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To Investigate The Impact of Ceramic Tile Powder On Concrete Properties

Kishor B.Vaghela[1], Jayesh R. Pitroda[2]

[1]*Assistant Professor, Department of Applied Mechanics, Government Engineering College, Rajkot-360001, (Gujarat), INDIA*

[2]*Associate Professor, Department of Civil Engineering, BVM Engineering College, VV Nagar-388120, (Gujarat), INDIA*

[1]kbv.applied@gmail.com, [2] jayesh.pitroda@bvmengineering.ac.in

Abstract - *Cement is the most commonly used construction material on the planet. Its production plants are emitting approximately 7 percent of worldwide human-produced carbon dioxide [1]. As a result, minimizing cement usage and finding alternative materials that can partially substitute cement while still improving concrete performance have become crucial. Ceramic tiles are an important building material in this industry. Approximately 2% to 5% of tiles are wasted during the manufacturing, handling, and transportation of tiles. At first, people have started unloading such waste materials close by their plant in open land, and due to its current circumstance, and land gets contaminated. Consequently, the usage of such waste materials is fundamental for the business and climate. This paper presents the consequences of tests performed to inspect the impact of Tiles waste powder on the strength and permeability of M30 grade concrete. The Ceramic Tiles Powder (CTP) was replaced by 5%, 10%, 15%, and 20% of the cement. We had cast 5 types of concrete mixes utilizing various percentages of CTP. Compressive strength, Tensile strength, Water absorption, Water Permeability, and RCPT tests were performed. The results of the tests show that by replacing cement with Ceramic Tiles Powder, the concrete's strength and durability were increased. At 28 days, the maximum compressive and tensile strength obtained with 10% replacement of cement was 12.19 percent and 7.32 percent, respectively. The maximum reduction in water permeability coefficient Kw and Chloride ion permeability is found 21.68% and is 18% respectively at 28 days, indicating that the concrete is more durable. The outcome is that 10% cement substitution with CTP is an ideal concentration that benefits the concrete of the grade M30.*

Keywords - *Ceramic Tiles Powder, Sustainable Concrete, Industrial Waste Use in Concrete, Durable Concrete.*

I. INTRODUCTION

India ranks second in the world for both cement production and consumption. The growth of long-term cement demand is estimated to be 1.2 times India's GDP growth rate [1]. The use of cement worldwide is increased annually by approximately 2.5%. The production of a ton of cement generates approximately one ton of CO2, accounting for 7% of global CO2 exits [2]. Thus, there is a need to utilize supplementary cementitious materials (SCMs) as a halfway substitution of cement in concrete. The use of SCMs decreases the utilization of normal Portland cement and, in this manner, lessens the energy utilization and ozone-depleting substance emanations related to concrete creation.

Fig.1a Ceramic tiles waste

Fig.1b Miller used for crushing of ceramic tiles waste

This paper explores the possibility of replacing cement in concrete with Ceramic tiles powder (CTP) [3]. India is the world's second-largest producer of ceramic tiles, making up 7% of global production. The growing demand for housing accounts for 70% of India's demand for tiles [4]. The tiles industry has about 2.5% tiles waste material generated during the manufacturing, handling, and transportation of the tiles. Presently the tiles broken pieces are stored in the backyard of the industry or dumped nearby the industry in open land, as shown in fig.1a. Because of such activity land, air and water get polluted. So, it is dangerous for human health and the environment. One of the options to save the environment and people's health from such industrial waste is to use them in making concrete. Hence in this study, we have partially replaced 5%, 10%, 15%, and 20% weight of cement with Ceramic Tiles Powder. We have crushed ceramic tiles waste in a crushing miller, as shown in fig.1b. CTP is a reactive pozzolanic material due to its surface fineness and high silica content. [5]. It reacts with calcium hydroxide and produces additional CSH gel.

II. PROGRAM OF EXPERIMENTATION

A. Materials:

a) Cement

In this study, conventional cement of grade 53 was used. The cement utilized was new and without irregularities. The quality of cement must justify all the criteria given in IS:12269-2013 [6].

b) Ceramic Tiles Powder (CTP)

The waste of ceramic tiles is collected from the industrial area of Morbi(India) and crushed in powder form, which size is less than 90 microns. Physical and chemical properties of Ceramic Tiles Powder are carried at YOR LAB (NABL approved); its results are as per below. The tests to check the quality of CTP were performed as per the guideline of ASTMC-1240, ASTMC-618 12a [7], [8].

Table-1 Cement and CTP physicochemical characteristics.

