Regression Analysis of Concrete Mix Design Using Admixture

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Abstract- A mathematical analysis using statistical techniques for the prediction of compressive strength of concrete was performed for the concrete data obtained from RMC plant in this study. The variables used in the prediction models were the mix proportioning elements. Here we compare the regression value of M25, M30, M35 and the best regression value we consider to procced our work. Regression analysis is a set of statistical methods used for the estimation of relationships between a dependent variable and one or more independent variables. We are considering the R^2 value which is much closer to 1 is good value for regression analysis. According to IS 10262: 2009 to calculate the mix design by keeping the regression value fixed. To compare the design value with that field data.

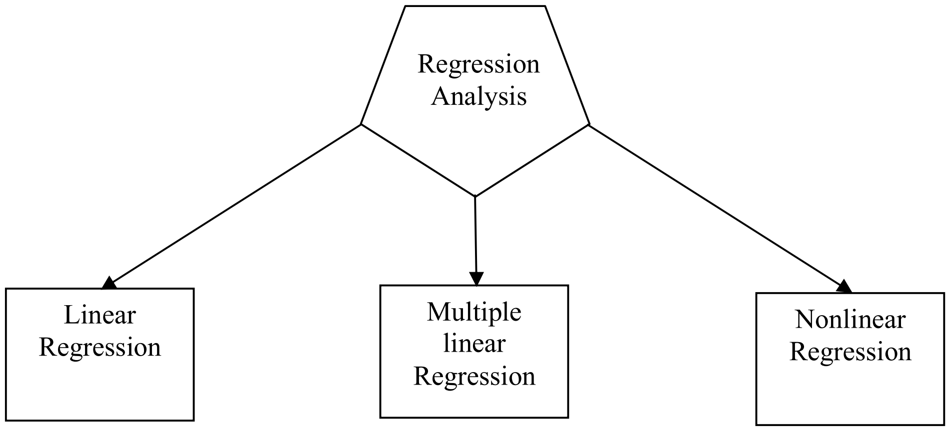
Keywords - Regression value, compressive strength , concrete mix design

I. INTRODUCTION

Concrete is the most important construction material in last few centuries. Not only good strength but also provide a good durability of a structure. We know that strength and workability get changed while varying the w/c ratio of the concrete, but now a days Workability can be increased or decreased by adding admixture without changing the w/c ratio. The results of compressive strengths vary not only for different concrete mixtures, but for the same mixture as well, which has been attributed to various factors. Here we are using statistical method for the analysis of compressive strength. There are many statistical methods but, in this case, we are using the regression analysis method. The present study says that a regression model was initially inspected as a performance prediction model which was used to predict the concrete compressive strength. In addition to this, examination was also conducted on the effects of the changes of the coefficients of regression model of the performance curve. Therefore, for this purpose, multiple regression analysis was executed for predicting the compressive strength of concrete using four variables, which are water-cementations ratio, fine aggregate-cementitious ratio, coarse aggregate-cementitious ratio and cementitious content. Regression models were developed at different curing ages (28, 56 and 91days) for concrete with medium and high workability. For the models which were designed to speculate the compressive strength at 56 days and 91 days, the compressive strength at lower ages were treated as parameters as well.

II. REGRESSION ANALYSIS:

Regression analysis is a set of statistical methods which is used for the estimation of relationships between a dependent variable and one or more independent variables. It is used to assess the strength of the relationship between variables and for creating the future relationship between them. Regression value always lies between 0 to1.



Regression analysis have several variations, such as linear, multiple linear, and nonlinear. The most commonly used models are simple linear and multiple linear.

- Regression Analysis – Simple Linear Regression:

Simple linear regression is a model that assesses the relationship between a dependent variable and an independent variable. The simple linear model is expressed using the following equation:

$$Y = a + bX + \epsilon$$

Where:

Y– Dependent variable

X – Independent (explanatory) variable

a – Intercept

b – Slope

ϵ – Residual (error)

- Regression analysis for compressive strength of concrete:

The principal factors that influence compressive strength of concrete are selected by a correlation analysis, and then simple linear regression analysis is carried out for predicting compressive strength according to water-cement, cement-aggregate ratio and cement contents.

Statistical techniques:

Anumber of research efforts have been using multivariable regression models to improve the accuracy of predictions.Statisticalmodelshavethetendencythatoncefitted they can be used to execute the predictions much more quickly and efficiently than other modeling techniques and are simpler to implement insoftware. PopovicsaugmentsAbramsmodel,awidelyaccepted equation which isrelated tothew/cratio ofconcreteto its strength with additional variables such as slump and uses least square regression to find the equation coefficients (Popovics and Ujhelyi,) 2008.Apart of its speed, statistical modeling has the advantage as it is mathematically rigorous and can be used to define confidence interval for the predictions. Statistical analysis can also come up with insight into the key factors influencing 28 days compressive strength through correlation analysis. For these reasons statistical analysis was chosen to be technique for the prediction of strength for this study.

III. DATA

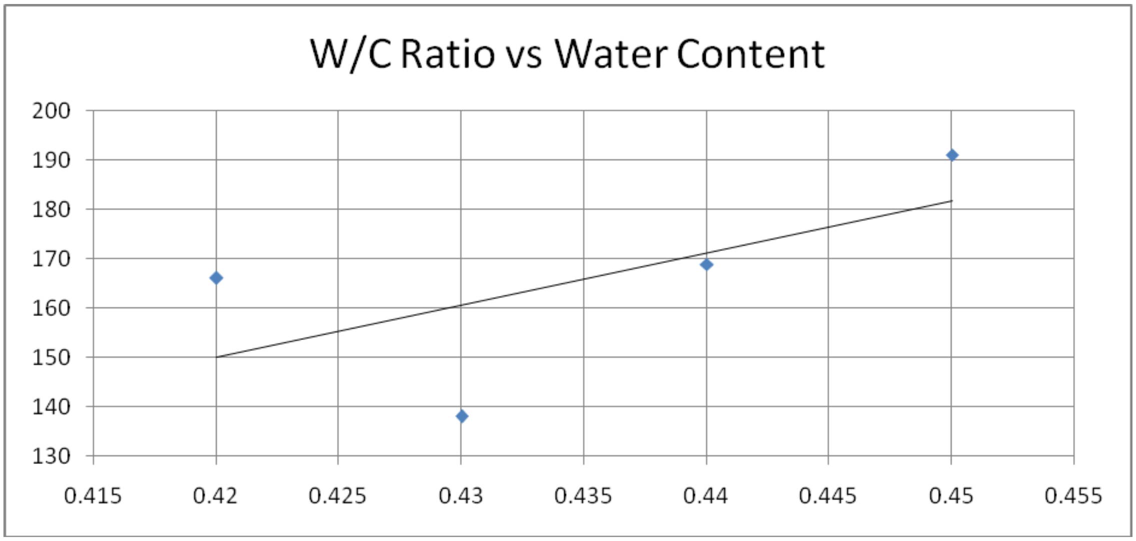
These design mix data received from different RMC Plants.

