Effect of Waste Ceramic Tiles as Partial Replacement of Cement and Fine Aggregate In M80 Grade Concrete

K. Srinivasa Rao[1], Mahesh Veeramalla[2], Vennela Puppala[2], Tharun Thatikonda[2], Vinay Kumar Dasari[2]

[1]Assistant Professor, [2]UG Student, [1,2]Department of Civil Engineering

[1,2]Kommuri Pratap Reddy Institute of Technology, Ghatkesar, Hyderabad, Telangana

ABSTRACT

Successful examples of high–rise buildings in the world are obvious evidences that the use of high–strength concrete is nowadays reality in construction worldwide. Whether focus on high–rise buildings up to 15– 24 storeys, or the super tall high–rise buildings that are few hundred of storeys high, high–strength concrete of different qualities is the unavoidable choice in search for structural material. If technology development and economic efficiency opened up a gate to high–strength concrete towards wider market, high–rise buildings for sure enhanced benefits and abilities of high–strength concrete as commonly available structural material. The global consumption of natural aggregates is high, due to the day-by-day innovations and development in construction field. At the same time production of solid waste from the demolitions and manufacturing units are also very high. This study presents the experimental behavior of concrete with partial replacement of waste ceramic tiles used as an alternative fine aggregate and cement, it is compared with controlled cubes and cylinders. Fine Aggregates and cement are replaced by waste ceramic tiles for various percentages 10%, 20% and 5%, 10%, 15% the strength is checked. It is expected that the strength of cubes and cylinder for replacements will not have any adverse effect on strength and there might be slight improvement in strength. This replacement would prove to some environment benefits and would be an economical or a cost-effective technique concreting for the future. The compressive and split tensile strength tests are conducted to evaluate the strength on M80 grade high strength concrete.

Keywords— Waste ceramic tiles, Compressive strength, split tensile strength, fine aggregate, cost, cement.

1. INTRODUCTION

Rapid growth of population and spiraling urbanization demand infrastructure development and housing. Scarcity of affordable building materials and environmental impacts due to the excessive utilization of non-renewable resources is a serious concern of today. Huge demand of raw materials leads to uncontrolled quarrying, results in the removal of top soil and thus negatively affects the flora and fauna of the terrain. It may lead to the extinction of certain useful species and lowering of water table. These frequent activities damage the natural eco system and adversely influence the quality of human life.Cement plays a significant role in all construction activities and its production is highly resource intensive. It is reported that the production of 1 ton of cement supposes the consumption of 1.4 tonnes of quarry material, consumes 5.6 GJ/ton of energy and causes the emission of nearly 0.9 ton of CO2, representing 5% of total anthropogenic CO2 emission. Also it causes airborne pollution by the emission of NOx, SOx, and other particulate matters which make the atmosphere highly poisonous and contribute to global warming and climate changes. Noise pollution and effects of vibration during machinery operations and blasting during quarrying negatively affect the health of workers. Stocking of fuel to run the manufacturing equipment within the industry and other machinery is reported to cause ground water pollution. Undoubtedly, from cradle to grave, cement manufacturing has a major role in environmental degradation. Apart from that, a huge quantity of solid waste is being annually generated from construction industry. As per a recent estimate 48 million tonnes of solid waste is annually generated in India, 25% of which accounts to construction industry. These wastes are heavy and are unsuitable for disposal by incineration or composting. Potential of these wastes in construction applications are explored by many researchers over the years.

