Study on strength behaviour of Vitrified Tiles Powder Mix Concrete

Abhilash G S[1], Vanitha J C[2]
[1]Lecturer, Department of Civil Engineering Institute, Government Polytechnic, Soraba, Karnataka, India
[2]Lecturer, Department of Civil Engineering Institute, Government Polytechnic, Nagamangala, Karnataka, India

***Abstract*— In response to rising demands in infrastructure projects, the construction industry has seen a sharp increase in the use of natural aggregates, alongside significant growth in solid waste from construction demolitions. This has highlighted the need to reuse demolition waste materials, such as vitrified tile pieces, vitrified tile powder, and granite powder, to reduce solid waste and address natural aggregate shortages for concrete production. Vitrified tile waste arises not only from demolished structures but also from manufacturing processes, where 20-30% of produced material becomes waste. Reusing these materials can help mitigate natural resource constraints and reduce construction waste.**

In a study, crushed vitrified tile powder and granite powder were used to replace fine aggregates in concrete. The vitrified tile powder was substituted for fine aggregates at 5%, 10%, 15%, 20%, and 25% in an M20 grade concrete mix. Various concrete mixes were tested for workability, compressive strength, and split tensile strength after 7 and 28 days of curing. Results indicated that the concrete's strength increased with the addition of vitrified tile powder, with an optimal replacement level of up to 20%. This approach demonstrates a sustainable alternative in concrete production, improving both waste management and resource efficiency.

***Index Terms*— Structural behaviour, Vitrified tile powder, Workability, Strength**

I. INTRODUCTION

Traditional concrete mix design relies on cement, fine aggregate, and coarse aggregate as its primary components. However, the rapid growth of the construction industry has led to a scarcity of natural aggregates, highlighting the need for sustainable, alternative materials. By partially replacing conventional ingredients with low-cost substitutes, aggregate shortages can be alleviated without sacrificing concrete’s structural integrity or deviating from established standards. This shift is essential in countries focusing on resource sustainability within construction practices.

Construction and manufacturing activities produce large volumes of solid waste globally. Researchers are exploring various materials such as crushed plastic, stone dust, waste tires, slag, fly ash, broken glass, rice husk ash, and coconut shell ash as partial substitutes for natural aggregates. This practice helps preserve natural resources and supports recycling efforts by repurposing construction waste like tile pieces, thus reducing landfill waste and easing demand for traditional materials such as gravel and sand. The popularity of vitrified tiles for their aesthetic appeal has increased their production, with 30-40% of tile manufacturing typically resulting in waste due to defects and irregularities.

This study focuses on using waste vitrified tile powder as a partial substitute for fine aggregates in concrete, assessing its effectiveness as a sustainable replacement that maintains concrete’s performance. Utilizing vitrified tile waste addresses two primary issues: reducing solid waste and conserving increasingly scarce natural resources. Waste tile powder, which is often discarded into sedimentation tanks, contributes to environmental pollution and poses risks to agriculture and public health. However, research indicates that this waste powder, when added to cement, can enhance concrete's mechanical properties, offering cost-effective and ecological advantages.

With advancements in concrete technology, the construction industry has the opportunity to reduce natural resource consumption by reusing solid waste and identifying eco-friendly alternatives. In India, where industrial, municipal, and construction processes generate substantial waste, improper disposal poses significant environmental threats. Integrating waste materials into concrete mixes not only yields cost savings but also improves energy efficiency and mitigates environmental hazards, contributing to sustainable construction practices.

In this study, we evaluate the performance of vitrified tile waste in concrete by replacing fine aggregates with waste vitrified tile powder at various levels. Experimental tests include assessments of workability, non-destructive testing (NDT), and compressive strength after 7 and 28 days of curing. These evaluations offer insights into the suitability, durability, and strength of vitrified tile waste as a sustainable component in concrete, supporting environmentally responsible construction practices. The results are expected to affirm the potential of vitrified tile waste as an effective, resource-efficient alternative in concrete production.