Grade	Sample	Water Content (Kg)	Water Cement Ratio	Cement Content (OPC) (Kg)	Fly Ash (Kg)	Coarse Aggregate 1 (20mm) (Kg)	Coarse Aggregate 2 (10mm) (Kg)	Fine Aggregate (River Sand) (Kg)	Admixture (Kg)	Total Density of Fresh Concrete (Kg)
M25	SAMPLE: 1	168.89	0.44	299.8	75	664.8	544	741.8	2.436	2493
	SAMPLE: 2	166.05	0.42	329.1	72	661.3	541.1	723.3	2.601	2494
	SAMPLE: 3	191	0.45	380		622	509	743	2.47	2447
	SAMPLE: 4	138	0.43	320		977	380	751	1.6	2567.6
M30	SAMPLE: 1	165.72	0.4	339.7	74.6	660.4	540.3	713.8	2.693	2497
	SAMPLE: 2	165.72	0.39	348.4	76.5	659.2	539.4	706.8	2.762	2499
	SAMPLE: 3	186	0.4	417		624	510	717	2.92	2457
	SAMPLE: 4	132.33	0.4	407.34		703.44	470.09	800.29	3.06	2516.6
	SAMPLE: 5	161.86	0.395	280	130	547	545	764	3.49	2431.4
	SAMPLE: 6	190	0.45	420		1170		685		2465
	SAMPLE: 7	134	0.42	320		1321		668	1.6	2409
M35	SAMPLE: 1	164.07	0.37	376.9	66.5	659.2	539.4	695.6	2.882	2505
	SAMPLE: 2	180	0.36	446		628	513	701	3.35	2471
	SAMPLE: 3	166.8	0.35	352	120	469	617	694	4.293	2428.4
	SAMPLE: 4	160	0.45	275	118	1226		720	2	2501
	SAMPLE: 5	140	0.4	350		1140		896	7	2533
	SAMPLE: 6	162	0.4	337	145	1060		636	4.82	2344.8

Table: 5.1

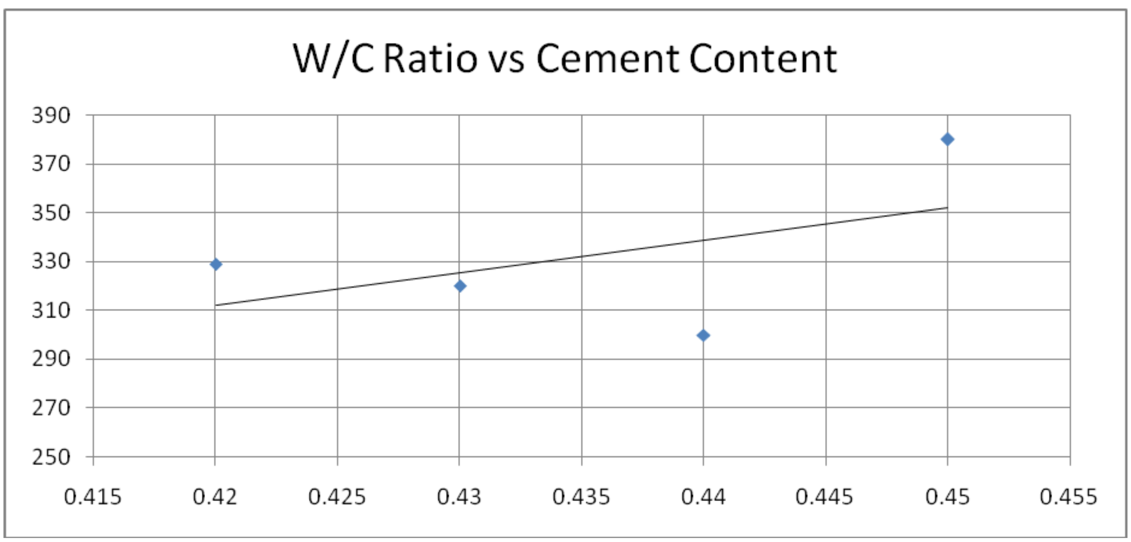
IV. ANALYSIS

1) For M25:



