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SUSTAINABLE PRODUCTION OF CONCRETE USING CERAMIC TILE POWDER AND STEEL FIBERS: DURABILITY PROPERTIES

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Abstract

Concrete in construction, is a structural material consisting of a hard, chemically inert particulate substance, known as aggregate (usually sand and gravel) that is bonded together by cement and water. Concrete is good in compression but weak in tension, hence new advancements are implemented like using steel fibres (SF) in concrete which will strengthen the tensile zone. An increased compressive, splitting tensile and flexural strength, flexural toughness, surface hardness, and abrasion resistance, and a decreased water absorption and sorptivity of concrete with an increased steel fibre content from 1% to 2% can be observed (Kaplan et al.2021).The main aim of this study is to achieve an acceptable ordinary-strength. Steel fiber (SF) is the most popular type of fiber used as concrete reinforcement. Addition of SFs in concrete significantly increases its flexural toughness, the energy absorption capacity, ductile behavior prior to the ultimate failure, reduced cracking, and improved durability.

Key Words: Strength, Concrete, Mechanical Properties, Durability.

1. Introduction:

Concrete is a material composed of cement, fine aggregates and coarse aggregates mixed with water. To increase the strength of concrete an alternative method we choose is to replace the cement with any other cementitious material. Ceramic powder is used as alternative. Indian ceramic production is 100 million ton per year. In ceramic industry, about 15%-30% waste material generated from the total production. The ceramic waste is durable, hard and highly resistant to biological, chemical, and physical forces. Common materials used to produce ceramic tiles include white clay, talc, sand, feldspar, dolomite and calcite. The Ceramic industries are dumping the powder in any nearby pit or vacant spaces, near theirunit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of a vast area of land, especially after the powder dries up so it is necessary to dispose the Ceramic waste quickly and use in the construction industry as the ceramic waste is piling up every day, there is a pressure on ceramic industries to find a solution for its disposal. The advancement of concrete technologycan reduce the consumption of natural

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resources.

2. Literature Review:

Bhikshma V, Ravande Kishor and Nitturkar (2005), This research investigates about the mechanical properties of the concrete which ismade by the steel fibres and recent advances in concrete and construction technology. A.M. Pande, M. GulfamPathan, Studied the compressive strength, flexural strength, Split tensile strength of steel fiber reinforced concrete (SFRC) containing fibers of 0%, 1%, 2% and 3% volume fraction . Steel fibers of 50, 60 and 67 aspect ratio were used and It is observed that compressive strength, split tensile strength and flexural strength are on higher side for 3% fibres as compared to that produced from 0%, 1% and 2% fibres. P. Balaguru, H Najm, An experimental investigation of high-performance fiber-reinforced concrete (FRC) was performed that showed high-performance FRC with fiber volume fractions up to 3.75% of 30 mm-long hooked steel fibers can be achieved using conventional mixing and appropriate matrix compositions. TefarukHaktanir, KamuraAri, Studied the effects of steel fiber addition on mechanical properties of concrete and RC beams and the flexural behavior and toughness of RC and SFARC beams for C20 and C30 classes of concrete are also determined. S.K. Madan, g. Rajesh Kumar, “Steel fibers replacement of web reinforcement for RCC deep beam in shear”, AsianJournal of Civil Engineering (Building and Housing), Senthamarai RM and Devadas Manoharan P(2005), The research is about the Ceramic Waste Powder as a material in place of cement in concrete and investigation about the properties of CWP comparing with cement. Electricwala Fatima, AnkitaJhamb, Rakeshkumar, This investigation about ceramic dust as construction material in rigid pavement American journal of civil engineering and architecture. O zimbili, W. salim, M. Ndambuki, A review on the usages of ceramic wastes in concrete production International journal of civil and environment engineering. PinchaTorkittikul, ArnonChaipanich, Utilization of ceramic waste as fine aggregate within portland cement and fly ashconcretes, cement and concrete composites. Amitkumar D. Raval1, Dr.Indrajit N. Patel, Prof. JayeshkumarPitroda (2013), Ceramic Waste : Effective Replacement Of Cement For Establishing Sustainable Concrete.

3. Methodology

3.1 Gathering Materials:

Materials are gathered from the near by sources, the materials required are cement, coarseaggregate, fine aggregate, ceramic tile powder, steel fibers and admixtures.

Ceramic tile powder – from nearby source, RAK ceramics,

samarlakotaCement bag – OPC 53 grade – Priya cement

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Coarse aggregates – 20mm size
Fine aggregate – passing from
4.75mm sieveSteel fibers –
ordered from online

3.2 Performing Initial Tests:

Before performing any tests on concrete initial tests are necessary, therefore initial tests are performed with cement, fine aggregate, coarse aggregate, ceramic tile powder and the readings and results are shown in the above chapters.

3.3 Mix Design:

Mix design of M35 is taken, the definite proportion of cement, aggregate and ceramic tile powder is calculated. Steel fibers of 1.75% of total volume is taken.

Initial mixing is done according to the mix design with addition of steel fibers and without replacing the cement with ceramic tile powder in percentages. These values are compared at the last with the results obtained.

