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Research paper

Study on Drying Shrinkage of Ternary Blended Concrete by Partial Replacement of Cement with China Clay and Fly Ash

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Abstract

The application of residue material from the industrial operation has been the focus on waste reduction research for economic, ecological and technical reasons. The most practical way is to diminish the ecological impacts of concrete without influencing its engineering properties and to reduce the amount of cement by partial replacement with industrial wastes in concrete. A partial substitution of cement by an industrial waste in concrete is to enhance the strength and durability properties. The present experimental investigation is majorly focus on drying shrinkage of ternary concrete made by partial substitution of cement with fly ash (10%) and china clay in various proportions i.e., 10%, 20%, 30%, 40%, 50%. It is observed that the compressive strength has increased and shrinkage strain is reduced at 30% china clay and 10% fly ash replacement of cement in concrete.

Keywords: *China clay (CC), Compressive strength, Drying shrinkage, Fly ash (FA), Shrinkage strains.*

1. Introduction

Generation of every one tonne OPC produces around one tonne CO_2 into nature, causing a worldwide temperature alteration. 50 % of CO_2 emission from cement industry occur during the calcination process of limestone. Cement industry produces about 5% of the total discharge of greenhouse gases in India. To diminish the ecological impacts of concrete without influencing its engineering properties is to diminish the amount of cement by partial replacement with industrial wastes in concrete. To meet the necessities of strength and durability properties of concrete we use the industrial byproducts like fly ash, silica fume, metakaolin etc. as SCM. Industrial wastes which are pozzolonic in nature can be used to substitute cement to reduce its cost without affecting its quality.

2. Literature Review

Li Jianyong et al [1] author conducted tests on the mechanical strength of HPC with silica fume and GGBS. From the outcomes, the strength of concrete with GGBS (40%) & SF (10%) has greater when compared to other concrete mixes. Drying shrinkage, creep decreased by use of GGBS and SF.
S. Vijaya Bhaskar Reddy et al [2] conducted tests on compressive strength of ternary concrete by using micro silica (0%, 5%, 10%, 15%) along with GGBS (20%, 30%, 40%, 50%). From the outcomes, it is observed that the ternary concrete with micro silica (10%) and GGBS (30%) has the highest compressive strength when compared to normal concrete.
S M Gupta et al [3] investigated on the shrinkage of HSC by utilizing fly ash and silica fume as an incomplete substitution for cement. From the test outcomes, it is reasoned that the shrinkage strains of HSC is less, when contrasted with ordinary concrete.
Banti A. Garden et al [4] studied with the effect of additional cementitious materials for durability of concrete. Therefore, a trial examination has been done under drying conditions to ponder the execution utilizing three various SCMs such as FA, SF and GGBS. From the outcomes, it is observed that the utilization of GGBS for halfway substitution of OPC concrete gives best performing outcomes for coefficient of permeability, shrinkage and creep.
S.Selva Sajitha et al [5] conducted tests on the mechanical properties of concrete by the incomplete substitution of a cement by china clay and the addition of polypropylene fibre. From the test results, it is concluded that the strength increases up to 20% of china clay replaced by cement with the 0.5% polypropylene fibre.
Nijad et al [6] the author tested the concrete prisms up to the age of 726 days for Fifty-two concrete mixes, and prisms were exposed to normal climate after 28-day of curing. The shrinkage of every crystal was measured by measuring frame that fit in with the British Standard Specifications. The least swelling and drying shrinkage recorded were those for concrete containing silica fume, trailed by concrete containing FA, and, the by concrete containing neither SF nor FA.

2. Experimental Methodology

2.1. Material used for Investigation

The properties of materials are mentioned below.

2.1.1. Cement

The OPC of 53 grade was used. The cement was tested for different properties according to IS 4031-1988. The specific gravity, fineness, initial and final setting time was recorded as 3.14, 7.9%, 60 min and 360 min. The chemical composition of cement consists CaO 63.6%, SiO_2 20.7%, Al_2O_3 6%, Fe_2O_3 2.4%, MnO 2.6%, MgO 2.4%, SO_3 1.4%.