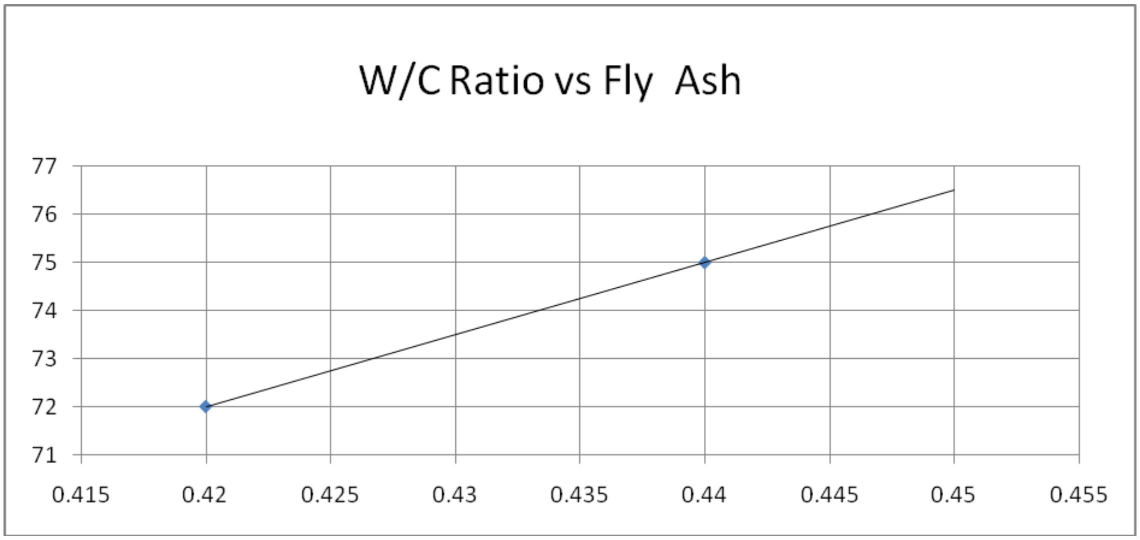
Graph: 6.1.1

$R^2 = 0.3944$
y = 1057.4x - 293.98



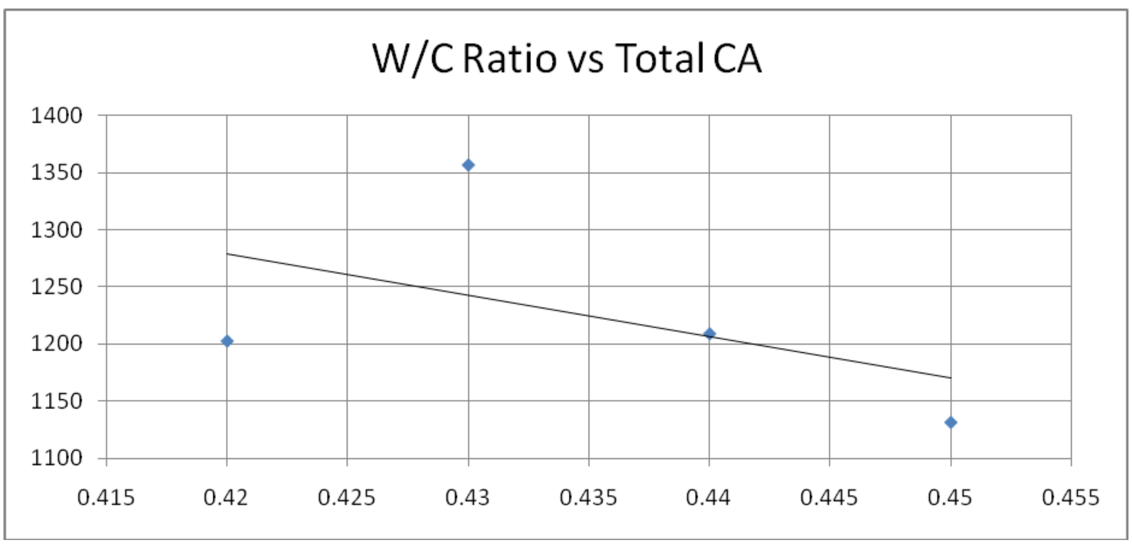
Graph: 6.1.2

$R^2 = 0.2513$
y = 1325x - 244.15



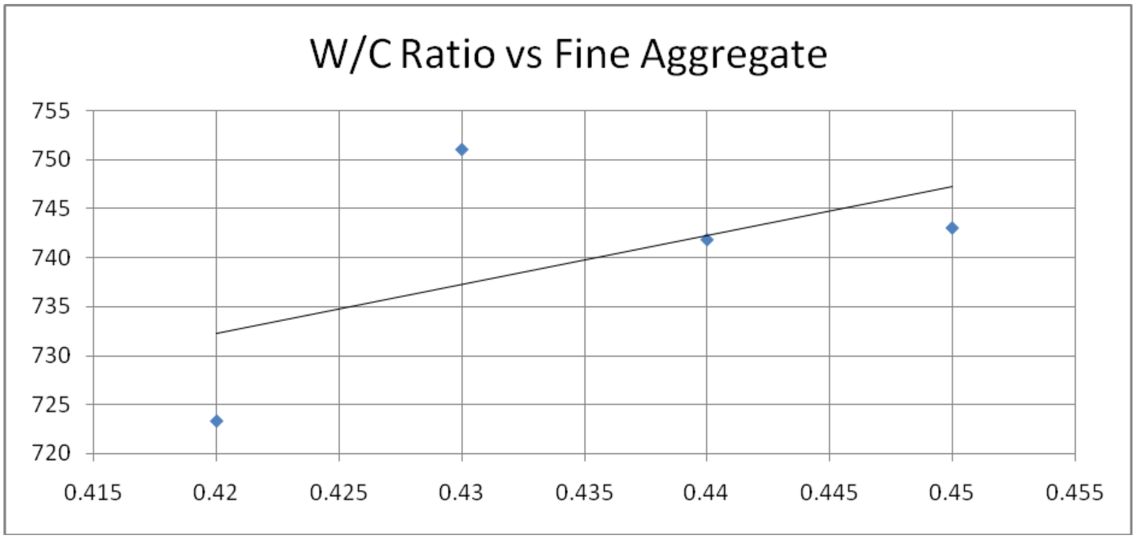
Graph: 6.1.3

$R^2 = 1$
$y = 150x + 9$



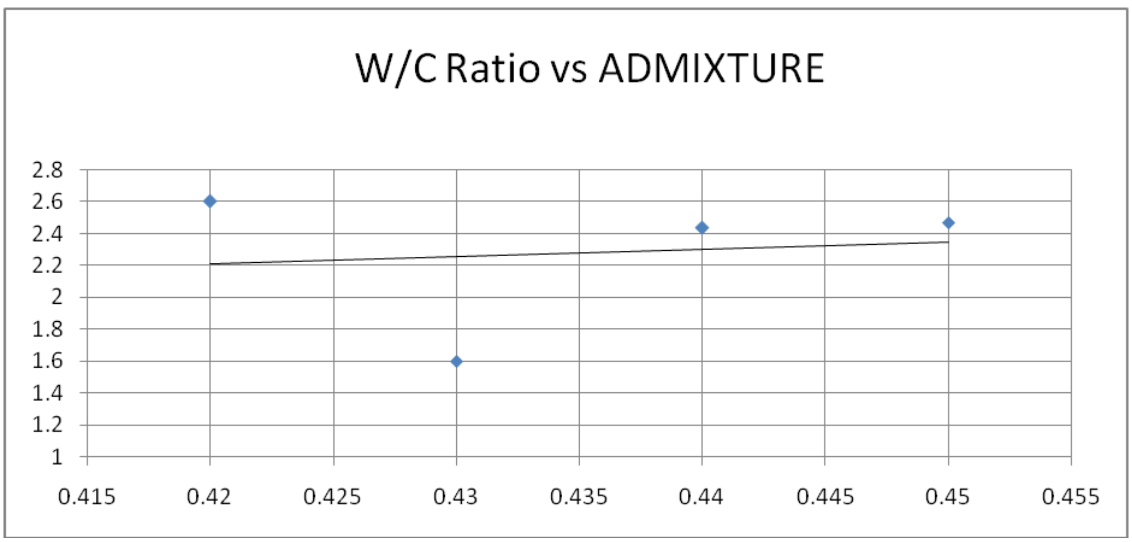
Graph: 6.1.3

$R^2 = 0.2429$
$y = -3624x + 2801.2$



Graph: 6.1.4

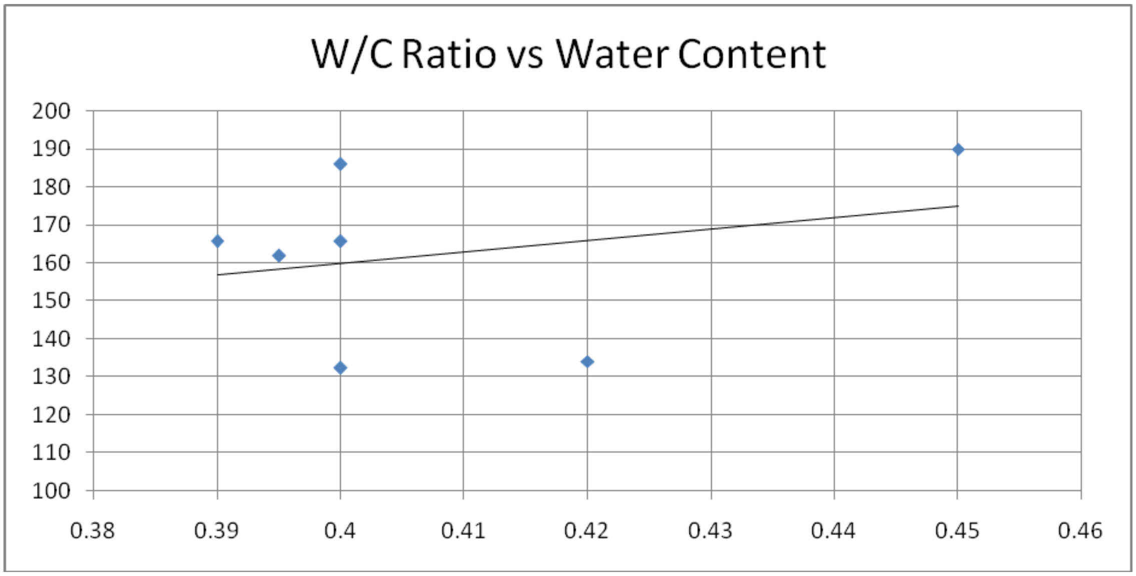
$R^2 = 0.3022$
$y = 499x + 522.71$



Graph: 6.1.5

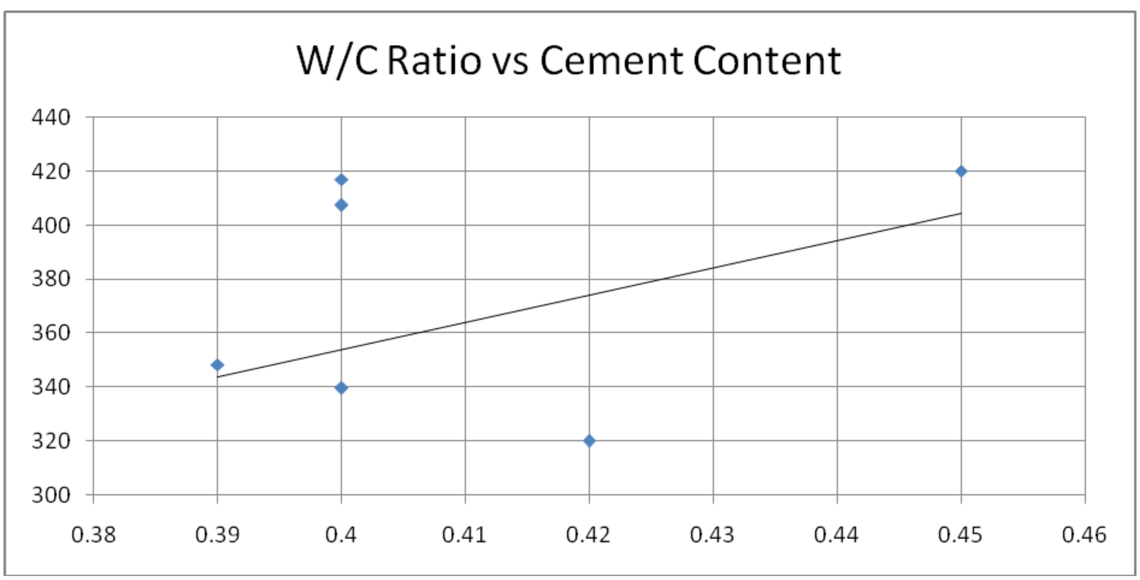
$R^2 = 0.0157$
$y = 4.43x + 0.3497$

2) For M30:



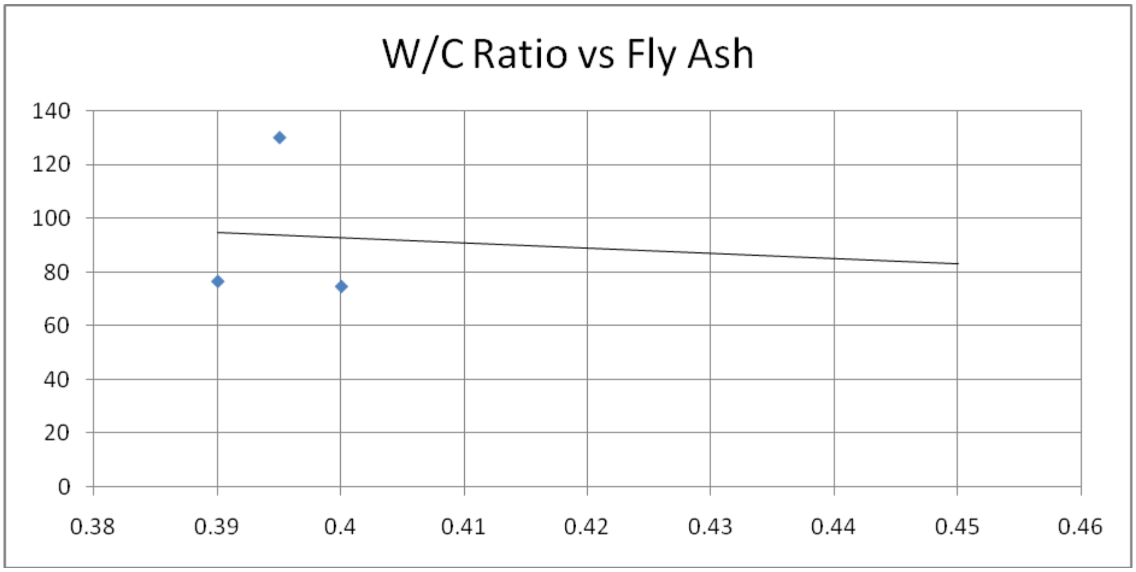
Graph: 6.2.1

$R^2 = 0.079$
$y = 304.95x + 37.857$



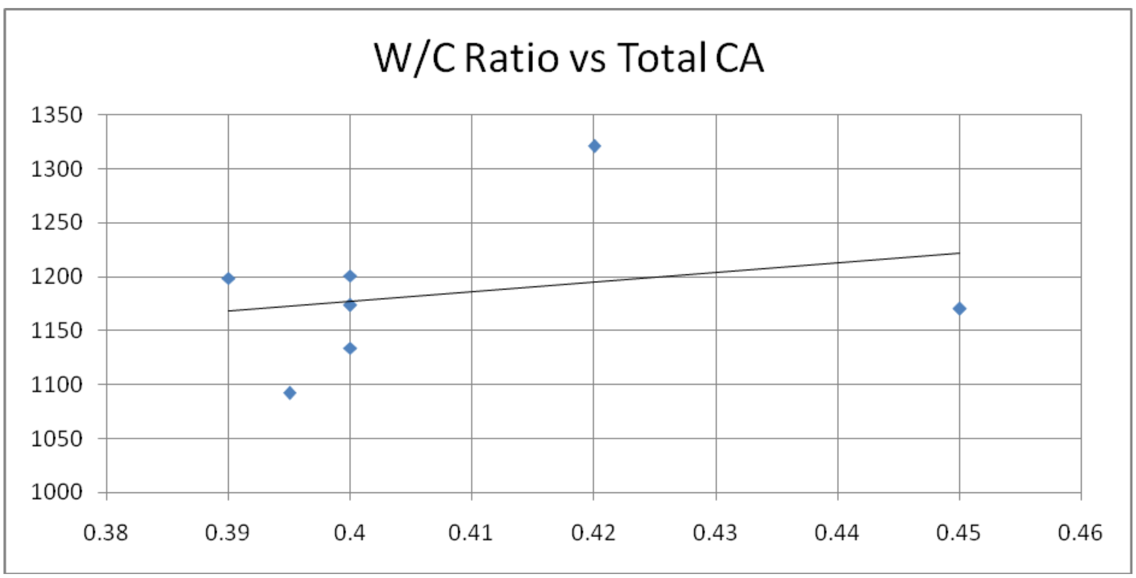
Graph: 6.2.2

$R^2 = 0.1501$
$y = 1009.8x - 50.075$



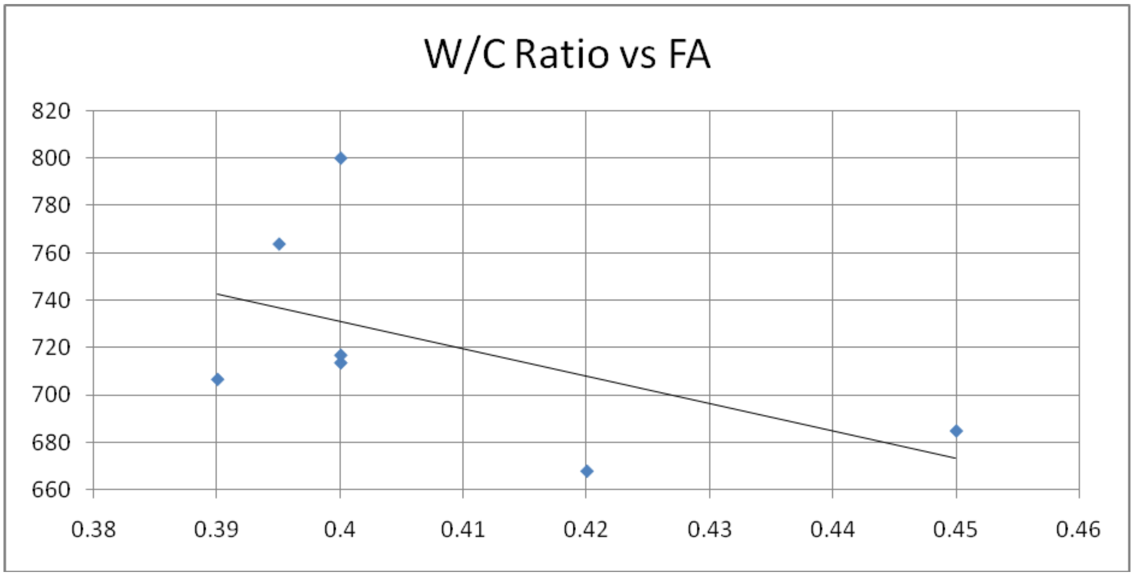
Graph: 6.2.3

$R^2 = 0.0009$
$y = -190x + 168.75$