2. Literature survey

Construction and Demolition waste (C&D) generation in India is about one-third of the total municipal solid waste generated. It is estimated that C&D waste generation in 2016 was 116 million tones and was disposed off as landfill. Owing to the growth in construction activities, it is expected that C&D waste generation in India will likely to double fold for the next two decades. Utilization of these wastes as a building material by recycling is an alternate solution for disposal issues and raw material scarcity for construction activities.The use of recycled materials in concrete manufacture has become more widespread in recent years. The use of recycled ceramic tile waste as aggregate in concrete would contribute to relieve industrial waste disposal problems and would help maintain natural aggregate resources. Fengli et al. concluded that it is feasible to reuse recycled ceramic aggregate under 9.5 mm as partial replacement of natural aggregate in concrete. Since the apparent density of ordinary concrete is higher than that of recycled ceramic concrete (RCC), this can be helpful to reduce the self- weight of constructions. Under similar workability condition, when the replacement rate is lower than 20%, the splitting tensile strength of RCC is poor because the ultra-fine sand has high mud content. Moreover, when the replacement rate is greater than 40%, the compressive strength and splitting tensile strength are higher than those of the reference concrete. The use of 100% recycled ceramic as fine aggregate increases both splitting tensile strength and compressive strength significantly.Torgal etal. studied the chemical and physical characteristics of crushed ceramic waste from landfills. Besides, ceramic powder was used in concrete mixes as partial substitution of cement, while fine and coarse ceramic aggregates were used as 100% substitution of fine and coarse natural aggregates. They found that compressive strength increases by incorporating ceramic waste in concrete. Al Bakri et al. used different types of recycled ceramic wastes as partial replacement of coarse aggregate in concrete mixes with different w /c ratio; 0.4, 0.5, and 0.7.

3. OBJECTIVE AND METHODOLOGY

3.1 Objective

- To determine the suitability of recycled tile waste with respect to strength and workability.
- To determine the optimum level of replacement of natural sand with recycled tile waste aggregate.
- To determine the optimum level of replacement of cement with recycled tile waste powder.
- To determine the strength of high-performance concrete in-term of compressive strength and tensile strength.

4. EXPERIMENTAL WORK

General

This chapter describes about the materials used and their properties, experimental methods and setups in this investigation.

4.1 Materials used

Ordinary Portland Cement of 53 grade with specific gravity 3.15 available in local market, fine aggregate which is chemically inert, clean conforming to grade zone II with specific gravity 2.6 were used. Coarse aggregate of 20 mm size uniform quality with respect to shape and grading conforming to IS standards was used. Fly ash obtained from NTPC Thermal Power Station (Class F) was used in this investigation to improve workability and durability. Ceramic waste obtained from 4.75mm and 75microns IS Sieved passed aggregates and powder are using for partial replacement of fine aggregates and cement. And Potable water available in the laboratory was used to cast concrete specimens and for curing.

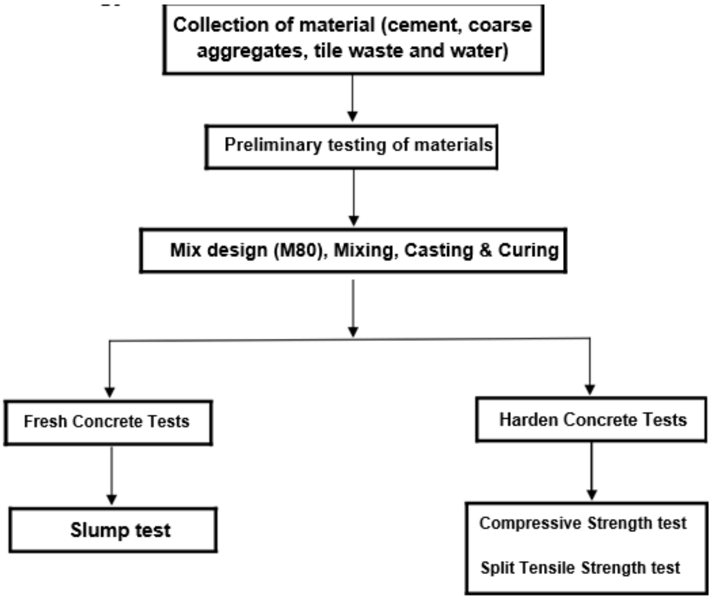

Fig. 1: Methodology Flow chart

4.2 PROPERTIES OF MATERIALS

Cement

In this investigation, 53 grade OPC conforming to IS 12269–1987 was used. The cement sample was tested as per the procedure given in IS 4031-1988 and 4032-1985. The physical properties satisfy the requirements of respective codes..