Physical Property	**Cement**	**Ceramic Tiles Powder (CTP) (ASTMC-1240)**
Color	Gray	Cream white
Sp. Gravity	3.15	1.217
Moisture content		0.19
Water absorption		19
Fineness		75 microns
Chemical Constituent by % of Mass		
SiO_2	23.29	65.04
CaO	61.87	0.66
Al_2O_3	6.14	22.56
Fe_2O_3	4.49	2.12
MgO	4.51	2.88
SO_3	3.13	0.10
$K_2O + Na_2O$	1.04	-

c) Fine Aggregate

A good gradation of fine aggregates is one of the most critical factors in producing workable concrete [5]. In good grading, fine aggregate, air voids, or gaps between two particles are very rare. Because of such lesser voids system, it required lesser cement paste to connect two particles, and the density of concrete is also improved. Table-2 summarizes the important properties of fine aggregate.

d) Coarse Aggregate

In the current study, coarse aggregates with maximum sizes of 10mm and 20mm were used. As per blending of aggregate, used 30% of 20mm sized aggregate and 70% of 10 mm size aggregate [9]. The following are the properties of coarse aggregate used in the testing, such as specific gravity, water absorption, and moisture content.

Table-2 The aggregates used in this analysis had the following physical properties.

Property	**Fine aggregate**	**Coarse aggregate**
Sp. Gravity	2.65	2.74
Grading Zone	Zone-II	–
Water Absorption	1.0 (%)	0.50
Moisture Content	0.00(%)	0.00

e) Water

When we apply water to a dry cement and aggregate mixture, the cement reacts and forms a gel. The CSH gel is a type of gel that binds two aggregate particles together. The heat of hydration is generated by the reaction between cement and water [10]. Over time, all of the cement particles hydrate with water, hardening the concrete. The quality of water should be checked as per the guideline of IS 456-2000 (fourth revision) [11].

B. Concrete cube and cylinder sample preparation

M30-grade concrete cube and cylinder samples were cast using OPC 53-grade cement with and without the addition of CTP. An additional mineral admixture and addition of known properties as indicated in Tables 1 and 2 were combined. The water-to-cement ratio used was 0.48.

The ratio of Cement-FA-CA was 1:1.76:3.15 for concrete. The concrete mix design was prepared to utilize the procedure and guideline given in IS:10262-2019[12]. The size of the concrete cube specimen was 150mm for compressive strength, and the size of the concrete cylinder specimen was 150mm dia. and 300 mm in length for split tensile strength. The water permeability test was assured by testing a concrete cylinder specimen of 150 x 150 mm as per IS 3085:1965 [13]. The water permeability of concrete was confirmed by testing a concrete cylinder specimen of 150 x 150 mm in accordance with IS 3085:1965. In this investigation, a total of five types of concrete mixes of the M30 grade were considered.

The first series consisted of a control mix (M1) made with ordinary tap water for M30 grade concrete. The second (M2), third (M3), fourth (M4), and fifth (M5) series were similar to the first series in terms of all ingredients used in concrete, but 5 percent, 10%, 15%, and 20% cement were substituted with CTP, respectively.

The concrete cube and cylinder specimens have been prepared in three sets, and each set contains 3 samples. The samples were cured in portable water at a temperature of 27 ± 2 deg. Celsius. For a fixed curing period according to IS:516-1959 [14]. The Universal Testing Machine having a capacity of 200 Ton was used for the compressive and tensile strength of concrete samples. The rate of application of load was kept at 0.5 mm/min. The guidelines of IS 516:1959 [14] have been followed for the testing of compressive strength, while testing for tensile strength has been done according to IS:5816:1999 [15].

Table-3 M30 grade Concrete mix design based on IS method

Type of Mix	Cement (kg/m^3)	CTP (kg/m^3)	Coarse Agg. (kg/m^3)	Fine Agg. (kg/m^3)	w/c or w/cm	Water (kg/m^3)
M1	387	-	1222	681	0.48	199
M2	387	19	1222	681	0.48	199
M3	387	38	1222	681	0.48	199
M4	387	58	1222	681	0.48	199
M5	387	77	1222	681	0.48	199

III. RESULTS AND DISCUSSION

A. Compressive strength

Figures 2a and 2b show the effect of different percentages of CTP on the compressive strength of M-30 grade concrete cube samples after 7 days, 28 days, and 56 days. The compressive strength of control concrete improved with an increase in the percentage of CTP up to 10% replacement of cement and then decreased at 15% and 20% replacement. The most extreme improvement in compressive strength was achieved when 10% of cement was replaced with CTP in all concrete cube samples. Individual increases in strength of compressive concrete are achieved in 7 days, 28 days, and 56 days M-30 grade concrete with 10% cement substitution for CTP as compared to the compressive strength of the control concrete.