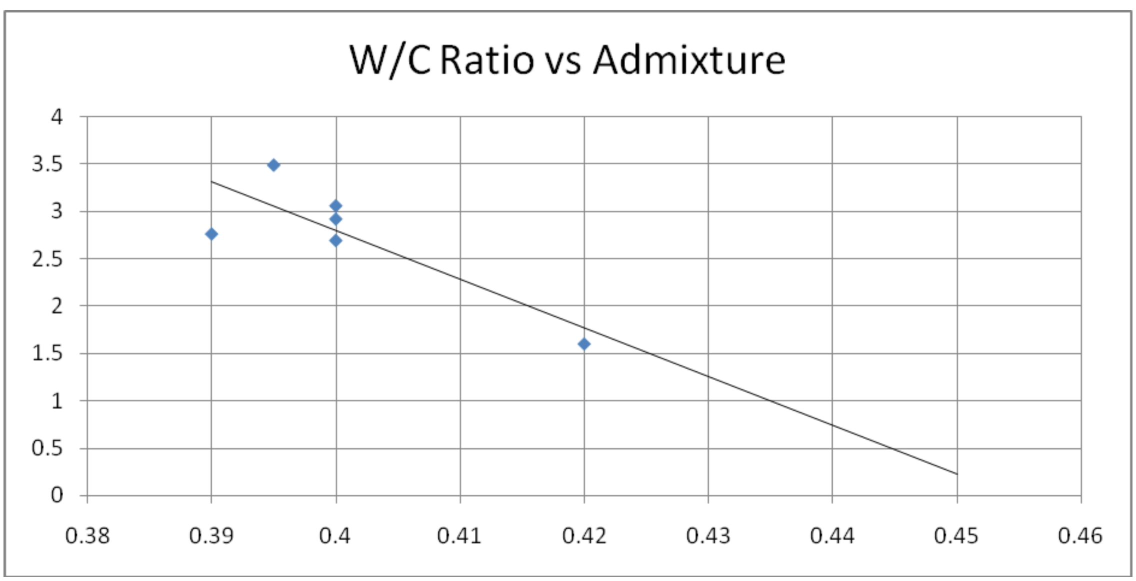
Graph: 6.2.4

$R^2 = 0.0691$
$y = 902.33x + 816.24$



Graph: 6.2.5

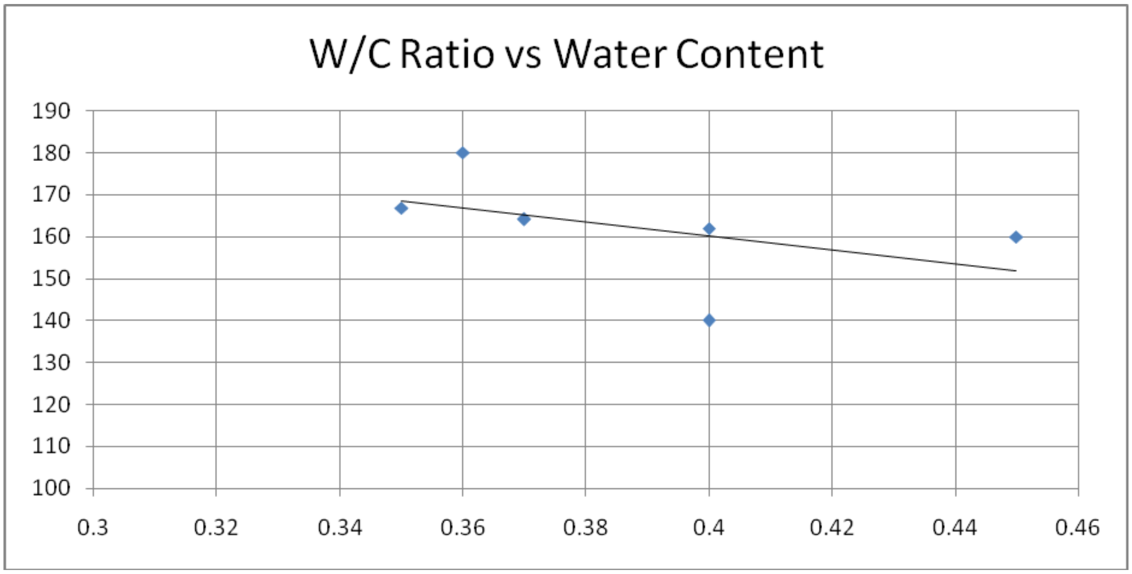
$R^2 = 0.2767$
y = -1155.1x + 1193.2



Graph: 6.2.6

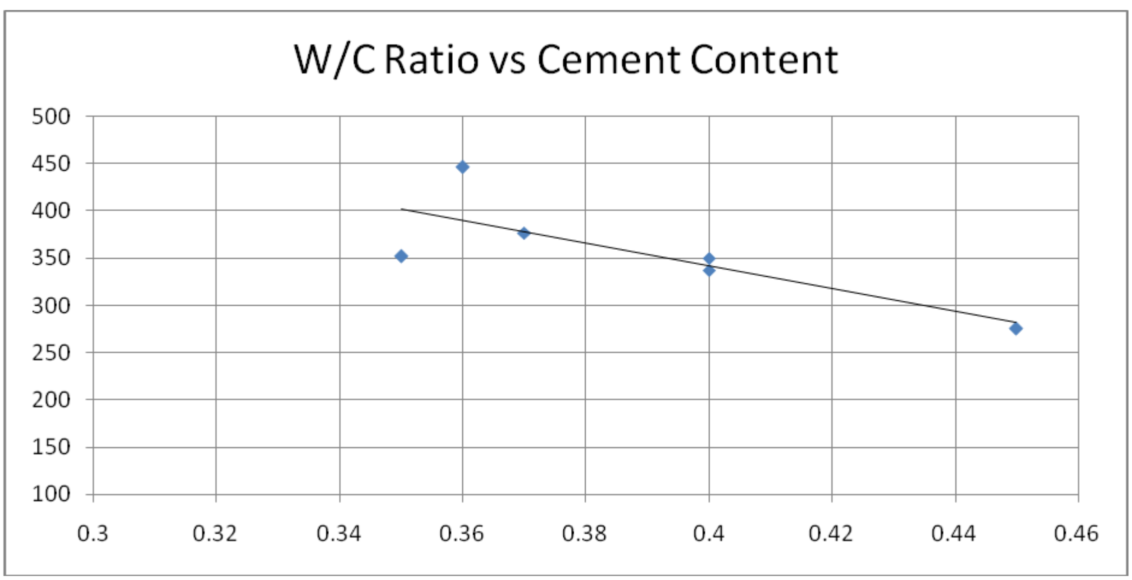
$R^2 = 0.6922$
y = -51.534x + 23.411

3) For M35:



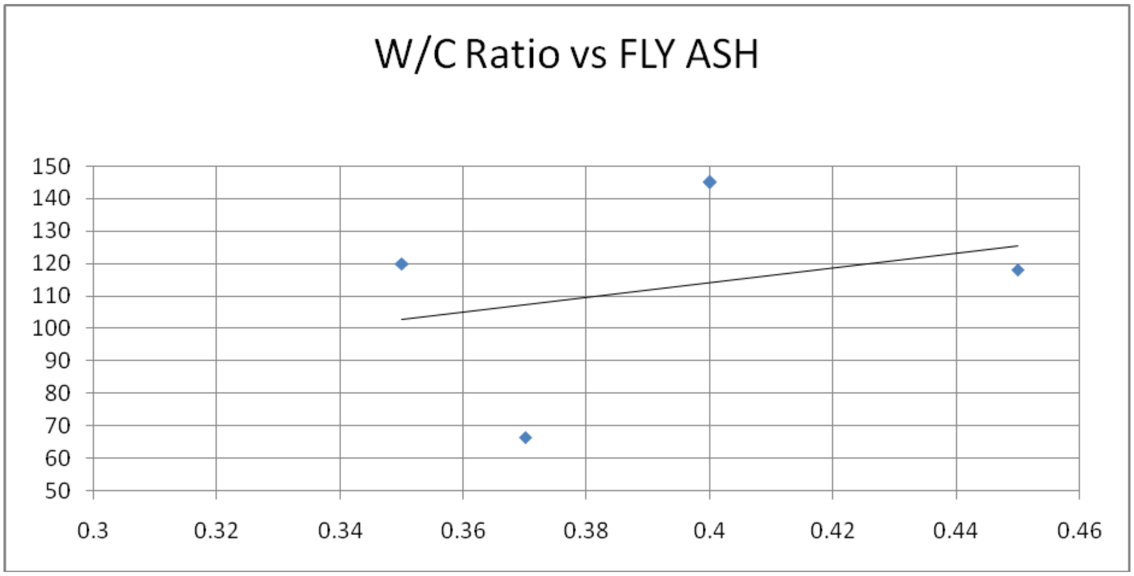
Graph: 6.3.1

$R^2 = 0.2205$
$y = -166.38x + 226.75$



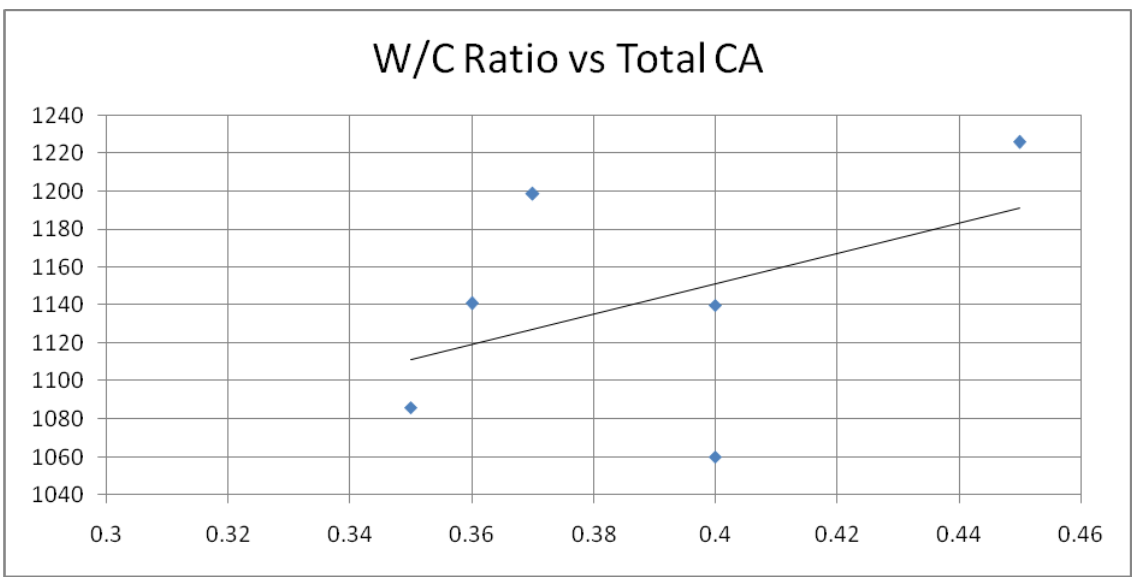
Graph: 6.3.2

$R^2 = 0.6277$
$y = -1207x + 824.85$



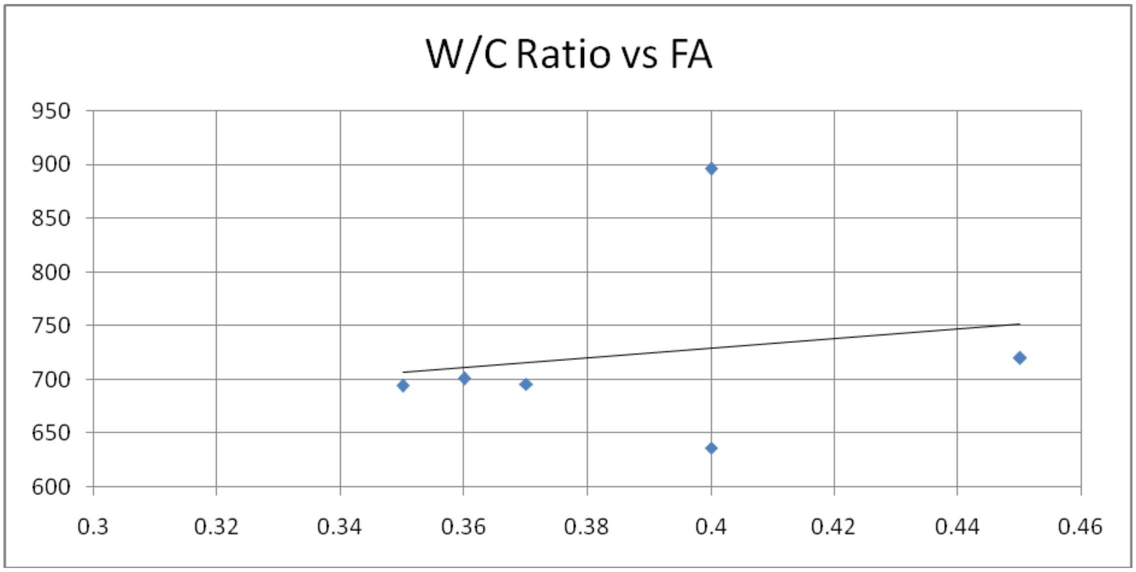
Graph: 6.3.3

$R^2 = 0.0881$
$y = 224.89x + 24.106$



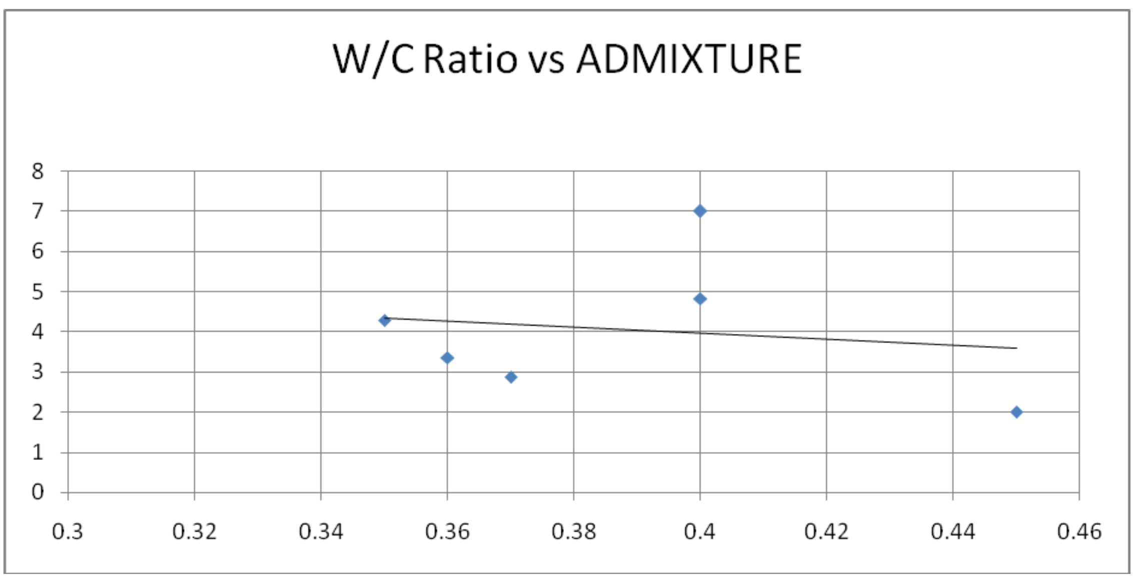
Graph: 6.3.4

$R^2 = 0.2118$
$y = 798.6x + 831.81$



Graph: 6.3.5

$R^2 = 0.0353$
$y = 457.21x + 546.22$



Graph: 6.3.6

$R^2 = 0.0252$
$y = -7.6264x + 7.0186$

1. VARIATION OF DATA WITH RESPECT TO WATER CEMENT RATIO OF DIFFERENT GRADES OF CONCRETE:

Grade of Concrete	Water Cement Ratio	Cement Content	R^2
M25	0.44	299.8	
	0.42	329.1	
	0.45	380	
	0.43	320	**0.251**
M30	0.4	339.7	
	0.39	348.4	
	0.4	417	
	0.4	407.34	
	0.395	280	
	0.45	420	
	0.42	320	**0.15**
M35	0.37	376.9	
	0.36	446	
	0.35	352	
	0.45	275	
	0.4	350	
	0.4	337	**0.627**

Table: 7.1

Grade of Concrete	Water Cement Ratio	Water Content	R^2
M25	0.44	168.89	
	0.42	166.05	
	0.45	191	
	0.43	138	**0.394**
M30	0.4	165.72	
	0.39	165.72	
	0.4	186	
	0.4	132.33	
	0.395	161.86	
	0.45	190	
	0.42	134	**0.079**
M35	0.37	164.07	
	0.36	180	
	0.35	166.8	
	0.45	160	
	0.4	140	
	0.4	162	**0.22**

Table: 7.2

Grade of Concrete	Water Cement Ratio	Total CA	R^2
M25	0.44	1208.8	
	0.42	1202.4	
	0.45	1131	
	0.43	1357	**0.242**
M30	0.4	0.4	
	0.39	0.39	
	0.4	0.4	
	0.4	0.4	
	0.395	0.395	
	0.45	0.45	
	0.42	0.42	**0.069**
M35	0.37	1198.6	
	0.36	1141	
