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MODELLING MECHANICAL AND DURABILITY PARAMETERS OF M60 GRADE CONCRETE INCORPORATING WASTE MATERIALS

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Abstract: This study examines the effects of fly ash, metakaolin, and fibres (0 to 1) for a water cement ratio of 0.32 on the formation of ternary blended M60 grade concrete at various percentages (0, 5, 10, 15, and 20) of cement replacement. At the age of 28 days, concrete samples were evaluated for mechanical properties like compressive and flexure strength. Entroy and Shaklock Method is used to produce mix design for high-strength concrete M60. To determine the criteria for durability, the Chloride Permeability Test was conducted. Metakaolin and fly ash integration have significantly enhanced the mechanical and durability properties of high-strength concrete. Further models have been created for charge, compressive strength, and flexure strength using independent variables such metakaolin, fly ash, and fibre replacement. Good precisions and correlations between models and experimental data are shown.
Keywords: High Strength Concrete, Compressive Strength, Flexure Strength, Chloride Permeability, waste materials

1. Introduction

Isanaka B.R., Akbar M.A etal (2021) presented a study on high performance concrete. Partial replacement of cement in High Performance Concrete with fly ash, GGBS, metakaolin and silica fumes is an environmentally safe way to cope with augmented construction requirements. Gowram Iswarya, M Beulah (2020), Moser, Robert, Jayapalan etal (2010), A.K.Mullck etal (2007), Jelica Zelic Ivana etal (2007), A Elahi, P.A.M. Basheer, S.V.Nanukuttan, Q.U.Z Khan (2010), found that there is huge reward in durable and mechanical properties of high strength concrete with replacement of Ordinary Portland Cement by fly ash, granulated slag and silica fume. [1, 2, 3, 4, 5, 6]

2. Experimental Investigation

Locally available Ordinary Portland Cement of 53 grade (specific gravity 3.10) confirms to Indian standards has been procured. Fine aggregate (fine modulus 3.77, specific gravity 2.46) confirms to Zone II of IS 383 and coarse aggregate of 20 mm size with specific gravity 2.65 being used. Mix details per meter cube obtained from Entroy and Shaklock method were w/c value 0.32, cement 615 kg, FA 394 kg, CA 1185 kg and water 201.5 kg.

2.1 Compressive Strength

Compressive strength test (IS: 516:1959) executed for samples embedded with metakaolin and fly ash both individually and combined. Table 1, Table 2 and Table 3 show metakaolin blended concrete compressive strength, fly ash blended concrete compressive strength and Ternary Blend Compressive Strength 28 day curing period. Similarly Figure 1, Figure 2 and Figure 3 shows compressive strength with metakaolin, fly ash and combined metakaolin and fly ash concrete samples.

Table 1 Compressive strength when cement substitute with Metakaolin

% of Metakaolin	0%	5%	10%	15%	20%
0% Fi	70.6	76.3	79.9	78.6	77.5
0.25% Fi	73.0	79.8	83.6	82.1	79.1
0.50% Fi	73.5	82.0	83.9	82.9	80.2
0.75% Fi	76.0	83.2	86.7	84.5	83.5
1.0% Fi	72.0	78.9	82.2	80.6	80.3

Table 2 Compressive strength when cement substitute with fly ash

% of Fly ash	0%	5%	10%	15%	20%
0% Fi	70.6	73	74.3	75.5	77.7
0.25% Fi	73	73.9	75.5	76.3	78.8
0.50% Fi	73.5	74.1	74.4	74.6	76.5
0.75% Fi	76	77	77.7	77.8	79.7
1.0% Fi	72	75.3	75.1	74.6	77.1

Table 3 Compressive strength when cement substitute with Metakaolin and fly ash

% Flyash & Metakaolin	F0%+M0 %	F0%+M20 %	F5%+M15 %	F10%+M10 %	F15%+M5 %	F20%+M0 %
0% Fi	70.6	77.5	80.8	84.9	82.2	77.7
0.25% Fi	73.0	79.1	81.7	83.5	80.6	78.8
0.50% Fi	73.5	80.2	83.1	86.4	82.2	76.5
0.75% Fi	76.0	83.5	83.7	88.1	83.3	79.7
1.0% Fi	72.0	80.3	78.2	81.6	77.7	77.1

