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PARTIAL REPLACEMENT OF CEMENT WITH FLY ASH TO IMPROVE CONCRETE PROPERTIES

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Abstract:
A comprehensive investigation into the impact of fly ash replacement on the strength and workability of concrete is presented in this research article. The study included the development of concrete mixes with varying amounts of cementitious content (300 to 500 kg/m3) and fly ash replacement levels (ranging from 0 percent to 50 percent). To maintain a consistent slump value of 200 mm 25 mm, the concrete mixes were proportioned using the absolute volume approach and contained a high-range superplasticizer. The study's findings contribute to a better understanding of the behaviour of fly ash mixed concrete, allowing engineers and researchers to make more informed decisions regarding its practical applications. The findings show that fly ash substitution has the potential to improve the performance and sustainability of concrete, while also revealing any limitations or issues related with its use. This research is a great resource for the concrete industry.

Introduction:

Concrete is one of the most extensively used building materials due to its versatility, durability, and low cost. However, the manufacturing of concrete involves massive energy consumption and greenhouse gas emissions, owing mostly to the production of cement, a critical component of concrete. As concerns about sustainability and environmental impact grow, there is a growing interest in researching alternative materials and technologies that might reduce reliance on cement without compromising concrete performance.

One such alternative material is fly ash, a byproduct of coal-fired power plants. Because of its pozzolanic properties, fly ash might be utilised to partially substitute cement in concrete. Numerous studies have demonstrated that incorporating fly ash into concrete has technical and environmental benefits such as enhanced workability, reduced heat of hydration, increased durability, and a lower carbon footprint. The effect of fly ash replacement on the strength and workability of concrete, on the other hand, is currently being investigated.

The goal of this study is to add to existing knowledge by evaluating the effect of fly ash replacement on the strength and workability of concrete. The study comprises a variety of

cementitious contents and fly ash replacement levels to examine the performance of fly ash blended concrete. The absolute volume technique is utilised for concrete mix design, which assures consistency and precision in the proportioning process. To maintain a constant slump value, a high-range superplasticizer is added to concrete mixes.
By thoroughly investigating the impact of fly ash replacement on the strength and workability of concrete, this study aims to fill gaps in the current literature and provide practical suggestions for the use of fly ash as a sustainable alternative to cement in concrete production. The study's findings may enlighten concrete industry professionals, engineers, and researchers, enabling for the development of more ecologically friendly and resilient concrete mixtures.
Ultimately, by reducing cement consumption through the incorporation of fly ash, this research contributes to the broader goal of sustainable construction practices and mitigating the environmental impact of concrete production.

Material Used:
1. Fly ash
2. Aggregate
3. Cement
4. Water
5. Admixture

Instruments:
1. Digital Compression Testing Machine
2. Tamping Rod
3. Cube molds
4. Waving Balance
5. Trial mixtures

Procedure:
The procedure involves preparing and testing concrete cubes for strength analysis.
1. Prepare the concrete mix according to the suggested proportions in the trial mix using a mechanical mixer.
2. Fill and compact the mixture in metal molds, ensuring three layers with proper compaction.
3. Mark and cure the specimens in a curing room for 24 hours.
4. After 24 hours, remove the molds and immerse the cubes in water for 7 days.
5. Clean the testing machine surfaces and center the cube on the lower platen.
6. Apply a controlled load until failure, recording the maximum load for each cube.
7. If not cured in water, immerse the cubes in water for a few minutes before testing.

Note: Testing should be done while the cubes are still wet.

Literature Review:

The available published literature on fly ash concrete technology are briefly reviewed.

1. Concrete and the environment

- Carbon dioxide (CO2) emissions trading is a critical factor for industries, including the cement industry, because the greenhouse effect created by the emissions is believed to cause an increase in global temperatures that can lead to climate change.
- Cement production is increasing by 3% per year (McCaffrey 2002). In the production of one ton of cement, about one ton of CO2 is released into the atmosphere due to the decarbonisation of limestone in the kiln during cement production and the burning of fossil fuels.

2. Mehta (2002) proposed using less natural resources, less energy, and reducing carbon dioxide emissions in order to manufacture ecologically friendly concrete. He labelled these short-term initiatives "industrial ecology." Reduced material usage can help to achieve the long-term objective of decreasing the effect of undesirable by-products of industry. Similarly, McCaffrey (2002) recommended three approaches to minimise CO2 emissions in the cement industry: lower the quantity of calcined material in cement, reduce the amount of cement in concrete, and reduce the number of structures that use cement.

3. Ashes

- Fly ash is described as "the finely split residue that comes from the burning of ground or pulverised coal and that is conveyed by flue gas from the combustion zone to the particle treatment system" by American Concrete Institute (ACI) Committee 116R. (ACI Committee 232 2004). A dust collecting system, either manually or by electrostatic precipitators, removes fly ash from flue gas before it is discharged into the atmosphere. Fly ash particles are generally spherical, finer than Portland cement and lime, and range in diameter from less than 1 m to no more than 150 m.