2.1.2. Fine aggregate

The sand used for this investigation confirming to zone-II according to IS 383-1970 and the aggregate is passing through a 4.75 mm sieve. The fine aggregate used for this investigation, according to IS 2386-1963. The Specific gravity, fineness modulus and water absorption were recorded as 3.07, 2.76 and 1.98%.-

2.1.3. Coarse Aggregate

In this study, a crushed coarse aggregate of 20 mm size was used and confirming according to IS 383-1970. The aggregate has been tested for various properties according to IS 2386-1963 and IS 383-1970. The specific gravity, water absorption, flakiness index, elongation index, aggregate impact and crushing values was recorded as 2.76, 0.502%, 11.3%, 18.9%, 26.45 and 28.6%.

2.1.4. Fly Ash

Fly ash is the fine mineral residue from the burning of coal in electric generating plant. Fly ash test for specific gravity and fineness according to IS 3812-2003. The Specific gravity and fineness was recorded as 1.89 and 7%. The chemical composition of fly ash consists of Oxides of Silica, Aluminum, Ferric 70%, Silicon Dioxide 35%, Reactive Silica 20%, Magnesium Oxide 5%, Sulphur trioxide 3%, Sodium oxide 1.5%.

2.1.5. China Clay

Kaolin, otherwise called china mud, is a characteristic earthy formed by compound weathering of aluminum silicate minerals like felspars. It is generally unadulterated mud dominatingly comprising of kaolinite ($Al_2Si_2O_5(OH)_4$), related with other earth minerals. Generally it is used in ceramic industry. The Specific gravity and fineness was recorded as 2.6 and 6.3%. The chemical composition of china clay consists CaO 0.3%, SiO_2 43.5%, Al_2O_3 39%, Fe_2O_3 0.7%, MgO 0.3%, SO_3 1.4%.

3. Experimental Investigation

In this investigation cement was replaced with CC and FA in various proportions.

3.1. Mix proportion

A sum of 4 series of drying shrinkage prisms of 75x75x285 mm specimens were cast. A picture of prism mould is shown in figure 6.

Table 1: Mix quantity of M30 concrete according to IS 10262-2009

Grade designation	Cement (Kg/m^3)	Fine aggregates (Kg/m^3)	Coarse aggregates (Kg/m^3)	Water (Kg/m^3)	W/C
M 30	330	725	1242	148.5	0.45

Table 2: Mix details of TCCFA concrete

S.No	Series	CC replacement for OPC	FA replacement for OPC
1	TCCFA 0	0%	0%
2	TCCFA 10	10%	10%
3	TCCFA 20	20%	10%
4	TCCFA 30	30%	10%
5	TCCFA 40	40%	10%
6	TCCFA 50	50%	10%

3.2. Shrinkage Testing Procedure (IS1199:1959)

The concrete prisms were cast with respected concrete mixes and kept for 28 days of curing. After curing the prisms were kept in store room which is free from moisture and it was air dried for 90 days. Measure the length of the prism to with least count of 0.005mm by the length comparator apparatus, the specimens were placed on the length comparator to take the initial reading of the specimen. After the dry estimation has been taken, measure the length of the prism neighboring the balls to the closest 0.5 mm and record this as the 'dry length'. Repeat the process and measure the length of the prism until constant reading or near reading attain. The reading from the dial gauge were recorded for 90 days of drying time period. The change in length of each specimen is calculated from the difference between the final and initial readings. Then the shrinkage strains were calculated.

4. Results and Discussions

4.1. Compressive Strength

A total number of 36 cubes of sample sizes of 150mmx150mmx150mm for M30 grade ternary concrete are casted with partial replacement of cement with FA 10% and CC as 10%, 20%, 30%, 40%, 50% by weight of the cement. The compressive strength test is done at 7, 28 days respectively.