II. RELATED WORK

Chintan P. Patel and K. Bhavasar examined the high contribution of ceramic materials to waste in the construction industry, where around 15%-20% of production becomes waste. Currently, ceramic waste is primarily disposed of in landfills due to the lack of standards, limited knowledge, and risk aversion regarding its use in construction. Recognized for its pozzolanic properties, ceramic waste has potential as a construction material. In their research, Patel and Bhavasar partially replaced cement and fine aggregates in M-30 grade concrete with different types of ceramic waste (wall tile powder, vitrified tile powder, and glossy tile powder) sourced from various ceramic industries. They tested ceramic waste additions at 0%, 10%, 20%, 30%, and 40% by weight for cement replacement and at 0%, 10%, and 20% by weight for fine aggregate replacement. The results, evaluated at 7, 14, and 28 days, indicated that replacing cement with ceramic waste up to 30% and fine aggregate up to 10% achieved the desired M-30 concrete strength, with added economic and environmental benefits. This substitution reduces landfill waste, preserving natural areas and resources.

Sabih Ahmad, Abdullah Anwar, and colleagues noted that the ceramic industry continues to produce 15%-30% waste, despite improved production processes. This waste, commonly discarded in storage areas or nearby open spaces, pollutes soil and air, particularly when the ceramic dust becomes airborne. Their research focused on the mechanical properties of M-25 grade concrete by partially substituting fine aggregates with ceramic powder. They tested various substitution levels—10%, 30%, 40%, and 50% by weight—and evaluated compressive, tensile, and flexural strengths after 28 days. The study aimed to determine the optimal ceramic powder proportion for enhancing concrete's mechanical performance.

Amos Kiptoo Koech investigated the feasibility of using crushed ceramic waste as a fine aggregate in concrete, particularly in light of increased resource depletion and environmental concerns due to population growth and construction waste. Koech sought to understand whether ceramic waste could achieve comparable strength to river sand in Class 25 concrete, a structural grade. Through an experimental approach, he prepared control specimens using river sand and compared them to specimens with crushed ceramic waste as fine aggregate. Tests included slump tests for workability, compressive, tensile, and flexural strength, and water absorption.

Results revealed that the use of crushed ceramic waste as fine aggregate led to a slight reduction in compressive, tensile, and flexural strengths compared to river sand concrete. Additionally, ceramic fine aggregate demonstrated higher water absorption (16.92% versus 5% for river sand), which reduced workability. The specific gravity of ceramic aggregate (2.53) was also lower than that of river sand (2.62), affecting the density and resulting in a reduced concrete density. Consequently, the concrete with ceramic waste did not achieve the required strength at 28 days for Class 25 structural applications. Koech concluded that due to its inferior engineering properties, crushed ceramic waste cannot fully replace river sand in structural concrete.

Together, these studies highlight the potential and limitations of ceramic waste as a sustainable substitute in concrete. Patel and Bhavasar found that ceramic waste can partially replace cement and fine aggregates in M-30 grade concrete, achieving economic and environmental benefits without compromising strength. Ahmad et al. suggested an optimal level of ceramic powder substitution for M-25 concrete based on mechanical performance. In contrast, Koech's research found that crushed ceramic waste may not be suitable as a complete replacement for fine aggregates in structural concrete, though it has potential for other, less demanding applications. These findings underscore the importance of understanding material properties to maximize the benefits of recycled waste in concrete production.

III. PROPOSED METHODOLOGY

The The main object of testing is to know the behaviour of vitrified tiles powder mixed concrete in fresh as well as in hardened state.

Concrete is prepared by adding the waste vitrified tiles powder in various percentage for partial replacement of fine aggregate by 0%, 5%, 10%, 15%, 20% and 25% were designated as F0, F5, F10, F15, F20 and F25 respectively.

The main parameters studied were,

1. Workability of fresh concrete (slump and compaction factor and vee-bee test)
2. Cube compressive strength
3. Spilt tensile strength
4. NDT on concrete

In the present study, an OPC 43 grade cement conforming to IS: 8112 from a single batch is used. Locally available fine aggregate is used for the present study. The sieve analysis data of fine aggregate were shown in table 2 and the Crushed ballast stone of size 12mm and 20mm down confirming to IS 383 - 1970 is used as coarse aggregate and properties were tested and tabulated in table 4 and table 5. The Potable water is used in the present investigation for both casting and curing and its pH ranges between 6.5 – 8.5. Waste vitrified tile powder was used and properties tabulated in table 7.

A. Mix proportion of concrete:

B. Mix design was carried out using the proportions of ingredients for M20 grade as per IS 10262- 2009; “Guidelines for Concrete Mix Design Proportioning” gives the minimum cement content for different mix proportions were used.