Result:

1. Trial mix Proportions

Table for trial mix Proportion

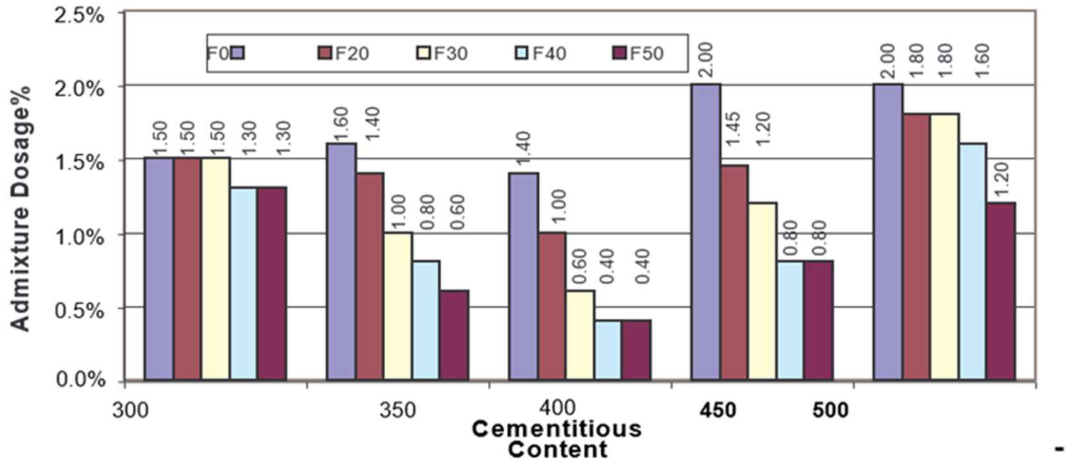
Mix Designation	Total Cementitious content (m^3)	Cement	Fly Ash	Water	W/Cm	Coarse Aggregates	Fine Aggregates	Admixture
	(Kg/m^3)	(Kg)	(Kg)	(Kg)		(Kg)	(Kg)	(Kg)
300 F0	300	300	0	150	0.50	1090	925	4.50
300 F20	300	240	60	150	0.50	1076	914	4.50
300 F30	300	210	90	150	0.50	1070	908	4.50
300 F40	300	180	120	150	0.50	1063	902	4.50
300 F50	300	150	150	150	0.50	1056	896	4.50
350 F0	350	350	0	158	0.45	1054	896	5.60
350 F20	350	280	70	158	0.45	1038	881	4.90
350 F30	350	245	105	158	0.45	1030	876	3.50
350 F40	350	210	140	158	0.45	1024	868	2.80
350 F50	350	175	175	158	0.45	1016	861	2.10
400 F0	400	400	0	160	0.40	1064	833	5.60
400 F20	400	320	80	160	0.40	1048	819	4.00
400 F30	400	280	120	160	0.40	1038	813	2.40
400 F40	400	240	160	160	0.40	1030	806	1.60

400 F50	400	200	200	160	0.40	1022	800	1.60
450 F0	450	450	0	158	0.35	1078	778	9.00
450 F20	450	360	90	158	0.35	1060	764	6.52
450 F30	450	315	135	158	0.35	1050	757	5.40
450 F40	450	270	180	158	0.35	1040	750	3.60
450 F50	450	225	225	158	0.35	1030	743	3.60
500 F0	500	500	0	150	0.30	1102	732	10.00
500 F20	500	400	100	150	0.30	1080	717	9.00
500 F30	500	350	150	150	0.30	1068	709	9.00
500 F40	500	300	200	150	0.30	1056	702	8.00
500 F50	500	250	250	150	0.30	1046	694	6.00

