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Experimental Study on Durability Properties of Concrete with Nano Fly ash and Kadapa Stone Powder

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ABSTRACT

In the specification for concrete the grade of concrete quantity of cement to be used, aggregate quantities, consolidation are being mentioned now a days. [2,5]The depletion of natural materials for manufacture of cement and the drawbacks of OPC demand for a durable concrete. The day is not far away then the people demand for a concrete with specifications for mentioning the standards of Chloride permeability/resistance, Water permeability, Acid resistance, Alkaline, Sulphate resistance etc. To make concrete economical, there is a need to use the supplementary materials for imparting Strength and durability to cement/concrete. In order to reduce the environmental problems that are caused by the large scale production of OPC, there is a direct need to use supplementary cementing materials, which are locally available. [3,8,9]In the present study, Kadapa Stone Powder , which is rich in Calcium in used along with Nano Fly Ash to replace partially the cement in M_{30} grade concrete and an attempt is made to study the durability properties namely acid resistance, Chloride permeability and Water permeability. The OPC is replaced by Kadapa stone powder from 5 to 15% and Fly Ash from 20 to 40% seperately and the combination of these two materials.

Keywords: Durability, Fly ash, Kadapa Stone Powder, Chloride permeability, Acid resistance, Water permeability

I. INTRODUCTION

Concrete is the most important construction material for civil engineering. [1,6,7]Concrete is one of the most durable material. Concrete's versatility, durability, sustainability, and economy have made it the world's most widely used construction material. The production of one ton of cement consumes about 1.5 tons of raw materials, 80 units of electric power apart from one tone of CO_2 released into the atmosphere. Out of the total CO_2 emissions (from various sources) worldwide, cement industry contributes about 7%of CO_2 emissions. Annual cement production rate of the world is increasing very much year by year. Pozzolans decrease capillary porosity, reduce micro cracking and density the interfacial transition zone in concrete. There are both technical advantages and social benefits in using Kadapa stone powder and fly ash in concrete. Because Kadapa Stone Powder contains large amount of calcium and fly ash contains large amount of silica content and it is a pozzolonic material which behaves like cement in the presence of lime and water[3,5,8]. In order to make the concrete more environmental friendly and greener there is a dire need to use Kadapa Stone Powder and Nano FA in concrete. After the selection of supplementary cementing materials for making of concrete, the other ingredients such as collected, aggregates were collected from the nearby quarries, 53 Grade Portland cement was used in all concrete mixtures. The Durability properties of the concrete were examined by the replacement of OPC with Nano FA and kadapa Stone Powder separately and combination of these two materials.

II. METHODS AND MATERIAL

2.1. Cement

Cement is the most important material in concrete and it acts as a binding material. Ordinary Portland cement 53

grade manufactured by Ultratech Cement Company confirming to IS 12269-1987 is used in this investigation. The physical properties of cement are presented in table 1.

TABLE 1. PHYSICAL PROPERTIES OF CEMENT

S.NO	PARTICULARS	RESULTS
1	Specific Gravity	3.15
2	Initial setting time	40 min
3	Final setting time	620min
4	Fineness	225 m^2/kg

2.2. Aggregate

After cement aggregate is the basic material used in any concrete to constitute the body of concrete to reduce the cementitious material quantity, and to reduce the consequent volume change of concrete.

2.2.1. Fine Aggregate:

The amount of the fine aggregate usage is important to fill the voids present in coarse aggregate. In this investigation natural sand was used as fine aggregate. The specific gravity of sand is found to be 2.6.The physical properties of fine aggregate are shown in table no 2. Sand was obtained from Bahuda River near Nandaluru in YSR Kadapa district.

TABLE 2. PHYSICAL PROPERTIES OF FINE AGGREGATE

S.NO	PARTICULARS	RESULTS
1	Type	Normal sand
2	Specific gravity	2.6
3	Grading size	4.75mm – 0.075mm
4	Water absorption	1%
5	Fineness modulus	2.88
6	Bulk density in Loose state Compacted state	 1378.82 kg/m^3 1544.67 kg/m^3

2.2.2. Coarse Aggregate

In the present investigation crushed granite aggregate of 20mm size was used. The specific gravity of coarse aggregate is 2.6. The physical properties of coarse aggregate are shown in table no 3. Fineness modulus is obtained by using sieve analysis.

TABLE 3. PHYSICAL PROPERTIES OF COARSE AGGREGATE

S.NO	PARTICULARS	RESULTS
1	Type	Crushed stone
2	Specific gravity	2.6
3	Maximum size	20mm
4	Water absorption	0.5%
5	Fineness modulus	4.30
6	Bulk density	1688 kg/m^3

2.3. Water

Water is used for mixing and curing of concrete. In the present investigation, tap water available in the campus was used for both mixing and curing of concrete.