B. Casting of concrete cube and cylindrical mould:
Cube moulds of size 150mmX150mmX150mm and cylindrical mould of size 150mm dia. and 300mm length were used for casting the concrete. The moulds were cleaned and before casting greasing to be applied on all the internal surfaces. All the cube moulds were filled in 3 layers. The heights of the mould and for each layer 1/3 rd of each layer 25 blows were given with the help of tamping rod over the entire cross section of the mould uniformly. After filling and compacting the mould, the top surface is made smooth and kept for drying for 18 hours. Waste vitrified tile powder by weight of cement 0%, 5%, 10%, 15%, 20% and 25% were used. Three cylindrical and cube moulds were casted for each percentage of Waste vitrified tile pieces for split tensile test. Three cube moulds were casted for each percentage of Waste vitrified tile pieces for 7 and 28-day compressive testcompressive test.

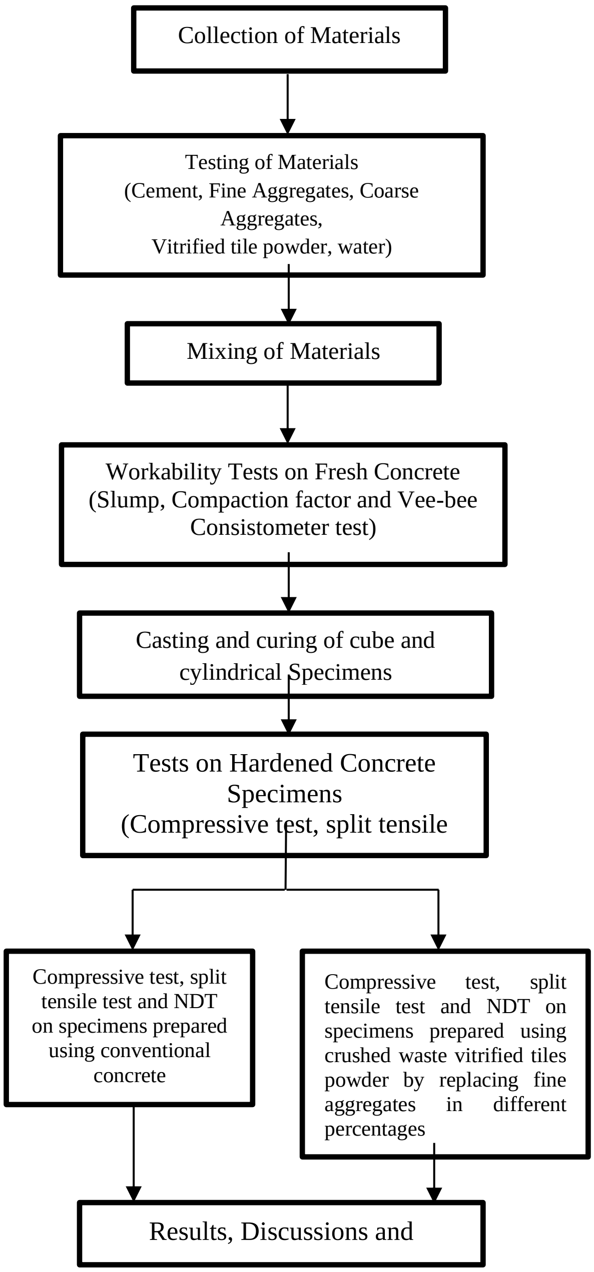

Fig 1: Methodology

IV. RESULTS AND DISCUSSIONS

In the present study, the observations were recorded for the slump, compaction factor and vee-bee Consistometer test values for fresh concrete and compressive Strength test, Splitting tensile strength test, density, and elastic modulus values for hardened concrete.

In the fresh state workability measurements were done using slump test, compaction factor test and vee-bee Consistometer test. Workability of concrete increases with the increase in percentage of waste vitrified tiles powder by the weight of fine aggregates.

Workability Test such as the slump test, the compaction factor test, and the vee-bee Consistometer test were utilized to determine the workability of the material in its fresh state. It is possible to achieve vee-bee seconds ranging from 3 to 4 and slump values ranging from 10 to 16. Compaction factor values range from 0.9 to 0.92.