Fresh and Hardened properties of Concrete

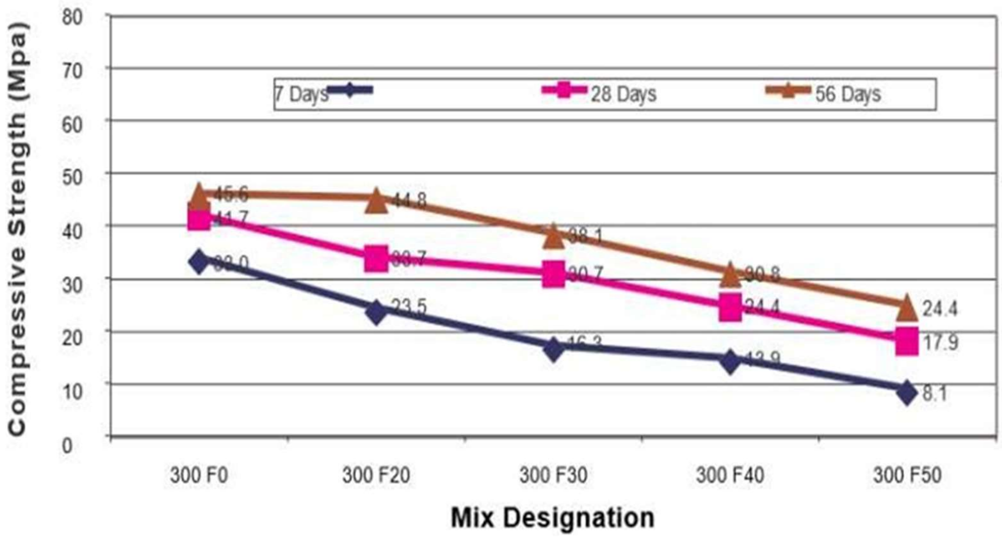
Mix Designation	Slump		Density	Air content	Setting Time		Compressive Strength			
	0 Min	30 Min			Initial	Final	7 Days	28 Days	56 Days	90 Days
	(mm)	(mm)	(Kg/m^3)	(%)	(Hr:Mins)	(Hr:Mins)	(N/mm^2)	(N/mm^2)	(N/mm^2)	(N/mm^2)
300 F 0	185	150	2468	1.3			33.0	41.7	45.6	
300 F 20	185	160	2450	1.5			23.5	33.7	44.8	
300 F 30	210	175	2442	1.2			16.3	30.7	38.1	
300 F 40	180	110	2430	1.6			13.9	24.4	30.8	
300 F 50	200	140	2422	1.3			8.1	17.9	24.4	
350 F0	210	190	2499	1.3	6:50	8:10	34.2	43.7	48.8	54.2
350 F20	230	220	2484	1.2	6:20	8:05	24.9	37.7	45.4	50.9
350 F30	220	200	2478	1.2	5:55	7:30	23.1	32.9	39.7	45.5
350 F40	220	180	2427	1.2	6:40	7:45	14.5	26.5	32.7	41.9
350 F50	210	160	2426	1.5	7:20	8:55	10.4	19.0	25.6	34.4
400 F0	210	190	2472	1.2			41.9	46.5	52.6	54.2
400 F 20	210	190	2480	1.6			29.5	41.2	47.8	52.9
400 F30	200	180	2465	1.5			25.6	37.9	44.3	50.4
400 F40	200	120	2466	1.7			19.4	32.9	35.8	43.5
400 F50	190	110	2445	1.6			15.5	23.2	30.2	36.8
450 F0	220	210	2486	1.3	8:20	9:05	45.9	55.2	60.3	61.2
450 F 20	220	210	2488	1.6	8:35	9:45	37.6	51.1	55.2	59.9
450 F30	220	200	2480	1.3	7:45	9:15	31.1	45.3	54.3	58.6
450 F40	180	170	2476	1.5	7:35	8:50	25.6	42.2	51.4	59.9
450 F50	210	200	2444	1.6	8:45	10:10	17.8	28.2	42.7	46.2
500 F0	200	180	2538	1.5			42.0	60.0	62.7	66.7
500 F20	180	150	2478	1.8			37.7	54.5	63.9	69.2
500 F30	200	170	2448	1.9			37.9	52.7	64.4	70.3
500 F40	230	220	2413	1.7			29.7	47.4	61.9	67.8
500 F50	220	200	2442	1.5			29.0	45.6	55.8	58.9

Charts & Graphs based on Admixture dosage & compressive strength results

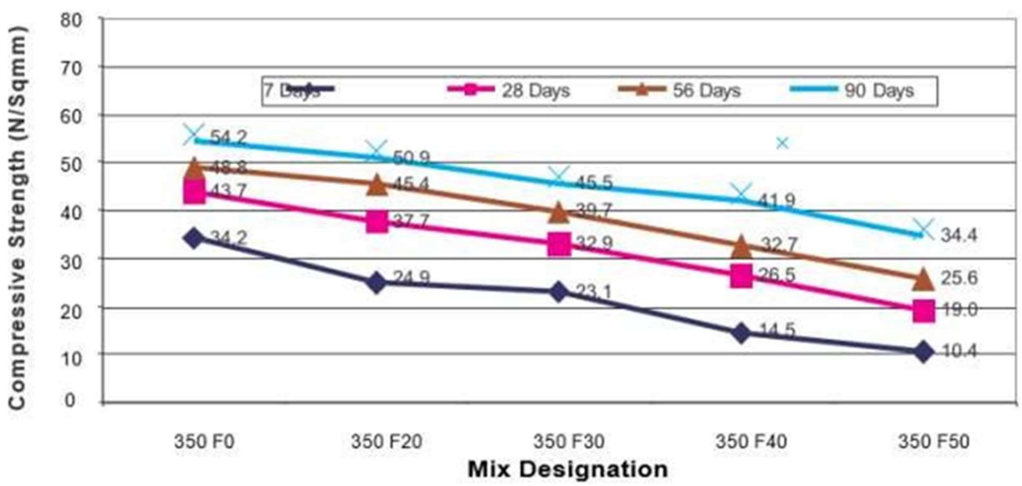


Raw material cost of mix per m^3 of concrete

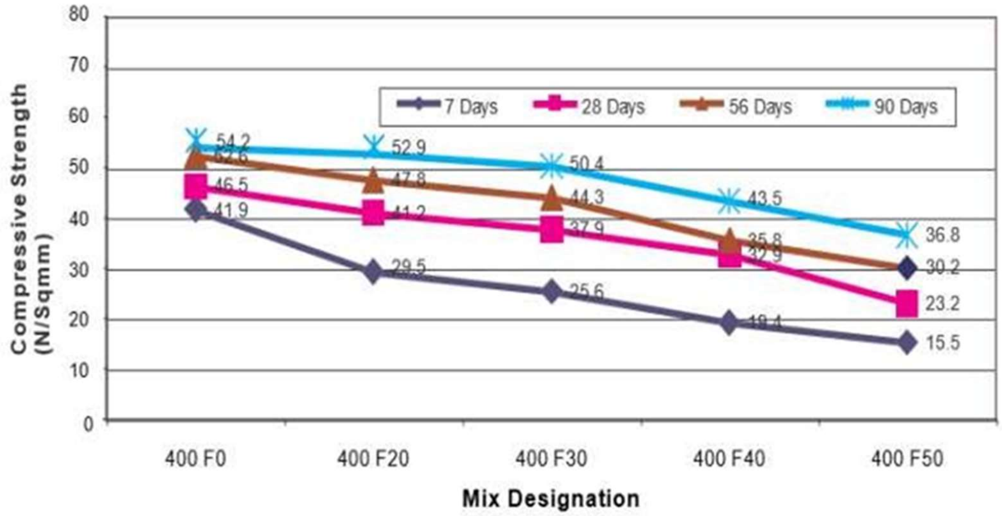
S.No	Mix Designation	Raw material Cost (Indian national rupees)
1	300 F 0	3886.70
2	300 F 20	3706.90
3	300 F 30	3573.10
4	300 F 40	3438.20
5	300 F 50	3303.30
6	350 F0	4191.80
7	350 F 20	3850.30
8	350 F30	3643.70
9	350 F40	3461.60
10	350 F50	3278.50
11	400 F0	4377.20
12	400 F 20	3963.60
13	400 F30	3726.20
14	400 F40	3519.40
15	400 F50	3343.40
16	450 F0	4702.40
17	450 F 20	4214.04
18	450 F30	3973.20
19	450 F40	3707.20
20	450 F50	3507.80
21	500 F0	4960.60
22	500 F 20	4481.40
23	500 F30	4258.60
24	500 F40	4000.00
25	500 F50	3705.40