Property	Value	Code recommendations
Specific gravity	3.15	3.10 – 3.15
Consistency	29%	25 – 35
Initial setting time	45mint	Not less than 30mint
Final setting time	6hours 35mint	Not greater than 10hours
fineness	4%	Not greater than 10%

Fig. 2: Physical Properties of OPC 53 Grade Cement.

Fine Aggregate

Locally available river sand was used as fine aggregate conforming to grade zone II in this investigation. The sand was cleaned and screened at laboratory to remove deleterious materials and tested according to IS: 383-1970. The results of fine aggregate water absorption was 0.75% and specific gravity was 2.68.

Coarse Aggregate

The coarse aggregate occupies more than 85% of the volume of concrete and their impact on various properties of the concrete is predominant. Coarse aggregate of 20 mm size uniform quality with respect to shape and grading conforming to IS standards was used. The results of coarse aggregate water absorption was 0.5% and specific gravity was 2.72.

Fig. 3: Cement

Fig. 4: Fine aggregate.

Ceramic waste

The results of ceramic fine aggregate water absorption were 0.2% and specific gravity was 2.3. The results of ceramic fine powder, specific gravity was 2.6.

Fig. 5**:** Ceramic waste.

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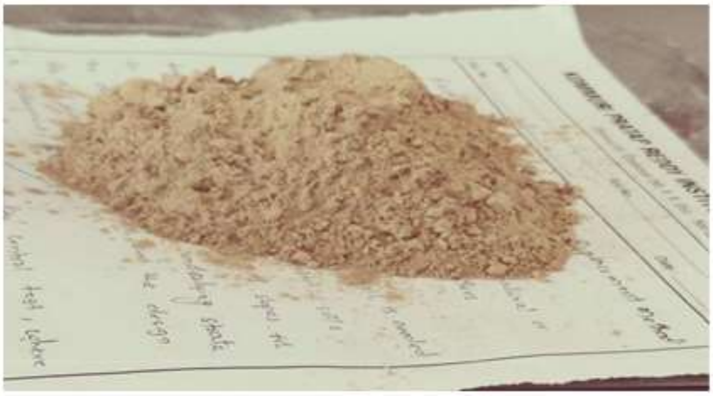

Fig. 6: Ceramic dust.

Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement in concrete. Drinking water available in the laboratory conforming to IS 456-2000 was used to cast concrete specimens and for curing in this investigation.

Fly Ash

Fly ash is a fine residue resulting from the burning of powdered coal at high temperatures. The most common sources of fly ash are electric power-generating stations. Fly ash becomes the predominant pozzolan in use throughout the world due to performance and common factors. In this investigation, class F fly ash obtained from NTPC Thermal Power Station was used. The results of flyash spec

ific gravity was 2.3 and fineness value was 2%.

Mix design

The concrete mix was designed for M80 grade concrete to study the various properties of the concrete as per IS 10262:2009. Following are the site considerations used for the mix design for nominal concrete in our experimental work.

Concrete Grade	: M80
Type of Cement	: OPC 53
Type of aggregate	: 20 mm Sub rounded
Exposure Condition	: Severe
Specific Gravity Of Cement	: 3.14
Specific Gravity Of Fly-ash	: 2.2
Specific Gravity Of GGBS	: 2.85
Specific Gravity Of Fine Aggregate	: 2.61
Specific Gravity Of Coarse Aggregate	: 2.83

Zone Provision	: Zone II
Workability	: 100 mm (slump)

4.3 Mixing and casting

The coarse, fine aggregates and tile aggregate were mixed initially for 1 minute. The cement, Fly ash were added and the dry mixing was done for about 2 minutes. Then water was added and mixing was continued for another 5 minutes. The freshly mixed concrete was cast into rigid steel moulds and compacted with 3layer each layer with 35 blows. After 24 hours, the specimens were demoulded and cured in water tank until the age of testing.