Compressive strength test results of the tests to determine the cube compressive strength of all mixes were plotted in graphs. The fluctuation of the cube compressive strength with age was shown in graphs. The density of concrete ranges from 21 to 24 kN/m3. Modulus of elasticity of concrete would be a property for the case when material treated as elastic. Modulus of elasticity is primarily influenced by the condition of curing and age of the concrete, the mix proportion and type of cement. Modulus of elasticity is normally related to the compressive strength of concrete. Obtained average modulus of elasticity is 27350 N/mm2.

TABLE I: Properties of Cement

Sl. No.	Properties	Results
1	Specific gravity	3.14
2	Fineness of cement	7%
3	Normal consistency	28%
4	Initial setting time	30 min
5	Final setting time	600 min

Table II: Sieve analysis of Fine aggregate

Sl. No.	IS sieve size (mm)	Cumulative % Passing
1	4.75	97.9
2	2.36	68.4
3	1.18	42.5
4	600 µ	34
5	300 µ	40
6	150µ	76

Table III: Properties of Fine Aggregates

Sl. No.	Properties	Results
1	Bulking	28%
2	Specific gravity	2.22
3	Bulk density	1.72 kg/ltr

Table IV: Sieve Analysis 20 mm down size coarse aggregates

Sl. No.	IS sieve size (mm)	Cumulative % Passing
1	20	83.6
2	12.5	29
3	10	20
4	4.75	0

Table V: Sieve Analysis 10 mm down size coarse aggregates

Sl. No.	IS sieve size (mm)	Cumulative % Passing
1	12.5	88.3
2	10	42.1
3	4.75	9.71

Table VI: Properties of Coarse Aggregates

Sl. No.	Properties	Results
1	Specific gravity	2.22
2	Bulk density	1.781 g/cc
3	Impact test	20%
4	Flakiness Index	32%

Table VII: Vitrified Tile properties

Sl. No.	Properties	Results
1	Specific gravity	2.32
2	Bulk density	1.781 kg/ltr
3	Percentage of voids	40.22%
4	Impact test	20%
5	Flakiness index	32%
6	Elongation index	29%
7	Water absorption	0.8%