Figure 1: Compressive Strength of Samples with metakaolin

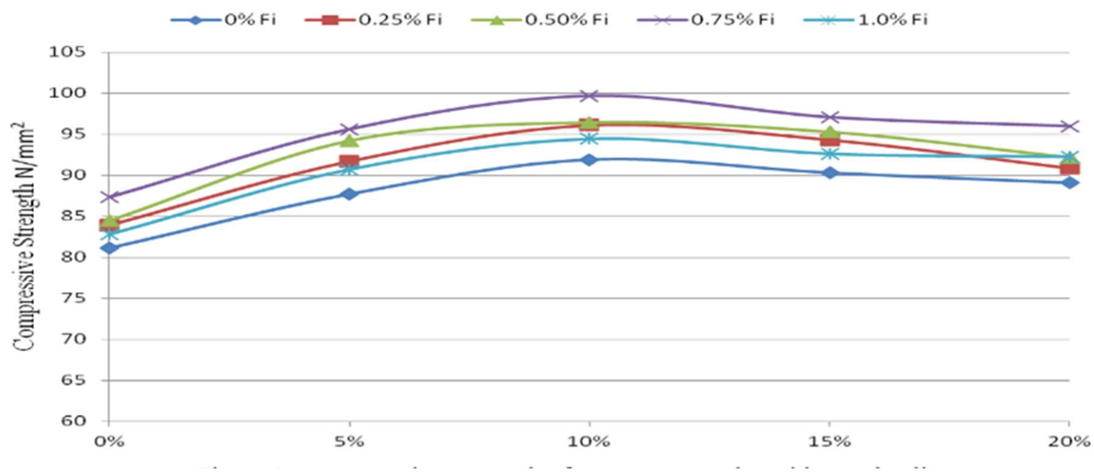


Figure 2: Compressive Strength of Samples with fly ash

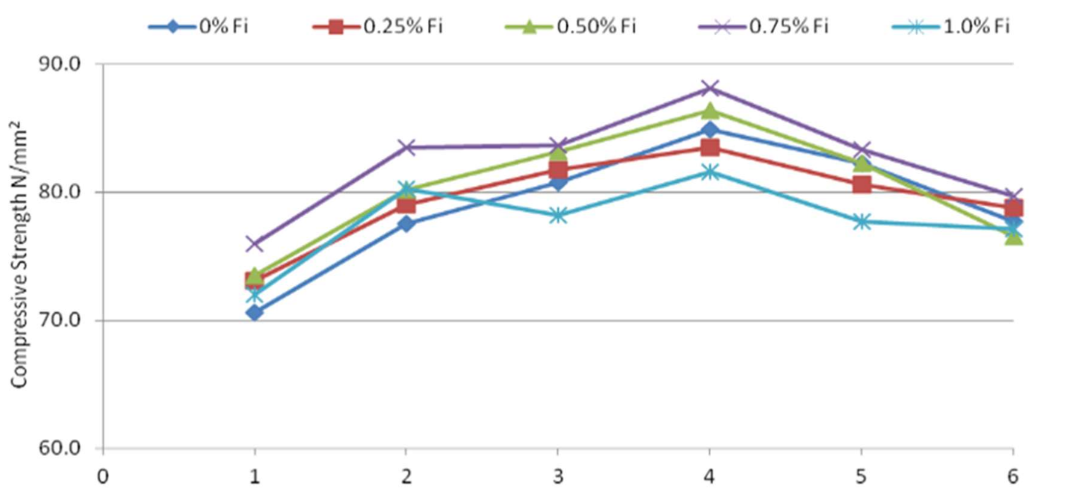
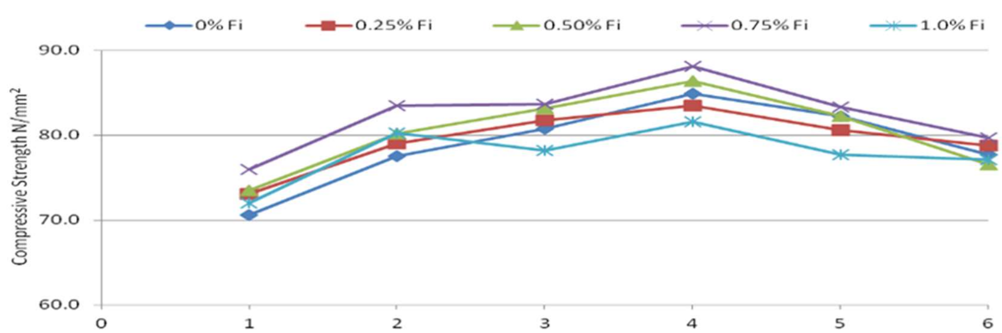