	0.35	1086	
	0.45	1226	
	0.4	1140	
	0.4	1060	**0.211**

Grade of Concrete	Water Cement Ratio	Fine Aggregate	R^2
M25	0.44	741.8	
	0.42	723.3	
	0.45	743	
	0.43	751	**0.3022**
M30	0.4	713.8	
	0.39	706.8	
	0.4	717	
	0.4	800.29	
	0.395	764	
	0.45	685	
	0.42	668	**0.276**
M35	0.37	695.6	
	0.36	701	
	0.35	694	
	0.45	720	
	0.4	896	
	0.4	636	**0.035**

Table: 7.4

Grade of Concrete	Water Cement Ratio	Admixture	R^2
M25	0.44	2.436	
	0.42	2.601	
	0.45	2.47	
	0.43	1.6	**0.046**
M30	0.4	2.693	
	0.39	2.762	
	0.4	2.92	
	0.4	3.06	
	0.395	3.49	
	0.45		
	0.42	1.6	**0.692**
M35	0.37	2.882	
	0.36	3.35	
	0.35	4.29	
	0.45	2	
	0.4	7	**0.025**

	0.4	4.82	

Grade of Concrete	Water Cement Ratio	Fly Ash	R^2
M25	0.44	72	
	0.42	75	
	0.45		
	0.43		**1**
M30	0.4	74.6	
	0.39	76.5	
	0.4		
	0.4		
	0.395	130	
	0.45		
	0.42		**0.0009**
M35	0.37	66.5	
	0.36		
	0.35	120	
	0.45	118	
	0.4		
	0.4	145	**0.0881**

Table: 7.6

VII. MIX DESIGN CALCULATIONS (M 35)

TARGET STRENGTH

f'_{ck} = fck+1.65 S

= 35 +1.65 × 5

= 43.25 N/mm^2

f'_{ck} = target average compressive strength at 28 days,

f_{ck} = characteristic compressive strength at 28 days,

S= standard deviation, From Table 1 of IS 10262:2009, standard deviation, S= 5.0 N/mm^2

SELECTION OF WATER-CEMENT RATIO

From Table 5 of IS 456 (2000), maximum water-cement ratio for "very severe" exposure = 0.45
From trial and error, water cement ratio was found as 0.38
0.38 < 0.45, hence OK.