2.4. Kadapa Stone Powder

In Kadapa district, there are number of stone polishing industries and huge quantities of fine powder from the grinding of rough Kadapa stones during the process of polishing the stones to convert them into polishing stone suitable for laying of flooring and other such works, is generated. This powder is finer than cement. The stone powder generated during the process of cutting and polishing is used as the partial replacement of cement.

TABLE 4. PHYSICAL PROPERTIES OF KADAPA STONE POWDER

S.NO	PROPERTY	VALUES
1	Silica (Sio_2)	22.35%
2	Calcium Oxide (CaO)	38.91%
3	Magnesium Oxide (MgO)	2.75%
4	Ferric Oxide (Fe_2O_3)	1.30%
5	Alumina (Al_2O_3)	2.80%
6	Loss of Ignition (LOI)	30.52%

2.5. Nano Fly Ash

The other supplementary cementing material used in this investigation is Nano FA. Fly ash used in this study contains more silica content and less calcium.[6] Nano Fly ash procured from Chennai. The particle size of Nano Fly ash is calculated by using X-Ray Diffraction (XRD) analysis. X-Ray Diffraction(XRD) analysis

gives not only grain size but also the crystalline structure, lattice parameters, Strain and Phase composition. The details of chemical compounds present in the fly ash are furnished in table 5

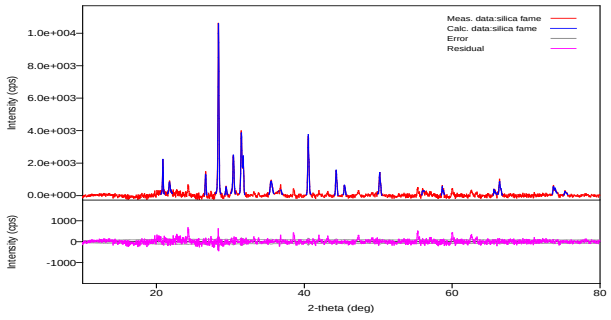

Figure 1. XRD results for Nano Flyash

TABLE 5. PHYSICAL PROPERTIES OF NANO FLYASH

Major element	% by weight in the nano fly ash	Requirement as per IS:3812-2003
SiO_2	58.80%	>35%
Al_2O_3	24.10%	-
Fe_2O_3	5.18%	-
TiO_2	6.14%	-
CaO	1.00%	-
MgO	0.38%	<5.0%
Na_2O	0.66%	<1.50%
K_2O	0.62%	<1.50%
P_2O_5	0.60%	-
SO_3	0.25%	<2.75%
Loss on ignition	6.25%	<12.00%

2.6. Mix Proportions

In the present investigation M_{30} grade concrete is used with a constant W/C ratio of 0.5. Concrete mixes were prepared by varying the percentage of replacement of cement with Kadapa Stone Powder (5%, 10%, and 15%) and Nano FA (20%, 30% and 40%) and their combinations (i.e., 5% of KSP with % of Nano FA replacement in cement, 10% of KSP with % of Nano FA replacement in cement and 15% of KSP with % of Nano FA replacement in cement).

TABLE 6. MIX PROPORTIONS

Mix Proportion	Proportions of Supplementary materials
A0	100% Cement
A1	5% KSP and 95% Cement
A2	10% KSP and 90% Cement
A3	15% KSP and 85% Cement
A4	20% Nano Fly Ash and 80% Cement
A5	30% Nano Fly Ash and 70% Cement
A6	40% Nano Fly Ash and 60% Cement
A7	20% Nano Fly Ash, 5% KSP and 75% Cement
A8	30% Nano Fly Ash, 5% KSP and 65% Cement
A9	40% Nano Fly Ash, 5% KSP and 55% Cement
A10	20% Nano Fly Ash, 10% KSP and 70% Cement
A11	30% Nano Fly Ash, 10% KSP and 60% Cement
A12	40% Nano Fly Ash, 10% KSP and 50% Cement
A13	20% Nano Fly Ash, 15% KSP and 65% Cement
A14	30% Nano Fly Ash, 15% KSP and 55% Cement
A15	40% Nano Fly Ash, 15% KSP and 45% Cement

2.7. Mixing of Concrete

The ingredients of concrete in the required quantities were charged into the 3cft capacity laboratory concrete mixer. After through mixing i.e., having achieved uniform color, workable consistency to concrete, the concrete was delivered into the pan for casting the specimens.