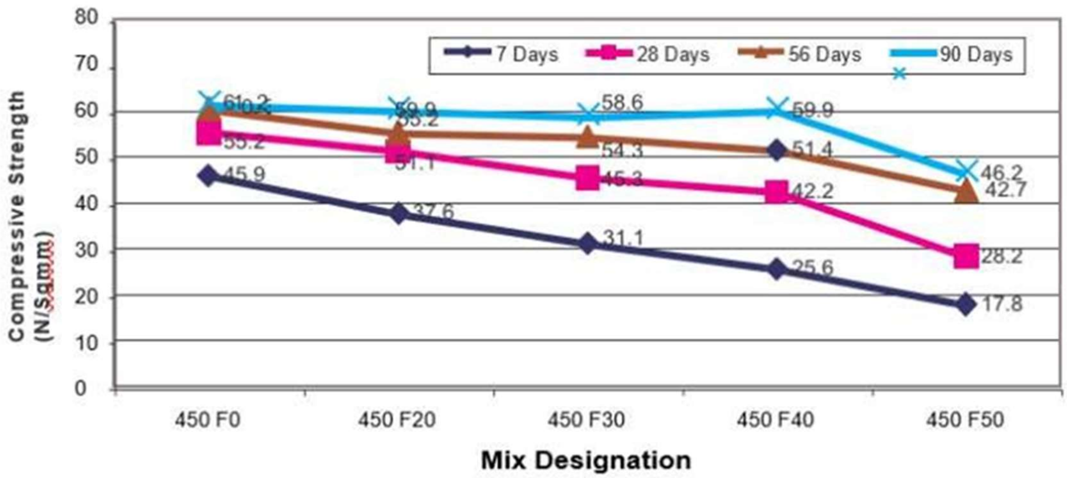
Development of Compressive Strength of 300 Mix



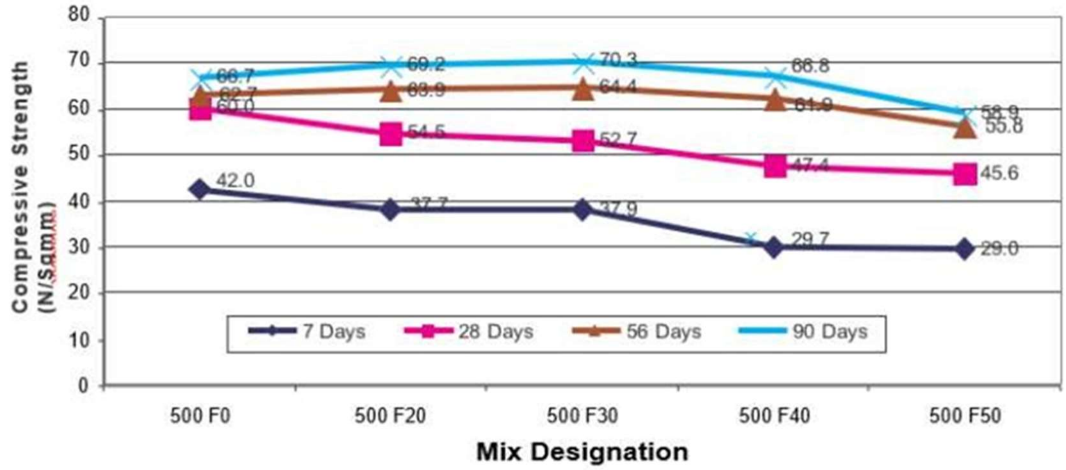
Development of Compressive Strength of 350 Mix