Testing methodology

The workability of the fresh concrete mixture was measured using slump cone test as per IS 1199-1959 (R1999).Compressive strength test was conducted on cube specimens as per IS 516-1999. Splitting tensile strength test was carried out on cylinder specimens as per IS 5816-1999. The compressive and splitting tensile strength tests were carried out on three specimens and impact resistance test was performed on five specimens at the age of 7, 14 and 28 days and the average values were calculated. The test results were compared with the control concrete specimen that contained cement and sand replacement with tile waste.

Tests on fresh concrete

A sample of prepared concrete mix is taken for the test. The internal surface of the frustum of cone is cleaned and greased to avoid the adhesion of concrete. A non-porous base plate is placed on a uniform surface and the slump cone mould is fixed on it. Concrete mix is filled in three equal layers in the mould. The excess concrete is removed and leveled. Now, the cone is lifted in upward direction and the concrete slumps down. The slump (Vertical settlement) is measured in mm.

Tests on harden concrete

4.4 Compressive Strength Test

The compressive strength test was carried out in accordance with IS 516-1999 specification. Compressive strength test was conducted on cube specimens (150mm x150mm x 150mm) with different proportions of tile waste. After 7, 14 and 28days curing period was over, the specimens were tested in the compression testing machine 2000 kN capacity with testing rate of 14 N/mm2/min.

Fig. 7: Compressive strength test for cubes.

Splitting tensile strength test was carried out on 150mm diameter and 300mm height cylinder specimens as per IS 5816-1999. After 28days curing period was over, the specimens were tested in the compression testing machine 2000 kN capacity with testing rate of 2 N/(mm2/min). Load was applied until the specimen failed. The splitting tensile strength test arrangement

5. RESULTS AND DISCUSSION

5.1 Fresh properties of concrete (Workability Test)

5.1.1 Slump Test

The Slump test was performed on the tile powder – tile aggregate concrete to check the workability of it at different replacements viz. 0%-0%, 5%-10%, 10%-10%, 15%-10%, 5%-20%, 10%-20%, 15%-20% and the following results were obtained, according to which it can be concluded that with the increase in % of tile powder – tile aggregate from M1 to M7, workability increases. The results obtained for Slump test are shown below in Table 5.1.

Table 5.1: Results of Slump test

Mix No	Tile powder – tile aggregate	Slump (mm)
M1	0-0	100
M2	5-10	103
M3	10-10	104
M4	15-10	106
M5	5-20	109
M6	10-20	110
M7	15-20	115