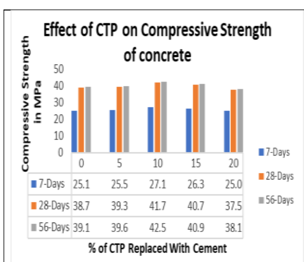

Fig.2a Effect of CTP on Compressive Strength of Concrete Grade-M30

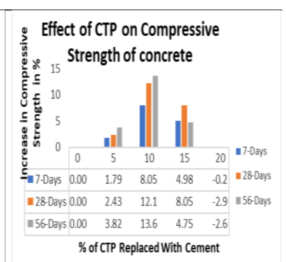

Fig.2b % of Compressive Strength Increase wit Increase in content of CTP

B. Splitting tensile strength

The effect of different CTP concentrations on the 7-day and 28-day tensile strength of an M-30 grade concrete cylindrical sample is shown in Figures 3a and 3b. The tensile strength of control concrete cylindrical samples increased as the CTP percentage increased up to 10%, then decreased to 15% and 20% CTP. The most extreme increase in tensile strength was reached at 10% for all concrete specimens. The split tensile strength of M-30 grade concrete treated with 10% CTP increased by 9.3 percent, 7.3 percent, and 10% for 7 days, 28 days, and 56 days, respectively, as compared to the tensile strength of control concrete specimens.

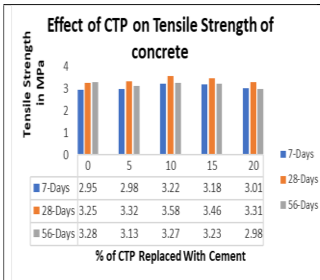

Fig.3a. Effect of CTP on Tensile Strength of Concrete Grade-M30

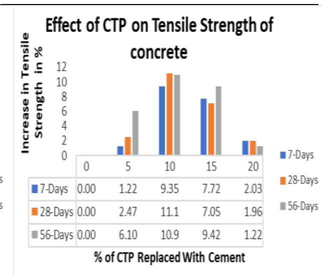

Fig.3b. % of Tensile Strength Increase with Increase in content of CTP

CTP has had a clear impact on the compressive and tensile strength test results of concrete [16]. The compressive strength of the concrete was increased by the inclusion of industrial waste in comparison to control concrete.

C. Water permeability test

The test was performed, and the estimation of the water permeability coefficient Kw was determined as IS 3085:1965 [13]. The impact of various concentrations of CTP on the M30 grade concrete is determined by performing a water permeability test. Fig. 4a and 4b show the effect of 5%, 10%, 15%, and 20% replacement of cement with CTP on the permeability of the concrete. It was found that at 10% replacement of CTP with cement, the lowest value of water permeability coefficient is achieved, and it is 4.30 at 28days and 4.10 at 56days. When the CTP concentration was increased from 5% to 10%, the value of Kw for the Control concrete decreased. When the CTP concentration was increased to 15% and 20%, the value of Kw for the Control concrete increased.

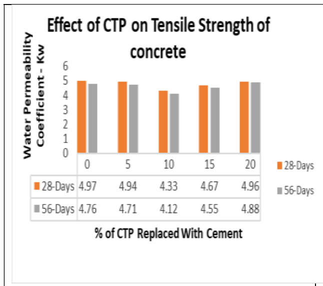

Fig.4a. Effect of CTP on Permeability of Concrete Grade-M30

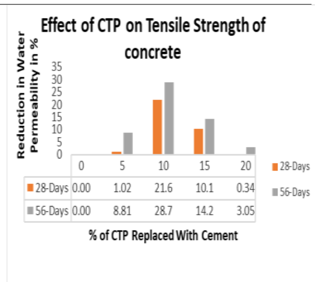

Fig.4b. % of Water Permeability Decrease with Decrease in content of CTP

The test outcomes demonstrate that mineralization decreases the water permeability of concrete by filling the pores with calcite precipitation. In general, the concrete cylindrical samples prepared by incorporating CTP were found to considerably diminish the water permeability by improving the density of the concrete with induced mineral precipitation. Earlier study it was also observed by the other researchers that replacement concrete ingredients like cement and aggregate could be possible by the ceramic waste materials [17]–[22]. The use of a limited amount of CTP instead of cement has no negative impact on the concrete's strength and durability.

D. Rapid Chloride Permeability Test

The Portland Cement Association created this test method as part of a Federal Highway Administration-funded research program (FHWA). Various departments and standard-setting bodies have updated and adapted the test method since its inception. The testing method was developed by the AASHTO T277 and ASTM C1202 researchers. The prepared specimen was 100 mm in dia. and 50 mm in height. Fig.4a shows the image of the concrete cylindrical specimen after demolding. The RCPT test was performed after completion of the curing period of 28 days. The specimen was removed from the curing tank after 28 days of curing and kept at room temperature for an hour before testing. Then put the sample in the RCPT cell as shown in fig.4b, where one end of the concrete sample is immersed in NaCl solution and the other end immersed in NaOH solution. Used silicon sealant to seal the gap between the concrete specimen and cell walls and allow it to dry. The left side of the RCPT cell will act as an anode, and the right-hand side will act as a cathode. The anode side is filled with a 3 percent NaCl solution, while the cathode side is filled with 0.3N NaOH solution, as shown in Fig.4c. As shown in fig.4d, the device is then connected, and a 60-volt potential is applied for 6 hours. Every 30 minutes, readings were taken. The sample was taken out of the cell after 6 hours, and the total number of coulombs passing through the specimen was measured.

