Performance of Concrete Using Vitrified Tile Aggregates

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*—The rapid advancement in construction has significantly increased the demand for natural aggregates, while also generating substantial solid waste, especially from building demolitions. Reusing demolition waste, such as vitrified tile and granite powder, is gaining attention as a sustainable approach to address both waste disposal and aggregate shortages in concrete production. Vitrified tile waste arises not only from demolished structures but also from tile manufacturing, where around 20-30% of production ends up as waste. This study explores the use of crushed vitrified tile waste and granite powder as partial substitutes for coarse and fine aggregates in M20 grade concrete. Crushed vitrified tiles replaced coarse aggregates at 5%, 10%, 15%, and 20% increments. Concrete mixes were tested for workability, compressive strength, and split tensile strength after 7 and 28 days of curing. Results showed that strength and performance improved with up to a 10% replacement level of vitrified tile waste; beyond this, benefits diminished, establishing 10% as an optimal replacement level. This method conserves natural resources, effectively manages construction waste, and maintains concrete quality.**

***Index Terms*— Concrete, Structural Behaviour, Vitrified tiles.**

I. INTRODUCTION

Concrete mix design has traditionally relied on cement, fine aggregate, and coarse aggregate as core materials. However, with construction expanding rapidly, the scarcity of natural aggregates is increasingly critical, prompting the search for sustainable, locally available alternatives. Replacing some of these essential ingredients with low-cost substitutes can help address shortages without compromising structural integrity or altering established mix standards—crucial for countries focused on resource sustainability in construction.

Globally, large amounts of solid waste are generated from manufacturing and construction. Researchers are investigating materials like crushed plastic, stone dust, waste tires, slag, fly ash, broken glass, rice husk ash, and coconut shell ash as partial substitutes for natural aggregates in concrete. This shift preserves natural aggregates and promotes recycled construction waste materials, like tile pieces, reducing landfill use and the demand for traditional aggregates.

This study focuses on using waste vitrified tiles as a partial substitute for coarse aggregates in concrete, aiming to see if these materials can enhance resource efficiency without compromising strength or performance. Using vitrified tile waste helps manage solid waste and reduces dependence on limited natural resources.

Advancements in concrete technology offer opportunities to reduce natural resource consumption by reusing waste and exploring eco-friendly alternatives. In India, where waste from industrial and municipal processes is common, improper disposal poses environmental risks. By integrating waste in concrete, we achieve cost savings, improved energy efficiency, and reduced environmental hazards, supporting sustainable construction.

Vitrified tile industry waste, often discarded due to flaws or defects, impacts the environment if unmanaged. Tile waste powder, usually discarded, contributes to environmental pollution but has been shown to enhance concrete when added to cement, offering cost-effective and ecological benefits.

This study evaluates the performance of vitrified tile waste in concrete by partially replacing coarse aggregates with it at different levels. Tests include assessments of workability, non-destructive testing (NDT), and compressive strength after 7 and 28 days of curing. Results provide insight into the suitability and durability of vitrified tiles as a sustainable component in concrete, supporting environmentally responsible construction.

II. RELATED WORK

Md Daniyal and Shakeel Ahmad observed that a large amount of vitrified material becomes waste during processing, transport, and installation due to its brittleness. Their study used crushed vitrified tile waste as a substitute for natural coarse aggregates at 0%, 5%, 10%, 15%, and 20%. Results indicated that using vitrified tile aggregate enhances concrete's compression and flexural strength [6].

Parminder Singh and Dr. Rakesh Kumar Singla researched using vitrified waste tiles from industry as a partial coarse aggregate replacement. Testing three concrete grades, they found results close to conventional concrete in terms of strength properties, advising a 20% replacement in M20 concrete as preferable [7].

Aruna D et al. proposed using tile waste for coarse aggregates, replacing them at 0%, 5%, 10%, 15%, 20%, and 25%, with fly ash partially replacing cement. Maximum compressive strength was achieved at 25%, though a 10-15% strength reduction was seen compared to conventional concrete. Tile waste concrete displayed medium workability, suitable for smaller projects [8].

Wadhah M. Tawfeeq studied the effects of using crushed tiles as coarse aggregates, focusing on concrete recycling technology in U.S. infrastructure. Their study with 50% and 100% tile replacement found that compressive strength increases as the water-cement ratio decreases, and concluded that replacing crushed tiles up to 50% has desirable properties [9].

In a study on granite waste powder as a partial fine aggregate replacement, the author tested 0%, 5%, 10%, 15%, and 20% levels. Results showed improved compressive and tensile strengths up to 10%, after which strength declined, suggesting granite powder as a sustainable fine aggregate substitute [10].