The values calculated under the mix design are:

- Target strength
- Water cement ratio
- Water content
- Cement content
- Aggregate proportions

4. Testing of Concrete:

The testing of concrete for cubes is done for 7days, 28days, 56days (compressive strength). Before testing them the specimens should be weighed individually. The testing of concrete for beams is done for 7days, 28days (flexural strength). The testing pf concrete for cylinders is done for 7days (split tensile strength). These test results are then compared with the standard M35 grade test results.

5 Tests On Fresh Concrete:

5.1 Slump Cone Test:

Slump cone test is most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for dry concrete, can only be adopted for freshly mixed concrete. If

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the concrete slumps evenly it is called true slump. If one half of the cone slides down, it is called shear slump. In case of shear slump, the slump value is measured as the difference in height between the mould and average value of subsidence.

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Fig 20. slump cone

5.2 Durability Properties:

5.2.1Compressive strength:

Compressive strength of concrete mixes made with partial replacement of cement with Ceramic Tile Powder in three different proportions and by adding a constant of 1.75% of steel fibers were determined at 7, 28, and 56 days of curing. The test results are given in table and shown in figure. The maximum compressive strength was obtained for a mix in which 15% of cement is replaced with Ceramic Tile Powder .The compressive strength is less than the controlled concrete strength.

5.2.2 Sorptivity Test :

Remove the specimen from the storage container and record the mass of the conditioned specimen to the nearest 0.01 g before sealing of side surfaces. Measure at least four lengths of the specimen at the surface to be exposed to water. Measure the length of the sides to the nearest 0.1 mm and calculate the average side dimension to the nearest 0.1 mm. Seal the side surface of each specimen with a suitable sealing material. The sealing material that is used here is liquid wax. Seal the end of the specimen that will not be exposed to water using a loosely attached plastic sheet . The plastic sheet can be secured using an elastic band or other equivalent system. Conduct the absorption procedure with tap water conditioned to the same temperature. Measure the mass of the sealed specimen to the nearest 0.01 g and record it as the initial mass for water absorption calculations. Place pan and fill the pan with tap water so that the water level is 3 to 5 mm above the top of the support. Maintain the water level 3 to 5 mm above the top of the support for the duration of the tests Record the time and date of initial contact with water. Record the mass at the intervals after first contact with water. The first point shall be at 60s and the second point at 5 mins. Subsequent measurements shall be within an acceptable error of 2 min of 10 min, 20 min, 30 min, and 60 min. The actual time shall be recorded to within 6 10 s. Continue the measurements every hour, with an acceptable

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error of 5 min, up to 6 h, from the first contact of the specimen with water and record the time within 6 1 min. After the initial6 h, take measurements once a day up to 3 days, followed by3 measurements at least 24 h apart during days 4 to 7; take a final measurement that is at least 24 h after the measurement at 7 days. The actual time of measurements shall be recorded with an acceptable error of 1 min. This will result in seven data points for contact time during days 2 through 8. Table 1 gives the target times of measurements and the tolerances for the times.

5.3 Water Absorption Test:

Water absorption on concrete cubes of 100 mm size was done as per the guidelines in BS 1881-122 after 28 days of normal water curing. Oven dried samples were kept in water for 24 hours and their initial and final weights were noted to find out the percentage water absorption as per the rules given in code.

5.4 Chloride Penetration Test:

For the permeability, the concrete samples' chloride penetration depth was analyzed through the silver nitrate (AgNO3) squirting test (Baroghel-Bouny et al. 2007). The 28-day cured cube samples were dipped in 3% NaCl solution. The specimens were periodically withdrawn from the solution and were split into two halves at 7 and 28 days after dipping. The chloride penetration depth was then measured by squirting 0.1 N AgNO3 solution on thesplit concrete surfaces. The color changes on the boundary indicated the depth of chloride permeability. The difference in the white color is due to the formation of AgCl when silver nitrate reacts with chloride ion present in the hardenedconcrete matrix whereas, Ag2O (dark brown color) is formed at higher depth whensilver nitrate reacts with hydroxyl ion present .

5.5 Acid Attack Test:

Acid attack test was conducted for 7, 28 and 90 days as per ASTM C 267-97 [22]. As per its recommendation the test method is intended to evaluate the chemical resistance of hydraulic cement concrete under predicted service condition for which 3% hydrochloric acid was used to estimate acidic resistance. The oven dried concrete cubes (150 mm) were weighed first and then completely submergedin Hydrochloric acid solution. The solution was changed after every 3 weeks. Three cubes of each mix were tested after each exposure period. Change in weight was compared with the initially measured weight. Compressive strength of acid cured specimens has been conducted at respective ages. The load of 140 kg/cm2/min was applied gradually without any shock as per IS: 516-1959 [23]. The achieved results were then compared with the compressivestrength of 28-days water cured concrete cubes.