Development of Compressive Strength of 400 Mix

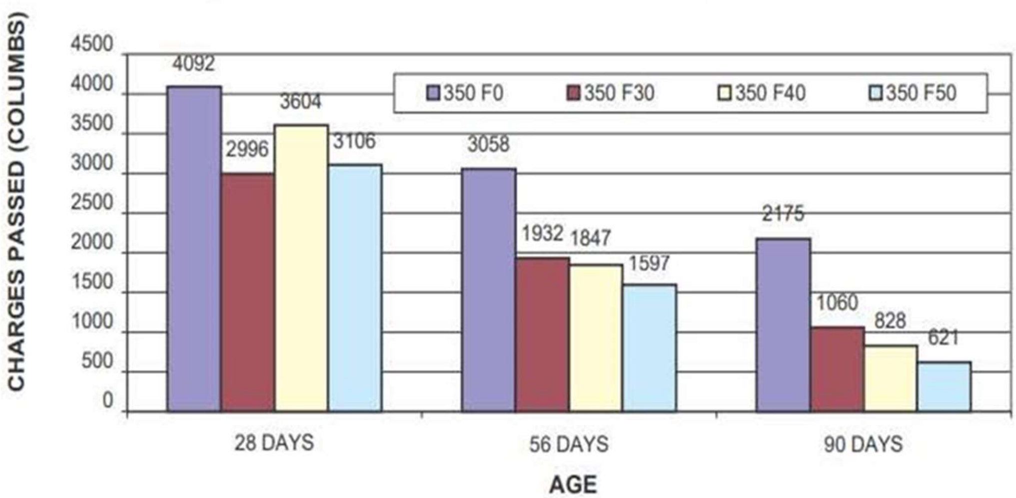


Development of Compressive Strength of 450 Mix



Development of Compressive Strength of 500 Mix

Charts & Graphs based on RCPT test results (Rapid Chloride Permeability Test)



RCPT Results of 350 Mix

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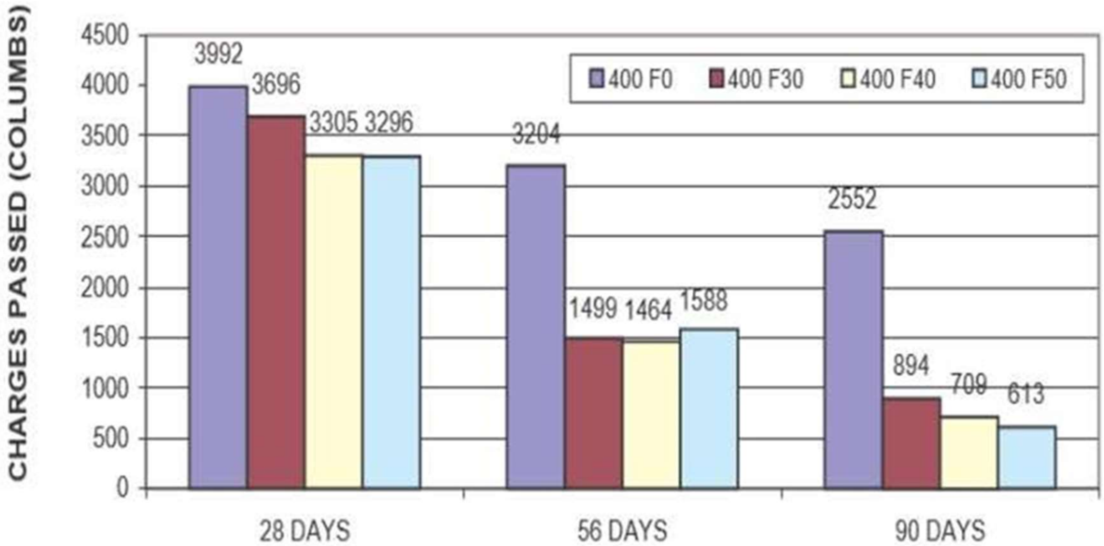
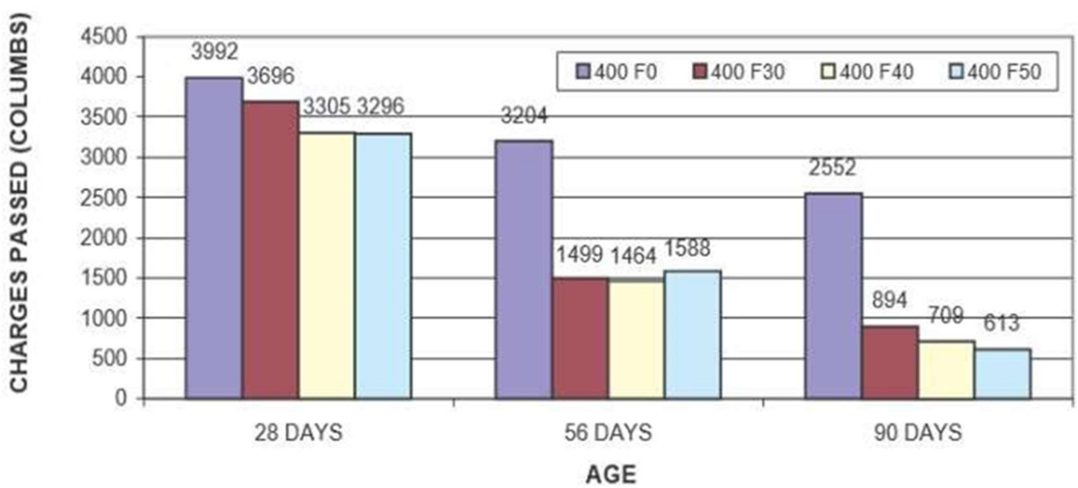