The author examined ceramic tile waste as a natural coarse aggregate replacement in M25 concrete at 0%, 10%, 20%, and 30%. Results showed significant compressive and flexural strength improvements at 10% replacement, with minor reductions beyond this, suggesting ceramic tile waste as an effective aggregate substitute [11].

The author studied demolished concrete waste as a partial coarse aggregate replacement at 0%, 15%, 30%, and 45%. Compressive strength improved at 15%, with minor reductions at higher levels, indicating demolished concrete waste's potential to reduce landfill usage and conserve natural aggregates [12].

Investigating fly ash as a cement replacement, the author added it at 0%, 10%, 20%, and 30%. Findings showed improved workability and compressive strength up to 20%, with a decrease beyond this, demonstrating fly ash as a viable additive for durability and environmental benefits in concrete [13].

The author explored recycled plastic waste as a coarse aggregate replacement at 0%, 5%, 10%, and 15%, analysing performance improvements. Results revealed enhanced cracking resistance and compressive strength, peaking at 10%. The study concluded recycled plastic waste is a sustainable option for concrete, aiding waste management and reducing reliance on natural aggregates [14].

III. PROPOSED METHODOLOGY

The main object of testing is to know the behaviour of vitrified tiles mixed concrete in fresh as well as in hardened state.
Concrete is prepared by adding the waste vitrified tiles in various percentage for partial replacement coarse aggregate by 0%, 5%, 10%, 15% and 20% were designated as C0, C5, C10, C15 and C20 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 pieces were used and properties tabulated in table 7.

A. Mix proportion of concrete:
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 pieces by weight of cement 0%, 5%, 10%, 15% and 20% 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 test.

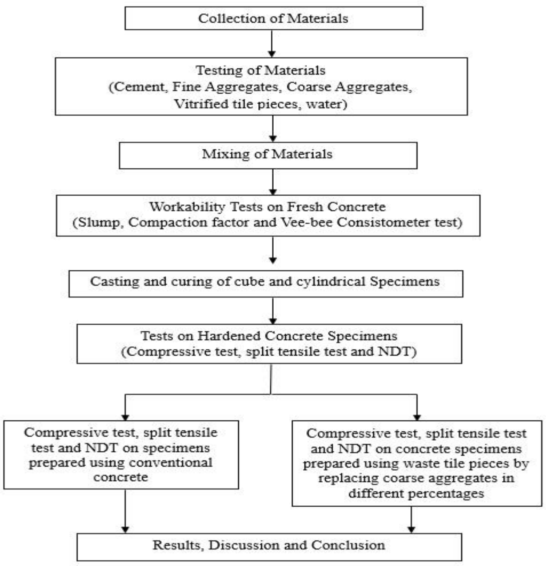

Fig 1: Methodology

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 by the weight of coarse 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 5 and slump values ranging from 13 to 16. Compaction factor values range from 0.85 to 0.98.

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. It is possible to observe that when the percentage of steel fibre in concrete increases, there is an increase in compressive strength. There is a range of 22 to 25 kN/m3 for the density of concrete. 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 modulus of elasticity is 23027 to 26410 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	82.7
2	2.36	73.5
3	1.18	61.9
4	600 µ	45.2
5	300 µ	12.3
6	150µ	2

Table III: Properties of Fine Aggregates

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

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	1.96
2	Density	2200 kg/m^3
3	Water absorption	0.8%