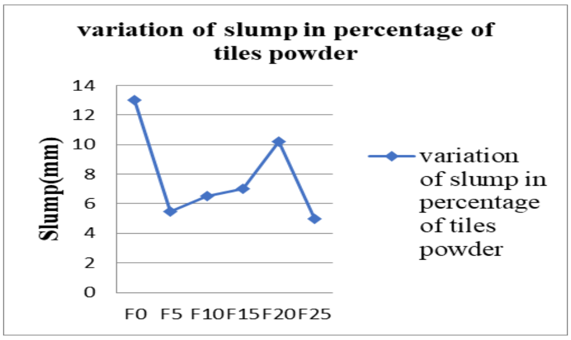

Figure 2: Slump V/S Percentage of Tiles Powder

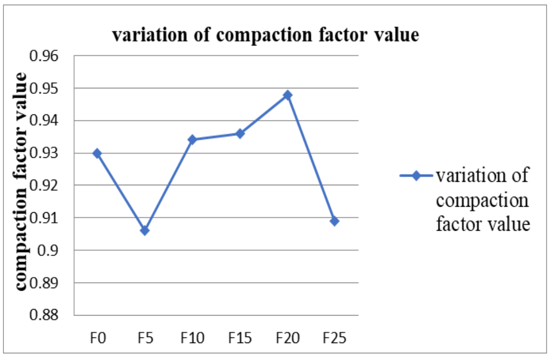

Figure 3: Compaction Factor V/S Percentage of Tiles Powder

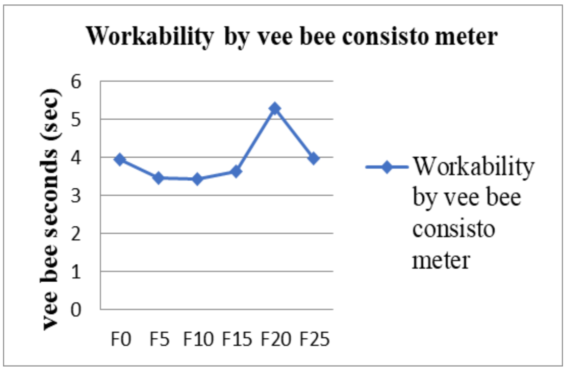

Figure 4 Vee-Bee Seconds V/S Percentage of Tiles powder

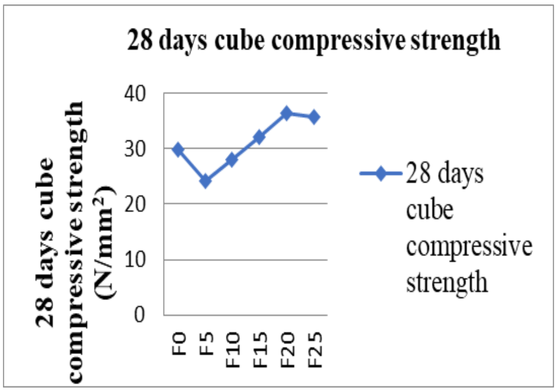

Figure 5: 7-day cube compressive strength v/s percentage of tiles powder

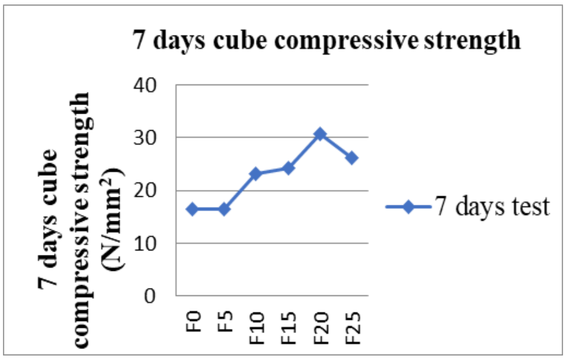

Figure 6: 28-day cube compressive strength v/s percentage of tiles powder

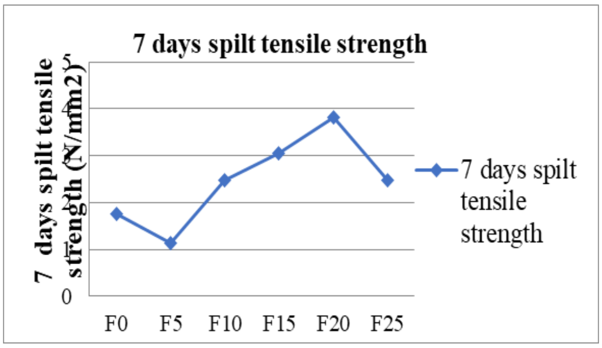

Figure 7: 7-Day Specimen Split Tensile Strength V/S Percentage of Tiles powder

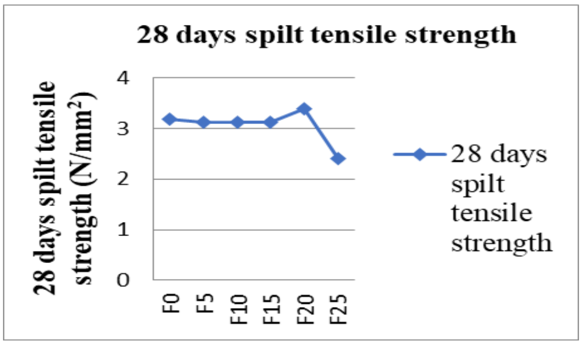

Figure 8: 28 days Spilt Tensile Strength V/S Percentage of Tiles Powder

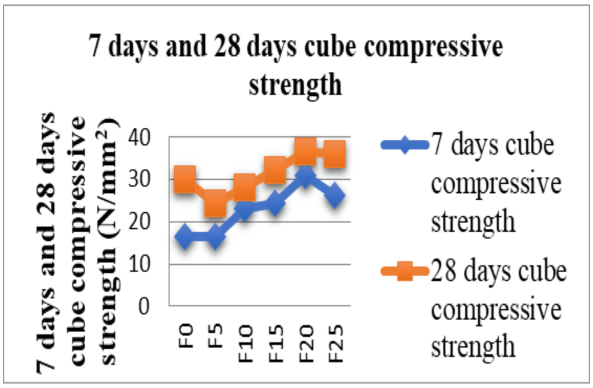

Figure 9: Cube compressive Strength of 7 days and 28 Days Test Result

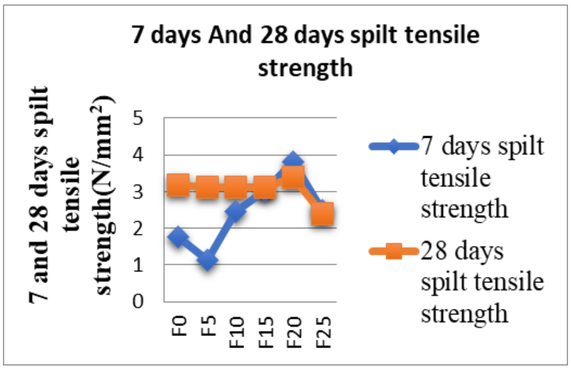

Figure 10: Spilt Tensile strength of 7 days and 28 Days Test Result

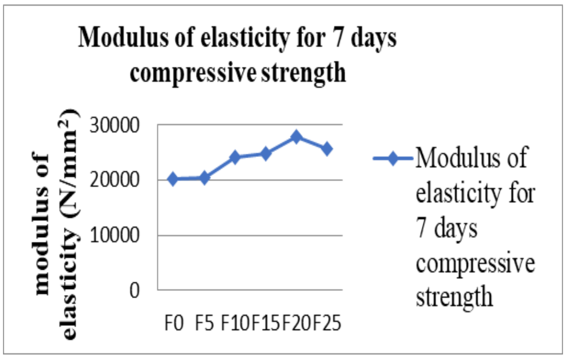

Figure 11: Modulus of Elasticity V/S Percentage of Tiles powder for 7 Days Compressive Test