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6. Results and Discussions:

6.1 Hardened Properties:

6.1.1Compressive Strength:

The above results are obtained by testing the cube specimens of size 150mm under compressive testing machine (CTM), it is observed that when compared to the control concrete each and every replacement proportions there is a decrease in strength, for every increase in percentage replacement of rice husk ash there is a decrease in strength of the concrete. Maximum results were obtained at 5% replacement and the minimum results were obtained at 15% replacement. As we all know that concrete is strong in compressive and week in tension, this is why everywhere throughout the world the first and foremost test performance will be compressive strength.

Table 6.1: Observations of Compressive Strength of hardened concrete

Mix.	Compressive Strength					
	7 days		28 days		56 days	
CC	28.00	29.33	38.00	39.87	51.00	46.17
	34.00		39.50		44.00	
	26.00		42.10		43.50	
MCTP5	39.18	35.53	36.20	42.10	43.00	47.20
	38.00		44.10		48.70	
	29.42		46.00		49.90	
MCTP10	41.00	39.10	42.00	44.80	52.00	52.47
	43.70		45.40		55.60	
	32.60		47.00		49.80	
MCTP15	44.00	47.33	43.50	45.10	61.20	55.10
	49.20		43.50		44.50	
	48.80		48.30		59.60	

6.1.2Density:

Table 6.2 : Observations of density of hardened concrete

Mix.	DENSITY 28 days	
CC	2100.00	
	2035.00	
	2256.00	2130.33
MCTP5	2128.00	
	2167.00	
	2197.00	2164.00
	2097.00	

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MCTP10	2092.00	
	2150.00	2113.00
MCTP15	2219.00	
	2128.00	
	2020.00	2122.33

6.1.3Sorptivity:

Hydration age	MCTP0	MCTP5	MCTP10	MCTP15
0 mins	0.1	0.21	0.17	0.15
1 min	0.24	0.28	0.19	0.17
5 mins	0.26	0.29	0.23	0.21
10 mins	0.42	0.41	0.35	0.26
20 mins	0.56	0.46	0.38	0.31
30 mins	0.59	0.52	0.49	0.37
60 mins	0.65	0.68	0.57	0.42
120 mins	0.74	0.76	0.61	0.49
180 mins	0.81	0.83	0.73	0.58
1440 mins	0.88	0.89	0.81	0.67
2880 mins	0.94	0.93	0.89	0.74
5760 mins	1.15	1.19	0.97	0.86
7200 mins	1.26	1.28	1.16	0.97
8640 mins	1.51	1.36	1.28	1.09
10080 mins	1.59	1.48	1.36	1.28

6.1.4 Acid Attack:

1) Compressive Strength:

As the percentage of CTP is increasing it is observed that the loss in compressive strength is also increasing and it is greater than the loss incurred in compressive strength of controlled concrete cubes due to the same acid attack. It has also been observed that concrete surfaces gets pulpified which results into development of cracks and erosion of surface layers

2) Loss in mass:

As shown in the table and figure as the amount of replacement of cement with CTP is increasing the percentage of loss in mass is also increasing. This might be due to the greater reactivity percentage of CTP which is about 300%

Table 6.3: Observations of acid attack of hardened concrete

	Compressive Strength (%)						**Loss in mass due to disintegration**					
Mix.	**7 days**		**14 days**		**28 days**		**7 days(%)**		**14 days(%)**		**28 days(%)**	
	-4.50		-9.56		-15.55		2.36		3.78		4.57	
CC		-4.50		-9.56		-15.55	2.88	2.45	3.66	3.67	4.88	
							2.12		3.58		5.12	4.86
			-8.98		-14.63		1.95		2.12		3.13	
MCTP5	-3.90	-3.90		-8.98		-14.63	1.84	1.75	2.15	2.42	4.23	
							1.45		2.98		4.98	4.11
			-8.12		-14.84		3.45		3.05		4.45	
MCTP10	-3.85	-3.85		-8.12		-14.84	3.55	3.66	3.65	3.29	3.34	
							3.98		3.17		4.65	4.15
			-9.55		-12.42		3.85		2.56		4.85	
MCTP15	-4.10	-4.10		-9.55		-12.42	4.12	3.89	3.12	3.04	4.15	
							3.70		3.45		4.95	4.65

7. Conclusion:

1 CTP is economical, the strength might be less when compared to the control concrete, but can be used for constructions in rural areas to decrease the construction cost. By doing this project we would give a contribution to the society by making the environment more eco-friendly by utilizing the ceramic tile powder scientifically. Thus by adopting replacement method we can overcome problems such as waste disposal crisis.

2 The compressive strength of concrete when replaced with rice husk ash in 5%, 10%, 15% percentages the strength gets gradually decreased when compared to the control concrete due to the decrease in workability, because the water absorption of CTP is high. The increase in percentage of CTP proportion there is a decrease in strength parameter. The density is obtained from cubes and the results are fluctuating due to the properties of CTP and increase with increase in age.

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3 The sorptivity values are observed by the testing of concrete cubes are changes with the CTP content and increases with increase in age of cubes.

4. Acid attack

1) Compressive Strength:

As the percentage of CTP is increasing it is observed that the loss in compressive strength is also increasing and it is greater than the loss incurred in compressive strength of controlled concrete cubes due to the same acid attack. It has also been observed that concrete surfaces gets pulpified which results into development of cracks and erosion of surface layers

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