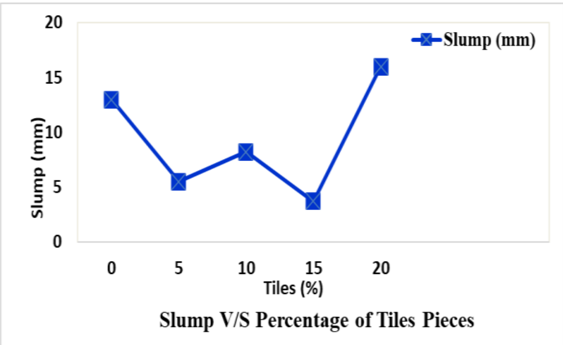

Figure 1: Slump v/s Percentage of Tile Pieces

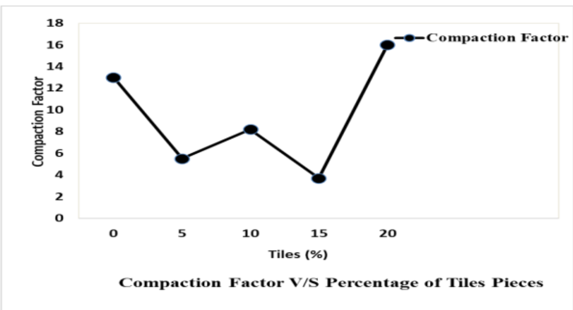

Figure 2: Compaction Factor v/s Percentage of Tile Pieces

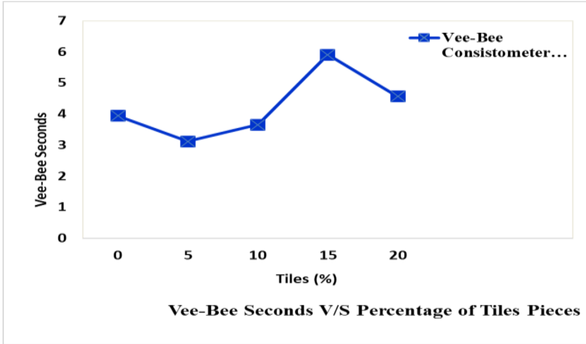

Figure 3: Vee-Bee Seconds v/s Percentage of Tile Pieces

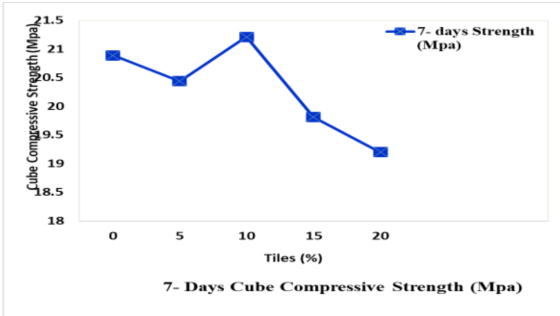

Figure 4: 7-days compressive strength v/s Percentage of Tile Pieces

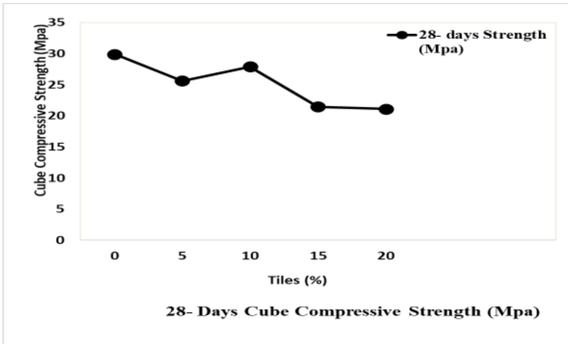

Figure 5: 28-days compressive strength v/s Percentage of Tile Pieces

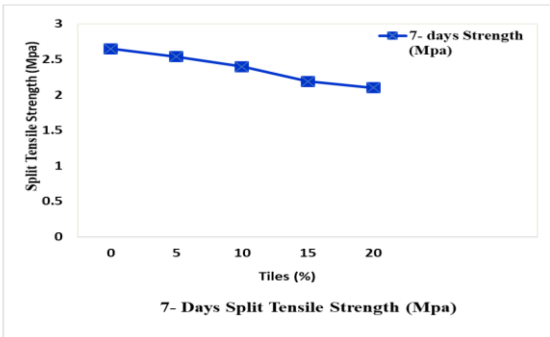

Figure 6: 7-days Split Tensile strength v/s Percentage of Tile Pieces

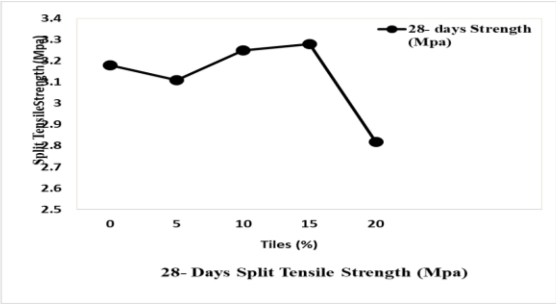

Figure 7: 28-days Split Tensile strength v/s Percentage of Tile Pieces

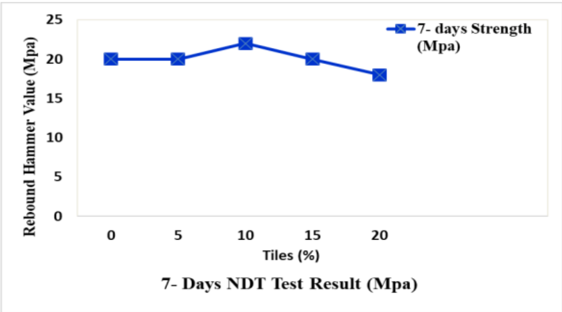

Figure 8: 7-days NDT Test v/s Percentage of Tile Pieces

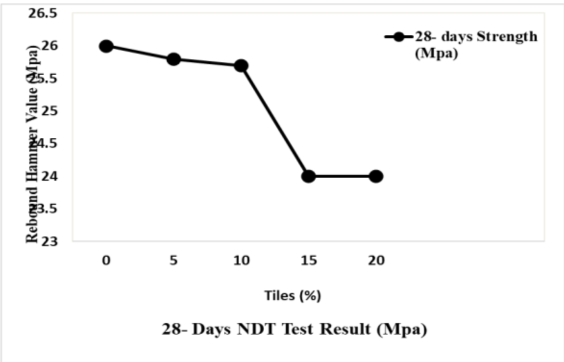

Figure 9: 28-days NDT Test v/s Percentage of Tile Pieces

V. CONCLUSION

This study investigated the impact of using waste vitrified tiles as a partial replacement for coarse aggregates in concrete, focusing on both physical and mechanical properties. The results showed a significant improvement in concrete workability with increased percentages of waste vitrified tiles, enhancing handling and placement characteristics. Conventional concrete exhibited a density range of 24.15 to 23.75 kN/m³ and a modulus of elasticity between 24,571.32 and 24,274.47 N/mm². The cube compressive strength reached 21.21 N/mm² after 7 days and 27.90 N/mm² after 28 days, with split tensile strengths recorded at 2.40 N/mm² and 3.25 N/mm² for the same durations. Rebound hammer values showed consistent trends, with 7-day and 28-day cube compressive strengths at 22 N/mm² and 26 N/mm², affirming the concrete's structural integrity.

With the incorporation of 10% waste vitrified tiles by weight, the concrete density varied between 21.21 and 27.90 kN/m³, and the modulus of elasticity ranged from 23,027 to 26,410 N/mm². The compressive strengths at 7 and 28 days were similar to conventional concrete, at 21.21 N/mm² and 27.90 N/mm², while the split tensile strengths remained stable at 2.40 N/mm² and 3.25 N/mm². Rebound hammer values also reflected these results, showing 22 N/mm² and 26 N/mm² for compressive strength at the respective curing periods. At a 5% tile addition, rebound hammer tests for cylindrical strength remained steady at 22 N/mm² for 7 days and 26 N/mm² for 28 days, indicating no adverse effects on concrete core strength properties.