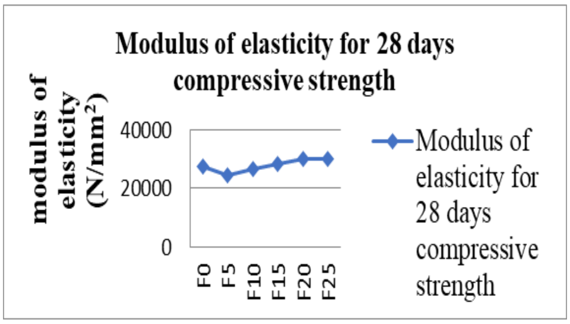

Figure 12: Modulus of Elasticity V/S Percentage of Tiles powder for 28 days Compressive test

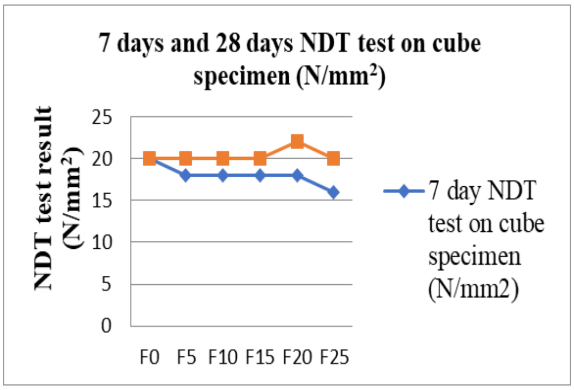

Figure 13: NDT Cube specimen 7 days and 28-day test result

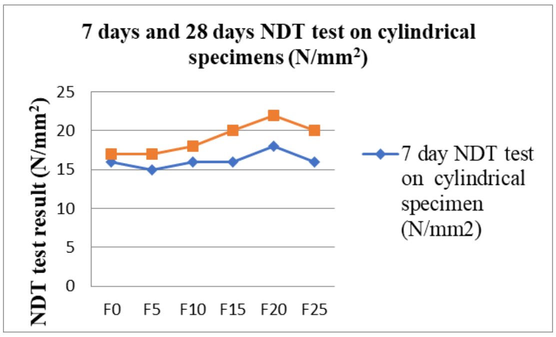

Figure 14: NDT Cylindrical specimen 7 days and 28-day test result

V. CONCLUSION

This study evaluated the use of waste vitrified tiles as a partial replacement for fine aggregates in concrete, examining its effects on physical and mechanical properties. The addition of vitrified tiles powder significantly improved concrete workability, enhancing handling and placement. Conventional concrete displayed a density range of 24.62 kN/m³ to 24.24 kN/m³, with a modulus of elasticity between 20229.92 N/mm² and 27349.58 N/mm². The cube compressive strength reached 16.37 N/mm² at 7 days and 29.92 N/mm² at 28 days, while split tensile strengths were 1.77 N/mm² and 3.12 N/mm², respectively. Rebound hammer values for compressive strength remained consistent, with 7-day and 28-day strengths at 20 N/mm² and 26 N/mm².