RCPT Results of 400 Mix



RCPT Results of 450 Mix

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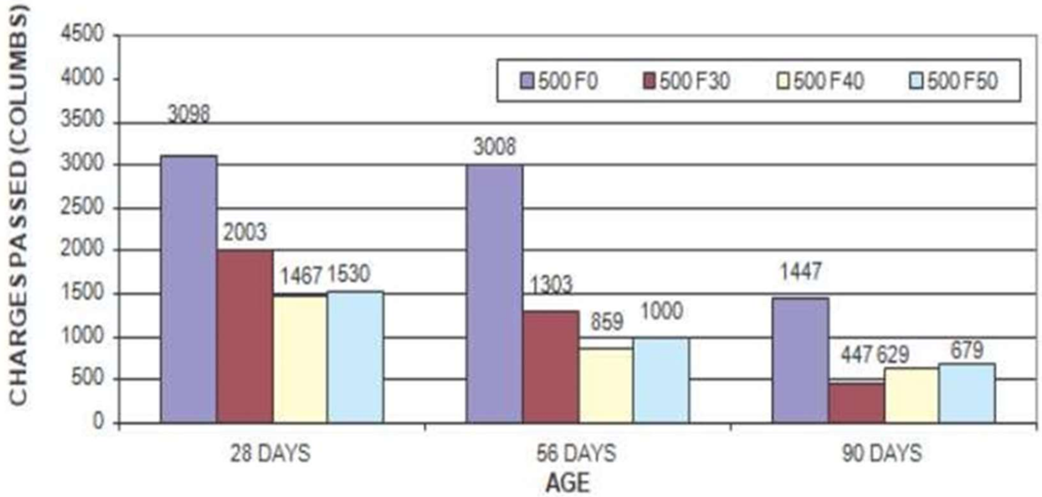
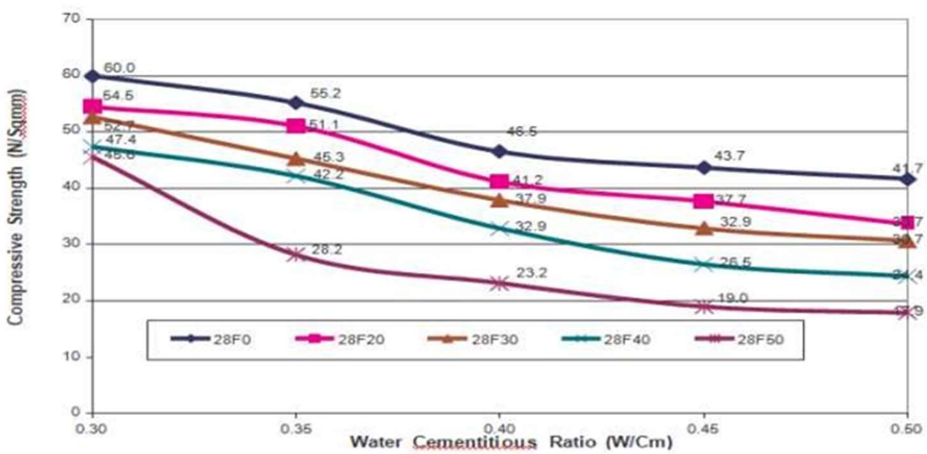
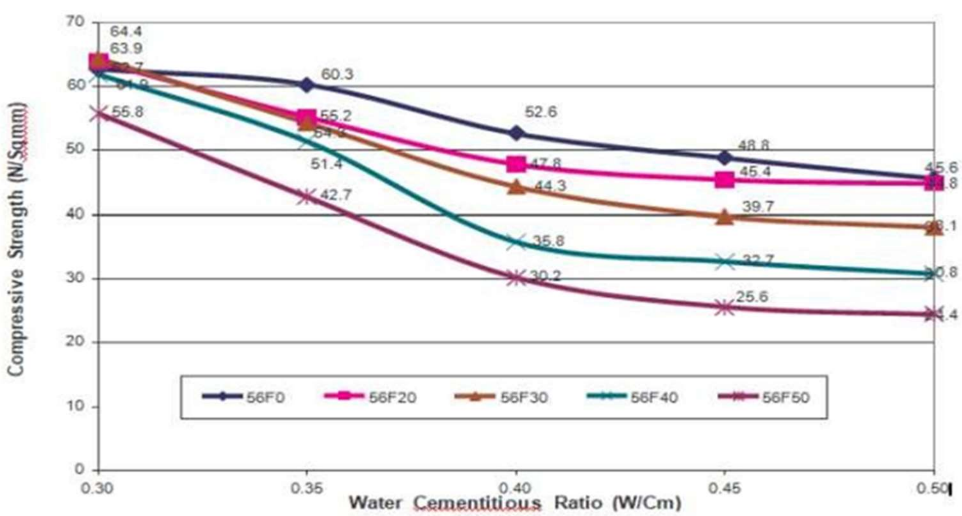


RCPT Results of 500 Mix



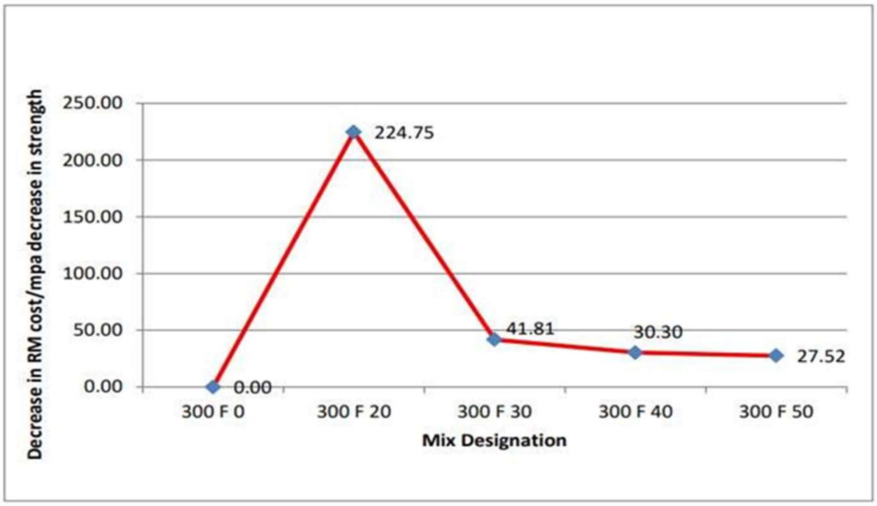
Graphs & Charts based on w/c ratio & Compressive Strength of concrete