These findings suggest that waste vitrified tiles can be effectively used in concrete as a sustainable alternative to natural aggregates. The results demonstrate that structural properties can be maintained while also improving workability, making this method a promising option for environmentally friendly construction practices. The study highlights the dual benefits of reducing solid waste and conserving natural resources in concrete production.

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

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

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

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

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

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

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

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

[9] 1.S.:516-1959 (Reaffirmed 1999), "Method of Test for Strength of Concrete." BIS New Delhi, 1959, pp. 1-25.

[10] I.S.:1199-1959 "Methods of sampling and analysis of concrete". BIS New Delhi, 1959

[11] Arun D, Rajendra Prabu, Subhash C Yaragal, katta venkataramana IJRET: eISSIN: 2319-1163 | pISSN: 2321-7308.

[12] Gambhir, ML. (1995). “Concrete Technology”. (2nd Edition), NEW DELHI Tata McGraw- Hill

[13] MS Shetty Reprint (2003) “Concrete Technology”, S. Chand & Co. New Delhi

[14] Neville, A.M, “Properties of concrete”, Third edition, Pearson Education publications

[15] Wadhah M. Tawfeeq, Othman Alshwereedah, and Taimoor Hossain," Properties of Concrete Mix with Crushed Pavement Blocks as Coarse Aggregate ", International Journal of Scientific & Engineering Research, Volume 7, Issue 7, July-(2016).

[16] Wadhah M. Tawfeeq “Replacement Effect of Coarse Aggregate by Crushed Tiles on Hardened Concrete Performance” International Journal of Advanced Engineering and Management Research ISSN: 2456-3676 Vol. 2 Issue 1, 2017

[17] Md Daniyal, Shakeel Ahmad “Application of Waste Vitrified Tile Aggregates in Concrete” International Journal of Innovative Research in Science, Engineering and Technology ISSN: 2319-8753 Vol. 4, Issue 12, December 2015.

[18] Parminder Singh and Dr. Rakesh Kumar Singla “Utilization Of Waste Vitrified Tiles As Coarse Aggregate In Concrete” Journal of Multidisciplinary Engineering Science and Technology ISSN: 3159-0040 Vol. 2 Issue 11, November – 2015.