2.8. Casting of Specimens

For casting specimens, the concrete has been placed in the standard metallic moulds in three layers and compacted with tamping rod by giving 25 blows. Before placing the concrete in the moulds a thin coat of oil was applied for the walls of the mould inside for easy removal. Then moulds were placed on table vibrator for 30 seconds after thorough compaction the top surfaces

of specimens were finished smoothly. Cubes of size 150× 150× 150 mm , RCPT moulds of size 100mm diameter and 50mm thickness and Water permeability moulds of size 200mm diameter and 125mm height are used.

2.9. Curing of Specimens

The concrete specimens were air dried for 24 hours and then the specimens were remolded and then kept in curing tank. Marking was done on the specimens to identify the percentage of Kadapa Stone Powder and Nano FA combinations. After curing 28 days some specimens were placed in Acid solutions. All the specimens have been cured for desired age and then tested for Compressive Strength.

2.10. Testing of Specimen

2.10.1 Acid attack test

The concrete specimen cured for 28 days and immersed in 5% of sulphuric acid (H_2SO_4) solution for 28 days and 60 days were tested for compressive strength.The pH value was periodically checked and maintained at pH 1.The test results are compared with the strength of standard concrete of M_{30} grade at 60 days and 90 days. The test for the measurement of acid attack was carried out as per IS:516-1959 on concrete cubes size 150mm × 150mm × 150mm.

2.10.2 Chloride Permeability Test

The Rapid Chloride Permeability test for different concrete mixtures was carried out as per ASTM C-1202-97. Standard cylindrical disc specimen of size 100mm diameter and 50mm thickness after 28 and 60 days water curing were used in this test. RCPT was done for every 30 minutes upto 6 hours.

2.10.3 Water Permeability Test

The Water permeability test determining the depth of penetration of water is applied at 5 bar pressure in hardened concrete. This concrete has been water cured. water is applied at 5bar pressure to the surface of hardened concrete. The specimen is then split and the depth of penetration of the water front is measured. Standard cylindrical disc specimen of size 125 mm height × 200 mm diameters after 60 days water curing were used in this test. Water permeability test should be done for 48 hours at 6V.

III. RESULTS AND DISCUSSION

3.1. Compressive Strength

TABLE 7. COMPRESSIVE STRENGTH

Mix Proportions	Compressive strength N/mm^2		
	28 days	60 days	90 days
A0	37.1	38.4	40.8
A1	33.93	36.6	37.2
A2	34.96	35.5	36.4
A3	31.13	32.2	33.5
A4	32.6	33.9	35.1
A5	34.7	36.5	37.9
A6	28.85	30.2	32.5
A7	30.29	32.7	34.2
A8	26.46	28.4	30.6
A9	26.06	27.6	29.1
A10	27.53	28.1	28.9
A11	31.13	33.3	35.4
A12	29.46	30.9	32.1
A13	27.96	30.2	33.4
A14	29.1	31.4	32.5
A15	25.6	27.9	29.6

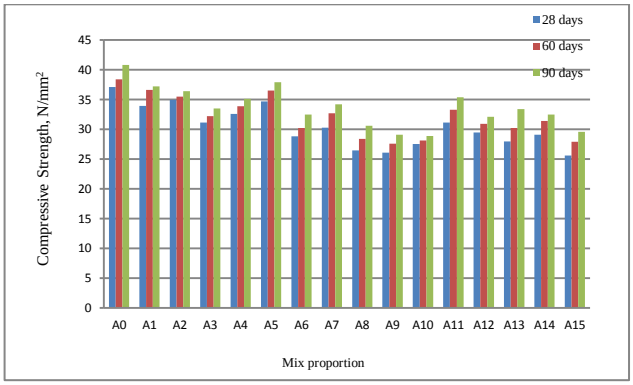

Figure 2. Compressive Strength

3.2. ACID Attack Test

The concrete specimen cured for 28 days and immersed in Acid water for 28 days and 60 days were tested for compressive strength. The test results are compared with the strength of standard concrete of M_{30} grade at 60 days and 90 days. The reduction in percentage of compressive strength was tabulated in table no.9

From the test results, it is observed that the standard concrete which has 38.4 and 40.8 N/mm^2 compressive strength at 60 days and 90 days yielded 34.2 and 31.5 N/mm^2 strength after 30 and 60 days of immersion in

Acid water. The percentage reduction in compressive strength is 10.9 and 22.8 at 60 and 90 days respectively.

The compressive strength of 5% Kadapa Stone Powder and 95% cement (i.e., A_1) concrete at 60 days and 90 days are 36.6 and 37.2 N/mm^2 respectively. After immersion in Acid water for 30 and 60 days, the compressive strength obtained for the above samples are 33.3 and 32.0 N/mm^2.The reduction in compressive strengths after 30 and 60 days are 9% and 13.9%.