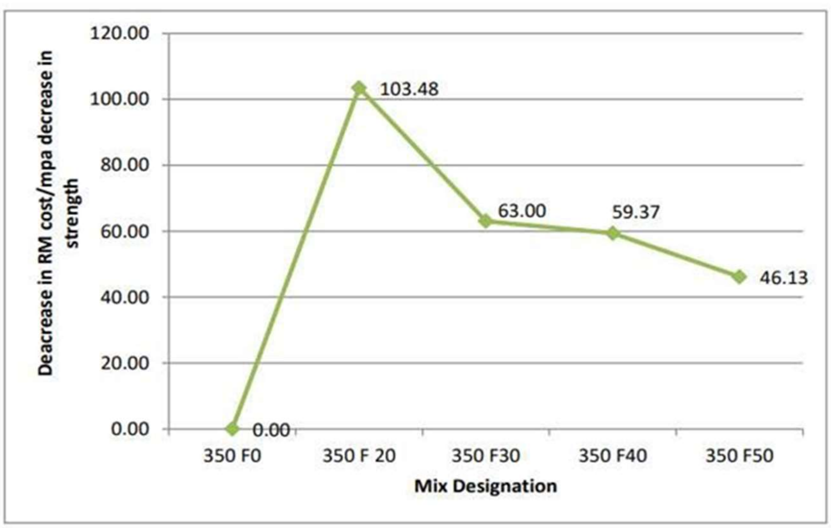
Compressive strength vs w/c ratio at 28 days

Compressive strength vs w/c ratio at 56 days

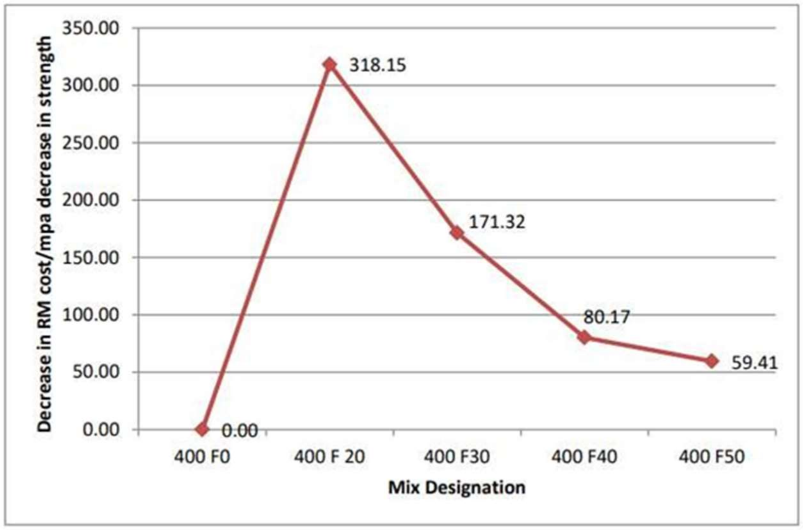
Graphs & Charts based Rm cost vs increase/decrease in ultimate strength (56/90 days)



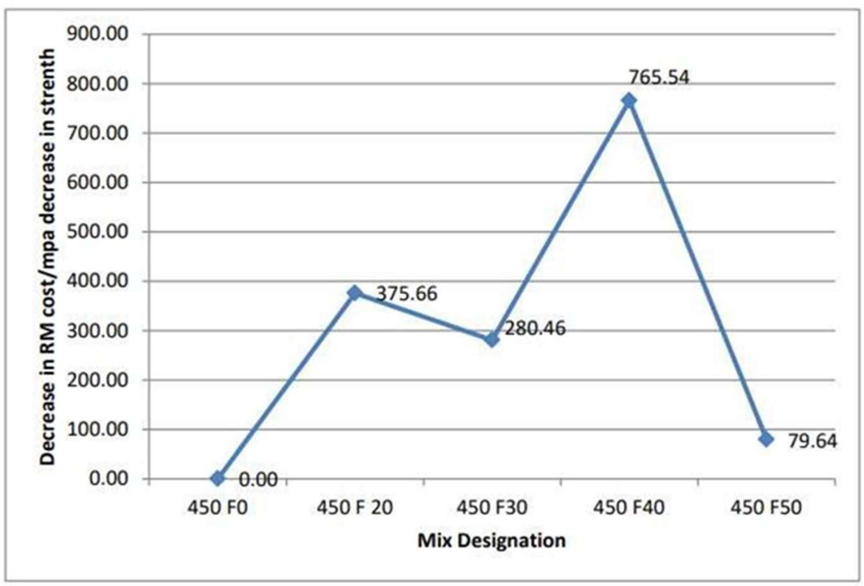
Decrease in rm cost/MPa decrease in 56 days strength for 300 F mix