With 20% waste vitrified tiles powder, the concrete density ranged from 22.05 to 23.63 kN/m³, and the modulus of elasticity was 27708.30 N/mm² to 30195.19 N/mm². Compressive strengths at 7 and 28 days were comparable to conventional concrete, reaching 30.71 N/mm² and 36.47 N/mm². Rebound hammer values supported these results, with 20 N/mm² and 22 N/mm² for the respective curing periods. Cylinder tests showed stable strength, confirming the viability of vitrified tiles as a sustainable replacement.

The study concludes that waste vitrified tiles can effectively replace natural fine aggregates, maintaining structural integrity and enhancing workability. This approach supports environmentally friendly construction by reducing solid waste and conserving natural resources.

ACKNOWLEDGMENT

We extend our heartfelt gratitude to our mentors and colleagues for their invaluable support and guidance throughout this work. We also appreciate the resources provided by the research community that facilitated our work. Finally, we thank our families and friends for their unwavering encouragement during this journey.

REFERENCES

[1] Chintan P Patel and Jay K Bhavsar "Enhancement of Concrete Properties by Replacing Cement and Fine Aggregate with Ceramic Powder", Journal of Civil Engineering and Environmental Technology, p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 3, Issue 3; January-March, 2016, pp. 232-236

[2] Sabih Ahmad, Abdullah Anwar, Bashar S. Mohammed, Mubarak bin Abdul Wahab, Syed Aqeel Ahmad "Strength Behavior of Concrete

by Partial Replacement of Fine Aggregate with Ceramic Powder", International Journal of Recent Technology and Engineering, ISSN: 2277-3878, Volume-8 Issue-2, July 2019

[3] Amos Kiptoo Koech, "Full Replacement of Fine Aggregate in Concrete with Crushed Ceramic Waste", Global Journal of Environmental Science and Technology: ISSN-2360-7955, Vol. 5(6): pp 488-520, September, 2017

[4] Dylan. J, Beulah. M, "Effect of Waste Materials in partial replacement of cement fine aggregate and coarse aggregate in concrete", International Journal of Inventive Engineering and sciences, ISSN:2319-9598, Issue-4, March 2014

[5] Lalji Prajapati, N. Patel, V.V. Agarwal, "Analysis of The Strength and Durability of The Concrete with Partially Replaced by The Ceramic Slurry Waste Powder," International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume4, Issue 3, March 2014.

[6] Umapathy U, Mala C, Siva K, "Assessment of concrete strength using partial replacement of coarse aggregate for waste tiles and cement for rice husk ash in concrete", International Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol.4., Issue 5(Version 1), May 2014

[7] O. Zibili, W. Salim, M. Ndambuku, "A Review on the Usage of Ceramic Wastes in Concrete Production", International Journal of Civil, Structural, Construction and Architectural Engineering, Vol:8, No:1, 2014

[8] A Mitkuar D. Raval, Indrajit N. Patel, Jaeshkumar Pitroda, "Eco Efficient Concretes: Use of Ceramic powder as a partial replacement of cement", International Journal of Innovative Technology and Exploring Engineering, ISSN: 2278-3075, Volume-3, Issue-2,

[9] IS-383-1970, "Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete," Bureau of Indian Standards, New Delhi, 1970.

[10] IS:1489-1991, "Specification for Portland Pozzolona cement Part 1 Fly ash based (Third Revision)", Bureau of Indian Standard, New Delhi, 1991

[11] IS:456-2000 "Indian Standard Code of Practice for Plain and Reinforced Concrete, (fourth Revision)", Bureau of Indian Standard, New Delhi, 2000.

[12] IS:10262-2009, "Indian Standard Recommended Guidelines for Concrete Mix Design", Bureau of Indian Standard, New Delhi, 1983.

[13] IS: 2386 (part-1)-1963, "Methods of testing for aggregate for concrete". Bureau of Indian standards, 1963.

[14] IS 2386(Part 3):1963 Methods of test for aggregates for concrete: Part 3 Specific Gravity, density, voids, absorption, and bulking.

[15] IS: 10086-1982 -Specification for moulds for use in tests of cement and concrete, Bureau of Indian standards, 1982.

[16] I.S.:5816-1999 "Splitting tensile strength of concrete method of test". Bureau of Indian standard, 1999.

[17] 1.S.:8112-1989 "Specification for 43 grade Ordinary Portland cement, grade specification". Bureau of Indian standard, 2013.