Figure 3: Compressive Strength of Samples with metakaolin and fly ash



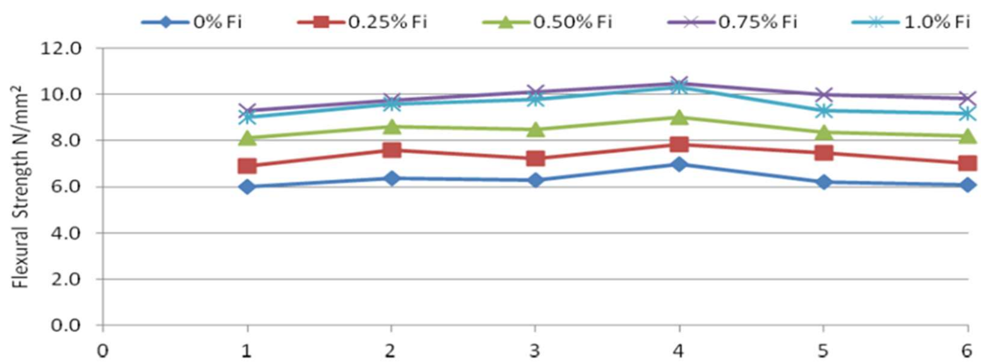
2.2 Flexural Strength

Flexural strength test results (IS: 516:1959) of concrete mixes performed for 28 days is shown in Table 4and Figure 4 shows effects of replacement of cement by Fly Ash and metakaolin on flexure strength.

Table 4 Flexural strength of Fly ash and Metakaolin blended Concrete in N/mm2

% Fly ash & Metakaolin	0% F+0% M	0% F+20%M	5% F+15%M	10%F+10% M	15% F+5%M	20%F+0% M
0% Fi	6.0	6.4	6.3	7.0	6.2	6.1
0.25% Fi	6.9	7.6	7.2	7.8	7.5	7.0
0.50% Fi	8.1	8.6	8.5	9.0	8.4	8.2
0.75% Fi	9.3	9.7	10.1	10.5	10.0	9.8
1.0% Fi	9.0	9.6	9.8	1 0.3	9.3	9.2

Figure 4: Flexure Strength of Samples with metakaolin and fly ash



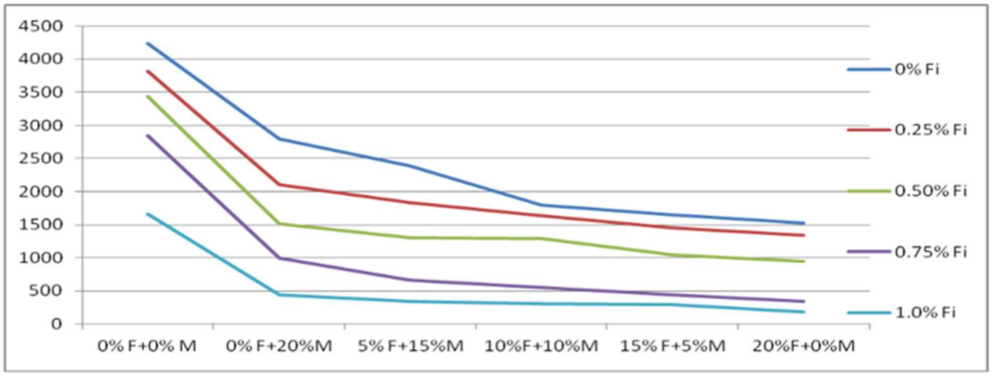
2.3 Rapid Chloride Permeability Test (RCPT)