Fig.5a. Concrete cylindrical specimen

Fig.5b. Fixing of Silicon Sealant

Fig.5c. Preparation of RCPT cell

Fig.5d. Shows the entire setup of RCPT test

Formula: The following formula was used for calculating the average reading;

$$Q = 900*(I0+2I30+2I60+2I90+2I120+2I150+2I180+2I210+2I240+2I270+2I300+2I330+I360)/1000$$

Where, Q = Charges measured in Coulomb = I x T

I0 = Initial current value at 0 min in mA

I30 = Successive current value at 30 min in mA

I60 = Successive current value at 60 min in mA

I360 = Final current value at 360 min in mA

Table-4 Chloride Permeability Based on Charge Passed [1]

Sr. No.	% of CTP replaced	Charges Measured in Coulomb	Average Charges in Coulomb	Chloride Permeability
1	0	1187	1204	Low
2		1211		
3		1214		
4	5	1187	1165	Low
5		1217		
6		1092		
7	10	1045	1051	Low
8		1021		
9		1087		
10	15	1008	987	Very Low
11		970		
12		982		
13	20	1013	994	Very Low
14		989		
15		981		

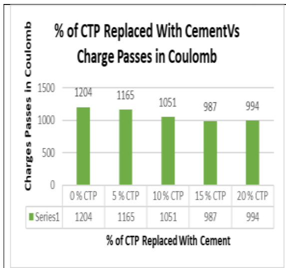

Fig.6a. % of CTP Replaced with Cement Vs Charge passes in Coulomb

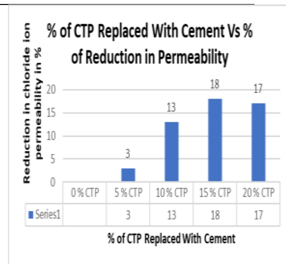

Fig.6b. % of CTP Replaced with Cement Vs Reduction in chloride ion permeability in %

Table 4 shows a higher percentage of charge passed from the specimen in controlled concrete than concrete when cement is partly substituted by CTP. Fig.5a shows the graph of % CTP Replaced with Cement Vs. Charge Passes in Coulomb. Fig.5b shows the graph of % CTP Replaced with Cement Vs. % of Reduction in Permeability of concrete. It was observed that as you increase the % of CTP replacement with cement, the permeability of concrete was reduced up to 15% replacement of CTP with cement. The maximum reduction in the permeability was observed at 15% replacement of CTP with cement.

IV. CONCLUSION AND SCOPE OF FUTURE WORK

The current project oversees the investigation of the effect of various percentages of CTP on the compressive strength, tensile strength, water permeability, and chloride ion permeability of M-30 grade concrete specimens. The results of this research contribute significantly to understanding the impact of various concentrations of CTP on the efficiency of normal structural concrete mixtures.

The findings of this analysis led to the following conclusions:

- It was concluded that the compressive strength of the control concrete increased with an increase in the concentration of CTP up to 10%, accompanied by a decrease in strength at 15% and 20% of CTP.
- The highest compressive strength rate attained at 28-day in M30 (standard) grade concrete was 41.78 percent. Thus, because of precipitation, the rise in compressive strength is attributable to the packing of the pores within the concrete cube specimen.
- The highest increase in concrete tensile strength occurs when 10% of cement is replaced with CTP, which was 7.32 percent for M30 grade concrete after 28 days.
- The largest reduction in chloride ion permeability was observed when 15 percent of the cement was replaced with CTP. In comparison to the control concrete specimen, the permeability was found to be 18% lower.
- At 28 days, the water permeability coefficient Kw has decreased by 21.68 percent, potentially improving the durability of concrete structures. This indicates that calcite precipitation may have blocked the voids in the concrete matrix.

The test estimated that the permeability and the strength of the concrete specimen were reduced, and the tensile strength was increased. CTP can also be used in the future as a green construction material to enhance concrete quality. The low-cost, natural and durable concrete can be substituted for the CTP concrete.

Concrete quality parameters by adding CTP other than strength such as shrinkage, disintegration, carbonation, and changes in chemical reactions throughout different hydration periods and their effect on concrete attributes are still to be examined. Its capacity should be tested on larger structural members for a longer period of time in non-ideal temperature ranges, high salty environments, and so on.

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