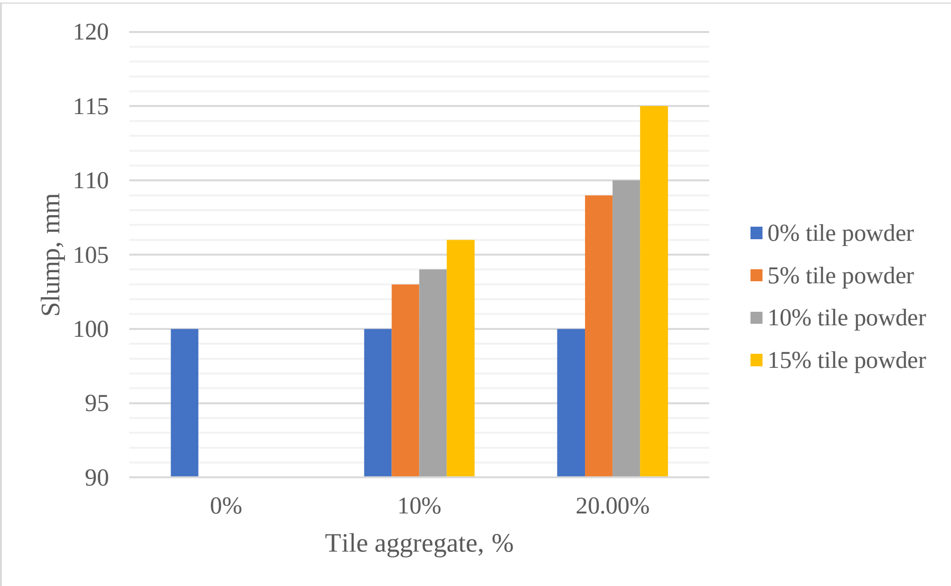

Fig 5.1: Slump test results

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The above figure 5.1 shows the slump results. It was observed that, the slumps increased from M1 to M7 mix with increased tile powder – tile aggregate in the mix. It was varied from Medium Workability to High workability.

5.2 Harden properties of concrete

5.2.1 Compressive Strength Test

The compressive strength test was performed on the cubes of size 15 cm x 15 cm x 15 cm to check the compressive strength of tile powder – tile aggregate based concrete and the results obtained are given in Table 5.2.

Table 5.2: Results of compressive strength test

Mix No	Tile powder – tile aggregate	Compressive strength of cubes (N/mm^2)		
		7 days	14 days	28 days
M1	0-0	54.25	78	87.5
M2	5-10	55.7	82.98	90.2
M3	10-10	58.4	85.8	94.3
M4	15-10	60	87.5	96
M5	5-20	56	85.7	93.2
M6	10-20	54.56	81.84	90
M7	15-20	53	79.1	88