SELECTION OF WATER CONTENT

From Table 2 of IS 10262:2009, water content for 20 mm aggregate = 186 kg/m^3 (for 50 mm slump without using superplasticizer).

Estimated water content for 100 mm slump = 186 + (6/100)x186
= 197.16
≈ **198kg/m^3**

As superplasticizer is used, the water content can be reduced by 20 percent.

Hence, the reduced water content
= 198 × 0.80
= 158.4 kg/m3
≈ **159 kg/m^3**

<u>CALCULATION OF CEMENT CONTENT:</u>

Water cement ratio was found 0.38

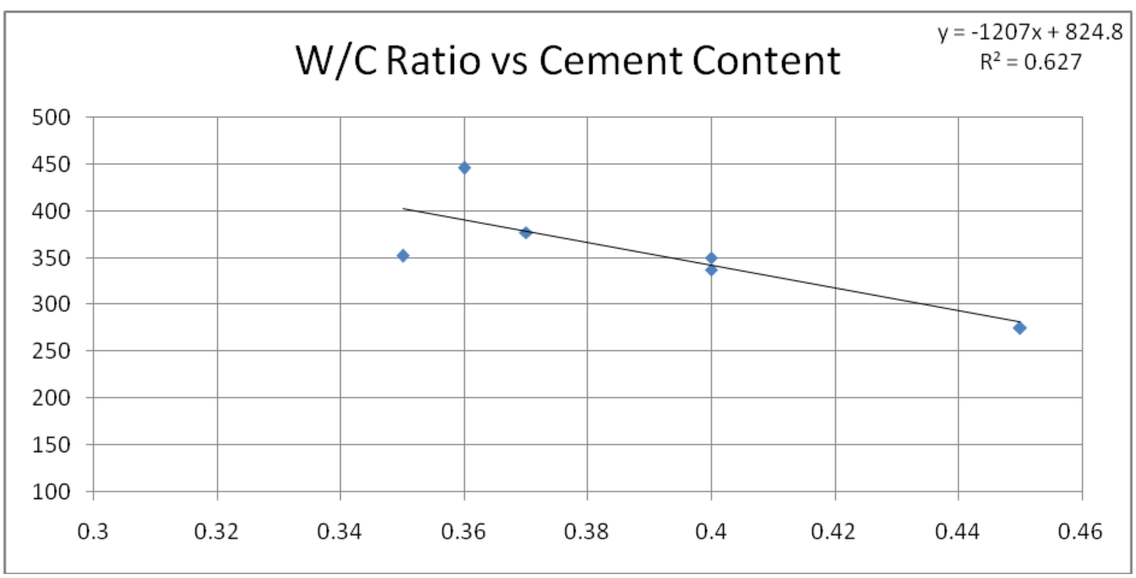
Cementitious Content = 159 / 0.38
= 418.42
≈ **419 kg/m^3**

From Table 5 of IS 456:2000, minimum cement content for 'severe' exposure condition
= 320 kg/m^3
Therefore = 419 kg/m^3 > 320 kg/m^3, **Hence O.K.**

Fly ash @ 15 percent by weight of cementitious material
= 419 × 0.15
= **62.85 kg/m^3**

Cement content = 419 – 62.85
= **356.15 kg/m^3**

<u>Data from different M35 Mix Designs:</u>



<u>Graph: 8.1</u>

Therefore, also from graph of w/c content vs Cement Content of M35 we found Cement
Content as = **356.534kg/m^3**

Admixture 0.65% = 419 x 0.0065
= **2.72kg/m^3**

VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From Table 3 of IS 10262:2009, volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate (Zone II) for water - cement ratio of 0.5 = 0.620

In the present case Water - Cement ratio is 0.38

Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the Water - Cement ratio is lower by 0.12, the proportion of volume of coarse aggregate is increased by
= 0.024

Therefore, Corrected proportion of volume of Coarse Aggregate for the Water - Cement Ratio of 0.38
= 0.620+0.024
= 0.644

For Pumpable concrete this value should be reduced by 5 percent. (IS:10262-2009, CL 4.4.1)
Therefore, volume of coarse aggregate = 0.644 x 0.95
= **0.6118**

Volume of fine aggregate content = 1 – 0.6118
= **0.3882**

VII. MIX CALCULATIONS

a) Total volume = 1 m^3

b) Volume of cement = (Mass of Cement /Specific gravity) x (1/1000)
=(419/3.15) x (1/1000)
= 0.1330 m^3

c) Volume of Water = (Mass of Water/Specific Gravity of Water) x (1/1000)
= (159/1) x (1/1000)
= 0.159 m^3

d) Volume of Admixture (CAC): (sg = 1.11)
= (Mass of Admixture/SG of Admixture) x (1/1000)
= ((419 x 0.0065)/1.1) x (1/1000)
= 0.0025 m^3

e) Volume of All-in-one Aggregates:

= [a – (b + c + d)]
= 1 – (0.1330 + 0.159 + 0.0025)
= 0.7055 m^3

f) Mass of Course Aggregates 20 mm:
= e x volume of 20 mm aggregates x Sg of CA x 1000 x 0.55
= 0.7055 x 0.6118 x 2.82 x 1000 x 0.55
= 669.45 kg

g) Mass of Coarse aggregates 10 mm:
= e x volume of 10 mm aggregates x Sg of CA x 1000 x 0.45
= 0.7055 x 0.6118 x 2.82 x 1000 x 0.45
= 547.73 kg

h) Mass of fine aggregates:
= e x volume of fine aggregates x Sg of FA x 1000
= 0.7055 x 0.3882 x 2.6 x 1000
= 712.07 kg

MATERIALS REQUIRED PER CUM. OF CONCRETE

Water	: 159 Liters
Water Cement Ratio	: 0.38
Cement	: 356.15 kg
Fly Ash	: 62.85 kg
Coarse aggregates 20 mm	: 669.45 kg
Coarse aggregates 10 mm	: 547.73 kg
Fine aggregates	: 712.07 kg
Admixture	: 2.72 kg

VIII. CONCLUSION

As we have seen from the above analysis that the cement content that we got from the graph is exactly same as what we have calculated according to IS-10262:2009.The influence of such standard model would possibly obtain the hard balance and equality between controlling the quality and saving time and expense, i.e., this model could be suited in construction to fabricate the essential modification on mix proportion used, to avoid situations where, concrete does not reach the exact design strength or by avoiding mixing of concrete that is unwantedly strong.

This methodology leads to a fast and accurate prediction of values for compressive strength on site. Common methods for estimation of in place strength requires extensive use of curing of mortar cubes at constant temperatures or the use of databases containing a large number of compressive strength values made at many ages and cured at different temperatures. These databases have to be fed with a statistical relevant amount of data before a reliable estimation of the strength can be made. Furthermore, all of these methods requires many hours of lab and field time for testing, collecting and analyzing data.

Furthermore, the existing variables in the model yielded good reasonable results. Also, it is not preferred to load the prediction model with large number of variables, because it is preferred to use a model with lesser number of variables with most higher possible accuracy to assure the rapid and easy use of the model.

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