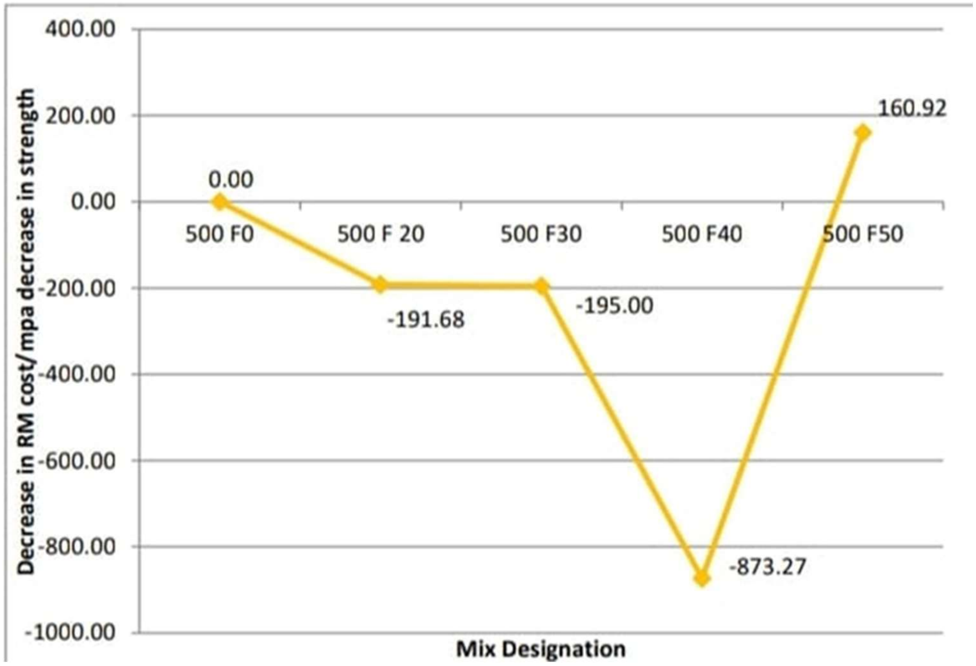
Decrease in rm cost/MPa decrease in 90 days strength for 350 F mix



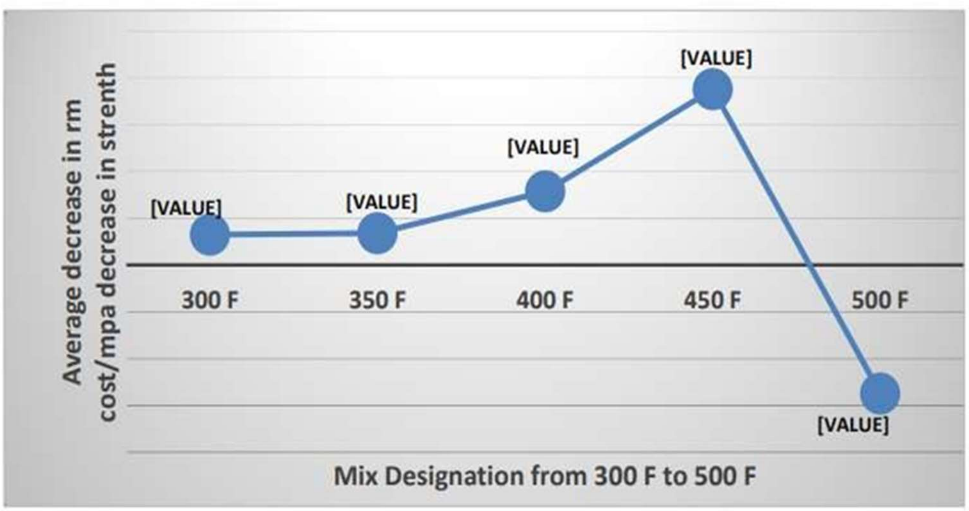
Decrease in rm cost/MPa decrease in 90 days strength for 400 F mix



Decrease in rm cost/MPa decrease in 90 days strength for 450 F mix



Decrease in rm cost/MPa decrease in 90 days strength for 500 F mix



Average Decrease in rm cost/MPa decrease in ultimate strength from mix 300F to 500 F

Conclusion:

As the high volume of fly ash production in India, there is an opportunity to address the challenges of fly ash disposal while simultaneously lowering cement usage, which is resource-intensive. Several organisations, most notably the Nuclear Power Corporation of India Ltd (NPCIL), are aggressively spreading awareness of the benefits of fly ash concrete and selling them. Several results on fly ash concrete have been reached from experimental experiments.:

1. Fly ash improves the workability of concrete, allowing for reduced water content or admixture dosage.

2. The density and air content of the concrete mix are generally unaffected by the use of fly ash.
3. Fly ash may slightly retard the setting time of concrete, but this is compensated by reduced admixture usage while maintaining workability.
4. Fly ash concrete exhibits reduced bleeding, improved cohesiveness, pumping characteristics, and surface finish.
5. Increasing the fly ash content in the concrete leads to a reduction in strength, particularly at earlier ages. This is due to the slower secondary hydration through pozzolanic action.
6. The rate of strength development at different ages is influenced by the water-to-cement ratio and the percentage of fly ash in the mix.

It is crucial to recognize that fly ash can be effectively utilized to produce strong, durable, environmentally-friendly, and cost-effective concrete.

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