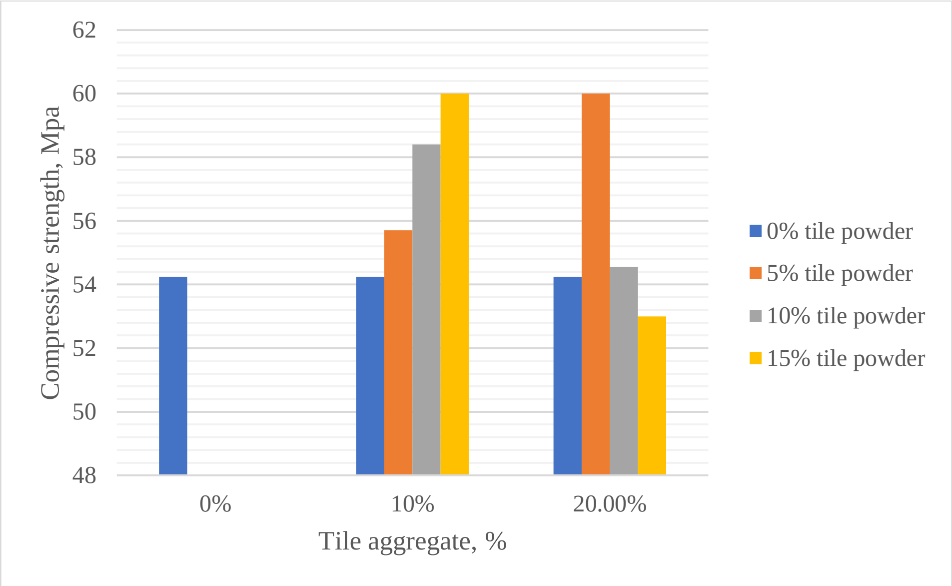

Fig 5.2: 7days Compressive strength test result graph

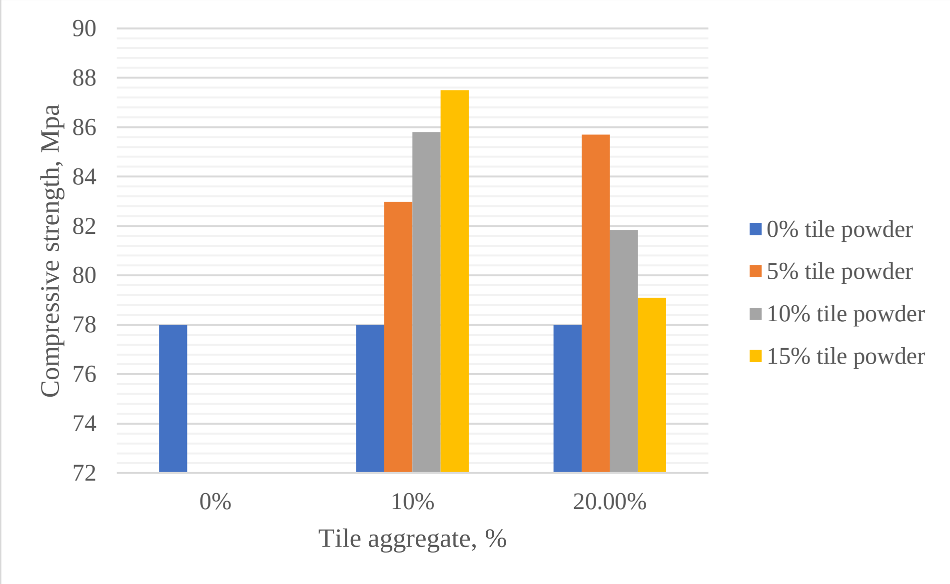

Fig 5.3: 14days Compressive strength test result graph

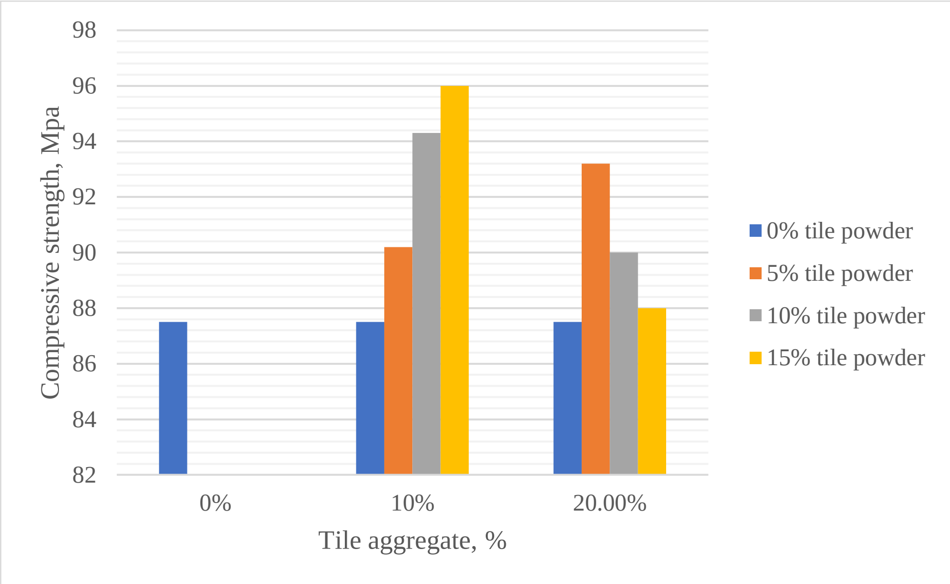

Fig 5.4: 28days Compressive strength test result graph

From the above results it was observed that with the increase in percentage of tile powder – tile aggregate from M2 to M7 in concrete the compressive strength more than control mix M1. The highest compressive strength gained for 15% tile powder – 10% tile aggregate replacing with cement and fine aggregate in the preparation of concrete. The optimum dosage suggested from this study was 15% tile powder – 10% tile aggregate.

5.2.2 Tensile Strength Test

The Tensile test was performed on the beams of size 300mm height x 150 diameter mm to check the Tensile strength of the concrete and the results obtained while performing the Tensile test on CTM are given in Table 5.3.

