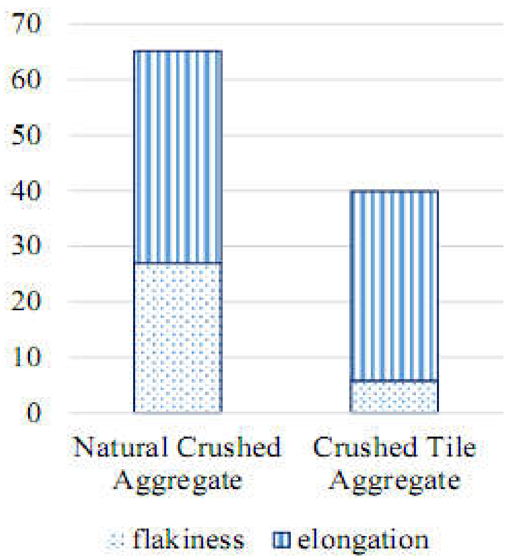

Fig 1 Flakiness and elongation index of aggregates

The **flakiness index** measures the percentage of aggregate particles whose thickness is less than 0.6 times their mean size. Flaky particles are undesirable because they reduce the strength and workability of concrete and asphalt.

Fig 2 Crushed waste ceramic Tile Separation

Table 5 Replacement Proportions for Various Concrete

S.No	Concrete Type	Coarse Aggregate Replacement WithCrushed Waste Ceramic Tileaggregate
1	C0	Standard Concrete
2	C1	5% Replacement
3	C2	10% Replacement
4	C3	15% Replacement
5	C4	20% Replacement
6	C5	25% Replacement
7	C6	30% Replacement
8	C7	35% Replacement

Table 6 Design Mix Proportions

Types of Mix	Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	W/C Ratio
0% CTA	1	1.50	2.71	0.479
5% CTA	1	1.50	2.67	0.482
10% CTA	1	1.31	2.31	0.463
15% CTA	1	1.31	2.28	0.464
20% CTA	1	1.31	2.15	0.484
25% CTA	1	1.31	2.09	0.484
30% CTA	1	1.31	2.07	0.492
35% CTA	1	1.23	2.00	0.478

Design mix proportions refer to the calculated ratio of cement, sand (fine aggregate), coarse aggregate, and water in concrete to achieve the desired strength and durability. The mix is designed based on factors such as workability, exposure conditions, and structural requirements.

 Nominal Mix: Used for small-scale construction where mix proportions are pre-fixed (e.g., M5, M10, M15, M20).

 Design Mix: Used for large-scale or critical structures where mix proportions are determined based on laboratory tests (e.g., M25, M30, M40).

For higher-grade concretes (M25 and above), proportions are determined by trial mixes considering:

- **Target Strength**:
  fck=fck+1.65×Sf_{ck} = f_{ck} + 1.65 \times Sfck=fck+1.65×S
  where **S** is the standard deviation.
- **Water-Cement Ratio**: Based on workability, exposure conditions, and strength.
- **Aggregate Proportions**: Determined from particle size distribution.

3.4 CONGRETE TEST

Table 8: Split Tensile Strength of Cylinders at 7 Days & 28 Days

Mix	OPC Cement	Fine Aggregate	Coarse Aggregate		No of Specimens	
		NFA	**NCA**	**CTA**	**Cube**	**Cylinder**
0%	100%	100%	100%	0 %	3	3
5%			95%	5 %	3	3
10%			90%	10%	3	3
15%			85%	15%	3	3
20%			80%	20%	3	3
25%			75%	25%	3	3
30%			70%	30%	3	3
35%			65%	35%	3	3

Sl. No.	Mix	Average Split Tensile StrengthIn N/mm^2	
		7 Days	**28 Days**
1	0%	1.06	2.65
2	5%	1.27	2.86
3	10%	1.27	2.97
4	15%	1.70	2.97
5	20%	1.80	2.76
6	25%	1.59	3.08
7	30%	1.06	3.29
8	35%	1.49	3.18

Table 9: Compressive Strength of Cubes at 7, 14, and 28 Days

Sl. No.	Mix	Average Compressive Strength In N/mm^2		
		7 Days	**14 Days**	**28 Days**
1	0%	20.78	23.89	29.67
2	5%	22.44	25.81	30.22
3	10%	24.67	28.37	30.33
4	15%	23.89	27.47	30.56
5	20%	22.44	24.68	30.89
6	25%	23.22	25.54	32.00
7	30%	22.26	24.43	31.78
8	35%	19.04	20.98	30.11

5. RESULT

Table 10: Flexural Strength of Values at 7 Days

Sl. No.	**Mix % of Ceramic tiles**	**Days**	**bd^2 1 x 10^6 (mm^3))**	**Load KN**	**Flexural Strength (N/mm^2)**
1	0%	7 Days	15cm x 15cm x 70cm (3.375)	21.25	3.78
2	10 %			23.75	4.22
3	20 %			26.25	4.67
4	30 %			25.00	4.44

Table 11: Flexural Strength of Values at 14 Days

Sl. No.	Mix % of Ceramic tiles	Days	bd^2 1×10^6 (mm^3)	Load KN	Flexural Strength (N/mm^2)
1	0%	14 Days	15cm x 15cm x 70cm (3.375)	33.00	5.87
2	10 %			35.00	6.22
3	20 %			36.875	6.55
4	30 %			39.375	7.00

Table 12: Flexural Strength of Values at 28 Days

Sl. No.	Mix % of Ceramic tiles	Days	bd^2 1×10^6 (mm^3)	Load KN	Flexural Strength (N/mm^2)
1	0%	28 Days	15cm x 15cm x 70cm (3.375)	3.375	6.44
2	10 %			3.375	6.90
3	20 %			3.375	7.33
4	30 %			3.375	7.67

6. Conclusions

This study investigated the feasibility of using ceramic tile waste as a partial replacement for coarse aggregate in concrete. Based on the experimental results, the following conclusions can be drawn:

1. **Strength Performance** – The partial replacement of coarse aggregate with ceramic tile waste showed an increase in compressive and tensile strength up to a 20% replacement level. Beyond this percentage, a decline in strength was observed due to increased porosity and weaker bonding between aggregate and cement matrix.
2. **Workability** – The workability of concrete decreased as the percentage of ceramic tile waste increased. This is attributed to the irregular shape and higher water absorption of ceramic aggregates, which reduced the ease of concrete mixing and placement.
3. **Durability** – Concrete containing ceramic tile waste exhibited satisfactory durability characteristics, making it a viable alternative for sustainable construction. However,

higher replacement levels may require additional measures to enhance the concrete's long-term performance.

4. **Environmental and Economic Benefits** – The incorporation of ceramic waste in concrete contributes to sustainable construction by reducing the demand for natural aggregates and minimizing landfill waste. This approach promotes resource conservation and offers a cost-effective solution for waste management.

Recommendations

- A replacement level of up to **20%** is recommended for optimal strength and workability balance.
- Further studies on long-term durability and water absorption properties are needed.
- The use of admixtures or water-reducing agents should be explored to improve workability.
- Large-scale implementation of ceramic waste in concrete should be encouraged in the construction industry to promote sustainability.

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