The permeability to the entrance of chloride is one of the key characteristics that affected toughness of concrete. Chloride ions may have a detrimental cause on both concrete and reinforcement. 28-day chloride ion permeability test (RCPT) of cured concrete executed. Chloride penetrability remark (Charge Value Variations) noted as per ASTMC1202 Table 5 and Figure 5 shows the RCPT test result when cement replaced with metakaolin and fly ash at 28 day curing period.

Table 5 Charge value for Fly ash and metakaolin concrete samples

% Fly ash & Metakaolin	0% F+0% M	0% F+20%M	5% F+15%M	10%F+10% M	15% F+5%M	20%F+0% M
% Fi	4232	2800	2394	1800	1650	1530
0.25% Fi	3823	2100	1840	1633	1450	1344
0.50% Fi	3433	1512	1305	1288	1050	945
0.75% Fi	2840	993	667	556	441	338
1.0% Fi	1659	445	344	305	298	177

Figure 5: RCPT Value of concrete samples with metakaolin and fly ash at 28 days



2.4 Regression Models

We attempt to develop a multi linear regression model for charge (Q), compressive strength (CS) and flexure strength (FS) as dependent variable and Metakaolin, Fly Ash & fiber replacement as independent variable. Considering cube, beam and cylindrical concrete specimen cured at 28 days, we have already experimental compressive, flexure and RCPT value (Q) of all specimens so in order to access the influence of Metakaolin, Fly Ash & fiber we proposed a linear equation connecting the Q, CS and FS, remaining independent variables. Figure 6 presents the Correlation Graph of Experimental and Predicted RCPT Values. Figure 7 presents The Correlation Graph of Experimental and Predicted compressive strength values. Figure 8 presents the Correlation Graph of Experimental and Predicted flexure strength Values.

Let the abbreviations X_1, X_2 & X_3 for Metakaolin, Fly Ash & fibre replacement than linear function will be

Q (@28 days) = CS (@28 days) = FS (@28days) = F (Metakaolin, Fly Ash, fibre)

$F(X_1, X_2, X_3) = a_1 + a_2 * X_1 + a_3 * X_2 + a_4 * X_3$

Where a_1, a_2, a_3 & a_4 are coefficients belongs to real numbers

$$Q\ (@28days) = 2.204 \times 10^{-4} \times X_1 - 23.1408 \times X_2 + 4009.2002 \times X_3 + 1001.10$$

$$CS\ (@28\ days) = 1.245 \times 10^{-4} \times X_1 - 13.8001 \times X_2 + 2021.1012 \times X_3 + 998.80$$

$$FS\ (@\ 28\ days) = 5.656 \times 10^{-4} \times X_1 - 3.3456 \times X_2 + 8478.1992 \times X_3 + 556$$