Table 3: Compressive Strength of TCCFA Concrete

S.No	Series	Compressive Strength (MPa)	
		7 days	28 days
1	TCCFA 0	28.6	38.2
2	TCCFA 10	29.4	39.7
3	TCCFA 20	31.9	40.8
4	TCCFA 30	32.6	42.8
5	TCCFA 40	26.1	36.2
6	TCCFA 50	25.8	34.9

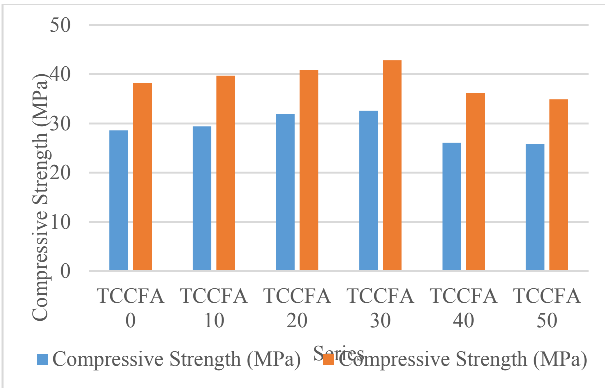

Fig. 1: Compressive Strength of TCCFA Concrete

4.2. Drying Shrinkage Results

The shrinkage strains of various TCCFA Concrete are presented in this section. After completing 28 days of curing, the drying shrinkage readings were recorded up to 90 days.

Table 4: Shrinkage Strains of TCCFA Ternary Concrete

S.No	Series	Shrinkage Strain ($\delta L/L \times 10^4$)			
		7 days	28 days	56 days	90 days
1	TCCFA0	5.3	14.3	17.4	18.67
2	TCCFA10	5.4	16	20.8	24.26
3	TCCFA20	5.5	16.8	21.9	23.53
4	TCCFA30	4.7	13.4	15.9	17.65