It is observed that the concrete with 10% Kadapa stone powder, 20% Nano Flyash, combination of 30% Nano Flyash and 10% Kadapa Stone Powder (i.e., A_{11}) have shown highest resistance to Acid attack.

TABLE 8. ACID TEST

Mix Proportions	Compressive strength N/mm^2			
	28 days	60 days	28 days	60 days
A0	34.2	31.5	10.9	22.8
A1	33.3	32.0	9.0	13.9
A2	31.8	30.4	10.4	16.4
A3	30.6	28.8	4.9	14.0
A4	31.3	29.5	7.6	15.9
A5	29.8	26.6	18.3	29.8
A6	29.5	25.4	2.3	21.8
A7	30.2	28.2	7.6	17.5
A8	26.6	24.3	6.3	20.5
A9	25.4	22.5	7.9	22.6
A10	26.2	24.8	6.7	14.1
A11	31.2	29.9	6.3	15.5
A12	29.8	26.6	13.2	17.1
A13	26.2	22.5	13.2	32.6
A14	28.5	26.5	9.2	18.4
A15	24.4	21.3	12.5	28.0

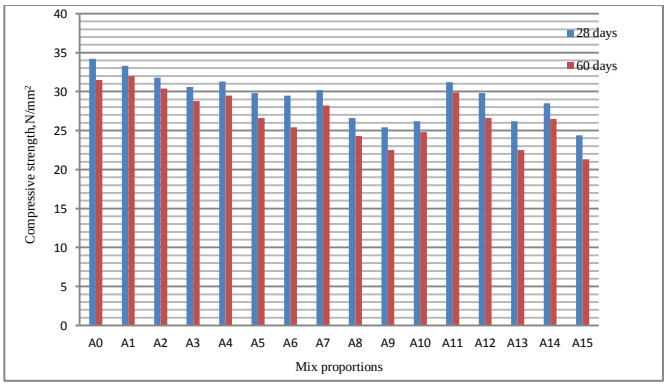

Figure 3. Acid Test

3.3. Rapid Chloride Permeability Test

The total charged passed through the M_{30} conventional concrete at 28 and 60 days is 2205.5coulombs (Moderate) and 1753.6 coulombs (Low) respectively. Concrete with 15% Kadapa Stone Powder and 85% Cement(i.e.,A_3), 40% Nano Flyash and 60% Cement (i.e.,A_6) ,40% Nano Flyash and 15% Kadapa Stone Powder (i.e.,A_{15}) have shown highest resistance to Chloride permeability. The total charge passed through the above specimen are 1128 coulombs (Low), 337 coulombs (Very low), 489 coulombs (Very low), at 28 days and 1070.9 coulombs (Low), 303.1 coulombs (Very low), 335.8 coulombs (Very low) at 60 days respectively.

TABLE 9. RAPID CHLORIDE PERMEABILITY TEST

Mix Proportion	Chloride permeability in coulombs	
	28 days	60 days
A0	2205.5	1753.6
A1	1523.5	1325.2
A2	1335.5	1320.5
A3	1128.8	1070.9
A4	642.4	594.4
A5	451.8	392
A6	337.2	303.1
A7	1088.9	966.6
A8	859.4	802.4
A9	654.5	578.9
A10	925.5	886.4
A11	785.2	707.4
A12	620.9	605.2
A13	882.4	792.8
A14	651.2	632.4
A15	489.3	335.8

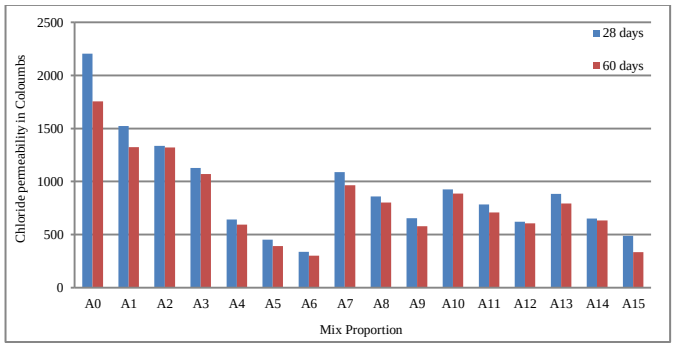

Figure 4. Rapid chloride permeability test

3.4. Water Permeability Test

The depth of penetration of water in M_{30} grade standard concrete at 60 days is 5.6cm and Coefficient of permeability is
1.46×10^{-12} m/sec.