Table 5.3: Result of Tensile strength

Mix No	Tile powder – tile aggregate	Tensile Strength for 28 days (N/mm^2)
M1	0-0	10
M2	5-10	10.91
M3	10-10	11.41
M4	15-10	11.61
M5	5-20	11.27
M6	10-20	10.89
M7	15-20	10.64

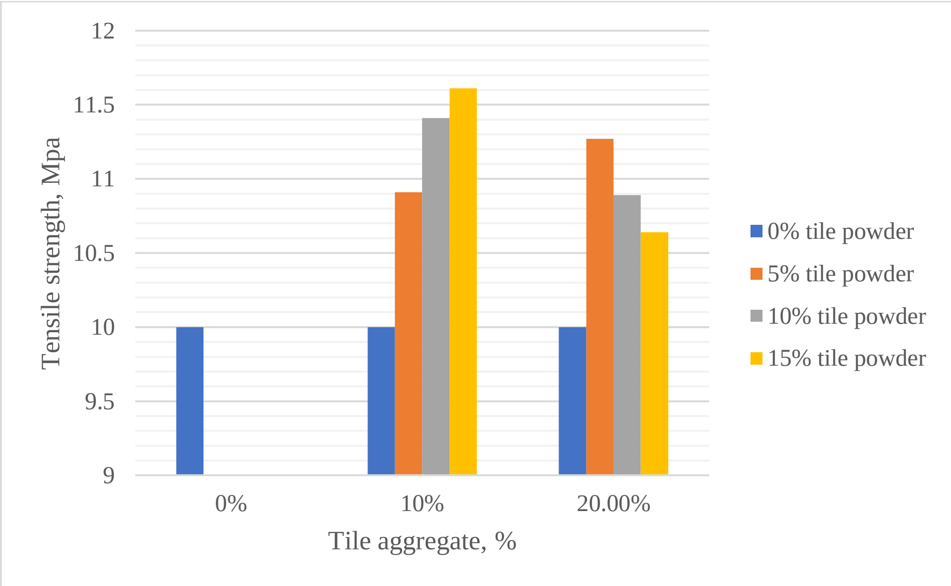

Fig 5.5: Tensile strength graph

From the above results it was observed that with the increase in percentage of tile powder -tile aggregate from M2 to M7 in concrete the tensile strength more than the control mix M1. The highest tensile strength gained for 15% tile powder – 10% tile aggregate replacing with cement and fine aggregate in the preparation of concrete. The optimum dosage suggested from this study was 15% tile powder – 10% tile aggregate.

5.3 Discussions

The workability was increasing with increasing tile powder – tile aggregate replacement in the cement and sand. The compressive and tensile strengths for tile powder – tile aggregate replacement in the cement and sand, was more than control mix. The strength increment percentages were mentioned below Table 5.4. The maximum or highest strength was gained for 15% tile powder – 10% tile aggregate replacing with cement and sand.

Table 5.4: Comparison of strengths

Mix	Tile powder – tile aggregate	28days compressive strength (Mpa)	Increment (%)	28days Tensile strength (Mpa)	Increment (%)
M1	0-0	87.5	-	10	-
M2	5-10	90.2	3.08	10.91	9.1
M3	10-10	94.3	7.77	11.41	14.1
M4	15-10	96	9.71	11.61	16.1
M5	5-20	93.2	6.5	11.27	12.7
M6	10-20	90	2.85	10.89	8.9
M7	15-20	88	0.57	10.64	6.4

6. CONCLUSIONS

In this experimental investigation, the effect of tile waste blended in control concrete with respect to tensile behavior of the concrete cylinders and compressive behavior of the concrete cubes have been investigated. The experimental results have been compared with the control mix concrete. The following conclusions are drawn from the present experimental investigation.

1. Workability increases with increasing in the tile waste and tile powder replacement in the concrete.
2. The compressive and tensile strength highest gains for 15% tile powder with 10% tile aggregate content.
3. The maximum strength gained for 15% tile powder with 10% tile aggregate replacing with cement and sand in the preparation of concrete. The compressive and tensile strength increased by 9.71% and 16.1% as compare to the conventional concrete.
4. By replacing Supplementary Cementitious Materials (SCMs) such as fly ash and tile powder, the cost of construction decreases and disposable problem of agricultural and industrial wastes reduces.

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