Figure 6: Experimental and Predicted RCPT Value

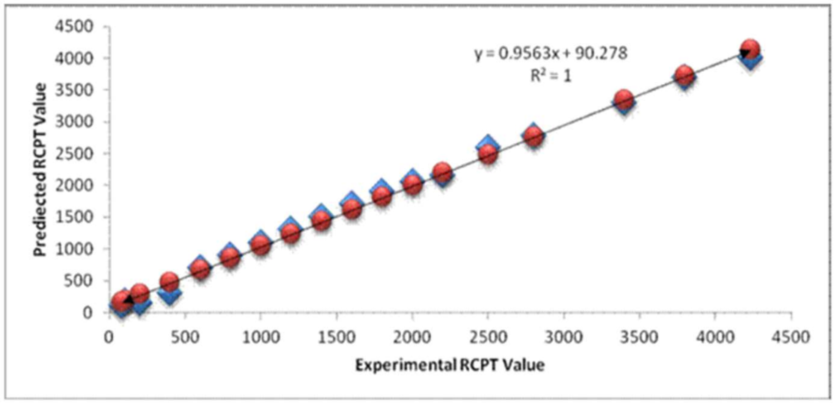


Figure 7: Experimental and Predicted Compressive Strength Value

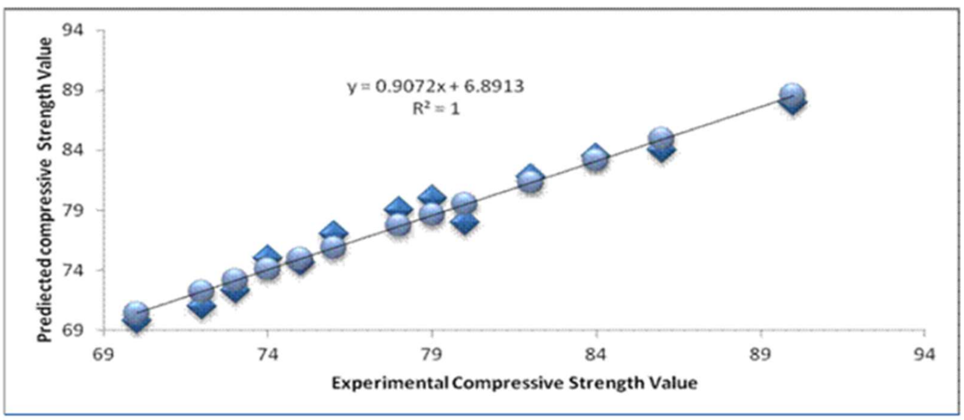
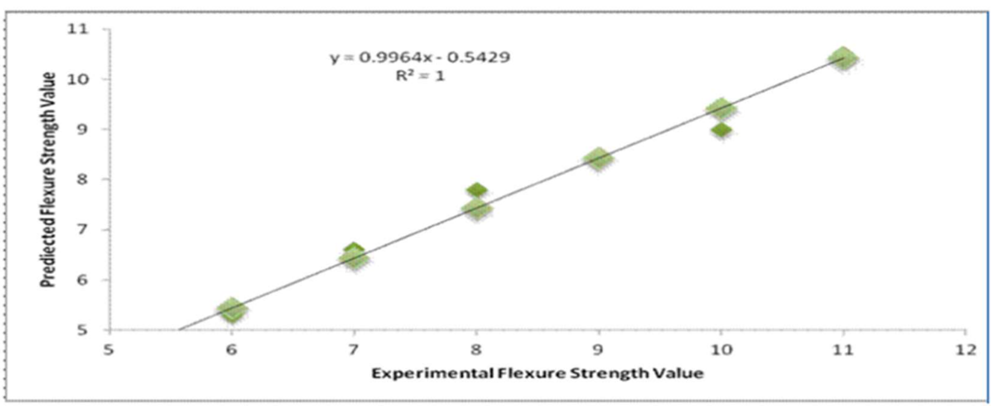


Figure 8: Experimental and Predicted flexure Strength Value



3 Conclusions

A blend of 7 percent of OPC and 10% of metakaolin is the best favorable substitution. effect of fibres is the reason for the increase in flexural strength. more lime is needed in order to increase the replacement percentages, the lime additive will give concrete a greater life span. All models exhibits good accuracy, precision, less percentage difference error & better agreement with Experimental actual data's results of Compressive Strength, flexure strength Test and RCPT test. In view of the experimental test results, the concrete with metakaolin and fly ash combination exhibits low permeability which means that concrete is durable at 28 day which suggests that concrete became denser due to void reduction. Concrete produced by the use of metakaolin and fly ash has superior durability properties and efficient micro filling capability also being enhanced.

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