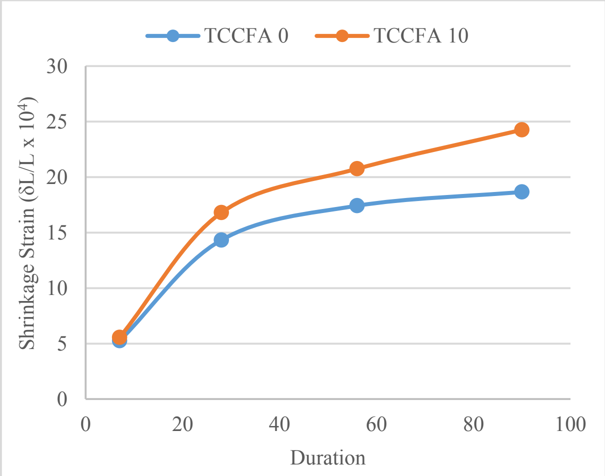

Fig. 2: Comparison of Shrinkage strain of Concrete for TCCFA 0 and TCCFA 10

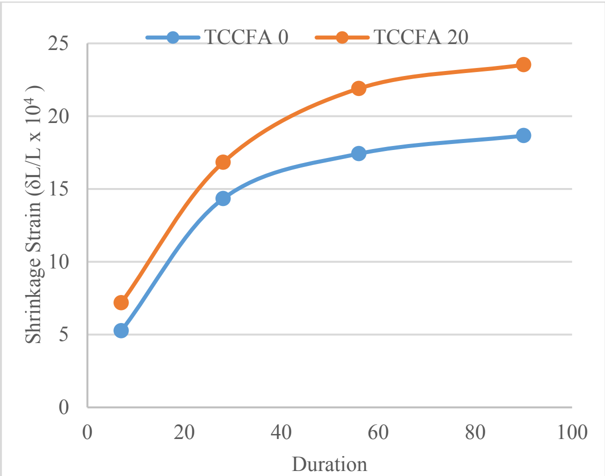

Fig. 3: Comparison of Shrinkage strain of Concrete for TCCFA 0 and TCCFA 20

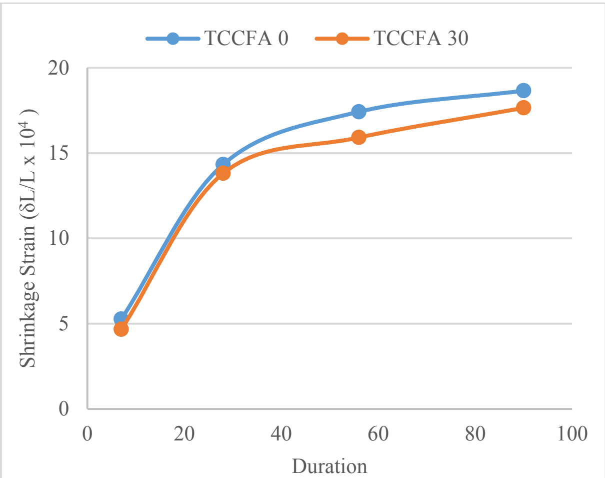

Fig. 4: Comparison of Shrinkage strain of Concrete for TCCFA 0 and TCCFA 30

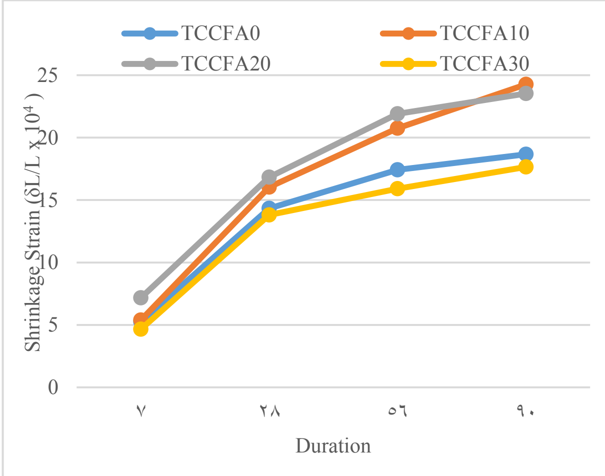

Fig. 5: Shrinkage strain of TCCFA Concrete for all mixes

Fig. 6: Prism mould of size 75 x 75 x 285 mm

Fig. 7: Length comparator with a standard calibrated rod

Fig. 8: Digital Length Comparator Apparatus with Specimen for testing

4.3 Discussions

- From the test results it is observed that at 7 days the compressive strength for TCCFA 10, TCCFA 20 and TCCFA 30 was increased by 2.8%, 11.5%, and 14% when compared to TCCFA 0. Whereas the TCCFA 40 and TCCFA 50 was decreased by 8.8% and 9.8% respectively.
- At 28 days curing the compressive strength for TCCFA 10, TCCFA 20 and TCCFA 30 was increased by 4%, 6.9%, and 12% when compared to TCCFA 0. Whereas the TCCFA 40 and TCCFA 50 was decreased by 5.2% and 8.7% respectively.
- Addition of china clay beyond 30% resulting in non-workable concrete associated with decrease in compressive strength.
- From Fig.2 it can be observed that TCCFA 10 concrete had greater shrinkage than TCCFA 0 at all the ages. Drying shrinkage of TCCFA 10 was observed to be higher when compared to TCCFA 0 by 2.39% at 7 days, at 28 days it was 11.89% higher, at 56 days it was 19.11% and at 90 days it was 29.2% higher than TCCFA 0.
- From Fig.3 it can be observed that TCCFA 20 concrete had extensively greater shrinkage than TCCFA 0 at all ages. Drying shrinkage of TCCFA 20 was observed to be higher when compared to TCCFA 0 by 36.5% at 7 days, at 28 days it was 17.58% higher, at 56 days it was 25.5% and at 90 days it was 26.3% higher than TCCFA 0.
- From Fig.4 it can be observed that TCCFA 30 concrete had lower shrinkage than TCCFA 0 at all ages. Drying shrinkage of TCCFA 30 was observed to be lower when compared to TCCFA 0 by 11.4% at 7 days, at 28 days it was 3.6% lower, at 56 days it was 8.6% and at 90 days it was 5.45% lower than TCCFA 0.

5. Conclusions

Based on the investigation results, the following conclusions are drawn:

1. The strength of concrete increases with increase in content of china clay upto a maximum percentage of 30%. Addition of china clay beyond 30% resulting in non-workable concrete associated with decrease in compressive strength.
2. The replacement of 30% china clay and 10% fly ash resulted in TCCFA30 mix with less shrinkage strain and without any loss of compressive strength.
3. The shrinkage strain is increasing with increase in content of china clay upto 20% and later decreasing to a minimum value at 30%. Beyond 30% replacement of china clay, the mix is becoming non workable and strength of the concrete is reducing significantly.
4. It is observed that shrinkage strain of ternary blended concrete at all replaced percentages increases with increase in age.

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