The concrete with 15% Kadapa Stone Powder and 85% cement (i.e., A_3) has shown in least penetration among the samples in which OPC is replaced by Kadapa Stone Powder.

M_{30} concrete with 20% Nano Flyash and 80% cement (i.e., A_4) has shown least water penetration among the concrete in which cement is replaced by Nano Flyash.
M_{30} concrete with combination of 30% Flyash and 10% Kadapa Stone Powder (i.e., A_{11}) has shown highest resistance to water penetration.

TABLE 10. WATER PERMEABILITY TEST

Mix Proportion	Weight gain (M in gm)	Depth of penetration (d in cm)	Coefficient of permeability (K in m/sec)
A0	45	5.6	1.46×10^{-12}
A1	50	5.8	2.577×10^{-12}
A2	55	6.2	2.40×10^{-12}
A3	50	5.4	2.67×10^{-12}
A4	45	5.1	2.06×10^{-12}
A5	60	8.7	2.577×10^{-12}
A6	55	6.5	3.224×10^{-12}
A7	50	6.1	4.8×10^{-12}
A8	45	5.4	2.15×10^{-12}
A9	50	5.5	2.5×10^{-12}
A10	50	6.0	2.71×10^{-12}
A11	55	5.2	3.15×10^{-12}
A12	65	7.0	4.1×10^{-12}
A13	60	6.7	3.63×10^{-12}
A14	55	6.3	3.12×10^{-12}
A15	55	7.5	3.72×10^{-12}

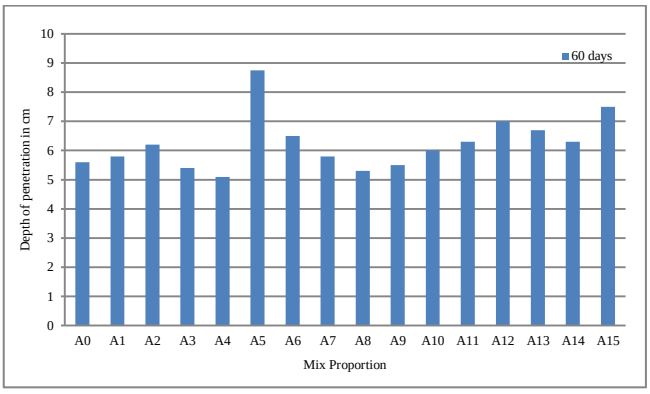

Figure 5. Water permeability Test

IV.CONCLUSION

1) The Durability properties of M_{30} concrete with replacement of OPC by Nano Fly Ash and Kadapa Stone Powder separately and the combination of Nano Fly Ash and Kadapa Stone Powder can be improved.
2) The Acid resistance of M_{30} conventional concrete reduces 10.9 and 22.8% strength at 28 and 60 days of immersion in Acid water and replacement of OPC by 15% Kadapa stone powder and 85% cement (i.e.,A_3), reduces 4.9% and 14% strength at 28 and 60 days, replacing of OPC by 20% Nano Fly ash 80% cement (i.e.,A_7), reduces 7.6 and 15.9% strength at 28 and 60 days and replacing of OPC by combination of 30% Nano Fly ash and 10% Kadapa Stone Powder(i.e., A_{11}), reduces 6.3 and 15.5% at 28 and 60 days. Hence, Fly ash and Kadapa Stone Powder can be used to improve the acid resistance of conventional concrete.
3) The Chloride permeability of M_{30} concrete having 15% Kadapa Stone Powder and 85% cement (i.e.,A_3), 40% Nano Fly ash and 60%cement(i.e.,A_6),combination of 40% Nano Flyash and 15% Kadapa Stone Powder (i.e.,A_{15}) have shown highest resistance to Chloride permeability. The total charge passed through the above specimen are 1128 coulombs (Low), 337 coulombs (Very low), 489 coulombs (Very low), at 28 days and 1070.9 coulombs (Low), 303.1 coulombs (Very low), 335.8 coulombs (Very low) at 60 days respectively.
4) The Water permeability of M_{30} concrete having 15% Kadapa Stone Powder and 85% cement (i.e., A_3) has shown least penetration among the samples in which OPC is replaced by Kadapa Stone Powder. And replacing OPC by 20% Nano Fly ash(i.e., A_4) has shown least water penetration among the

concrete in which cement is replaced by Nano Flyash. And replacing OPC by Combination of 30% Nano Flyash and 10% Kadapa Stone Powder (i.e., A_{11}) has shown highest resistance to water penetration.

5) The use of Nano Fly Ash and Kadapa Stone Powder makes conventional concrete not only durable but also economical.

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