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Experimental Study on Strength and Durability Index of Concrete Using Mineral Admixture

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***Abstract* :** Concrete is a common material used in the building industry. It is obtained by mixing cementitious materials, water, fine and coarse aggregates and sometimes admixtures in required proportions. Admixtures are added to concrete to modify its properties so as to make it more suitable for any situation. The aim of this research is to study the strength and durability index of concrete using mineral admixture of C30 grade concrete. The objective of this study is to investigate the effect of Mineral Admixture (Silica Fume) on the strength of concrete produced from cement (OPC). From previous studies it is observed that Silica Fume increases the strength of concrete, so this study has been conducted to know the effect of Silica Fume as an admixture on the compressive strength of concrete produced from cement (OPC). It also reflects the impact of adding admixture on the compressive strength and durability characteristics of concrete. Fifteen cubes were cast in mould with dimension 150mm x 150mm x 150mm. 15 cylindrical samples were cast in mould of dimension 100mm diameter and 50mm height for testing C30 grade concrete. Silica Fume was replaced in the following proportions (5%, 10% 15% and 20%) by weight of cement while mixing concrete and cured for 28 days in water. It is found that the optimum replacement of Silica Fume is 10% which gives the maximum compressive strength. Moreover sorpitivity tests on cylindrical sample shows that the durability index of concrete is within the acceptable range.

***Index Terms*: Compressive strength, Durability index, Silica Fume, Sorpitivity, Optimum replacement**

I. INTRODUCTION

Concrete is used in construction of buildings, roads and several other projects around the world. Fresh concrete or plastic concrete is freshly mixed material which can be moulded into any shape. Hardening of concrete is a result of chemical reaction between water and cement which is called hydration. Cement is a basic ingredient of concrete. Any material other than cement, if added in concrete either before or during mixing alters the properties to our desired requirement which are termed as admixtures. (Portland cement is the most common type of cement used while mixing concrete in general of concrete). Admixtures used in concrete influence and enhance the characteristics of concrete irrespective of the mix proportion used in construction activity.

II. LITERATURE REVIEW

The mix design was carried out for M25 and M40 grade concrete as per IS: 10262-2009.Water absorption and sorptivity of fly ash concrete shows lower water absorption and sorptivity at 10% replacement with fly ash for M25 and M40 grade concrete. There after the water absorption and sorptivity shows a increasing trend. Moreover the water absorption and sorptivity of fly ash concrete shows higher water absorption and sorptivity than traditional concrete. Water absorption and sorptivity of M25 fly ash concrete has low water absorption and less sorptivity than M40 grade concrete. Table 1.1 shows the acceptance limits for durability indexes. (Jayesh kumar & Pitroda, 2013)

Table 1 Acceptance limits for durability indexes

Acceptance Criteria		OPI (log scale)	Sorptivity (mm/hr)
Laboratory concrete		› 10	‹ 6
As-built Structures	Full acceptance	› 9,4	‹ 9
	Conditional acceptance	9,0 to 9,4	9 to 12
	Remedial measures	8,75 to 9,0	12 to 15
	Rejection	‹ 8,75	› 15

The aim of another research work was to add silica fume (S F) and fly ash (FA) as a replacement of cement. The methodology used in this research was carried by the researcher through assessing the mechanical properties of Normal Concrete and various SCC mixtures. Tests were conducted for 3. 28 and 130 days but the elasticity modulus test was only canned out for 28 days. For the SCC mixes, Slump flow, T50cm, L box and segregation resistance tests were carried out. Test results indicated that scc specimens with fly ash or silica fume had higher the compressive and tensile strength than Normal Concrete specimens. The results from these tests showed that all SCC mixes had good flow. Filling and passing are ability as well as segregation resistance. (Turk et.al, 2010)**.**

In one of the research work the effect of partial replacement of cement by fly ash/GGBS on the strength and durability properties of M35 grade concrete was determined experimentally. It was observed that 28 days compressive strength of concrete mix with GGBS is greater than that fly ash mixed concrete by 10%. For both concrete mixes with fly ash and GGBS the sorpitivity value is initially high and later decreases monotonically as time lapses. There is a significant reduction in the compressive strength due to sulphuric acid attack for both the mixes. Concrete with fly ash is more resistant to the alkali attack than concrete mixed with GGBS.
(Prakash,Agadi Kishan & Prem kumar, 2019).

Another experimental work carried out sorpitivity test on 56 cubes of 100mm size. In all mix designs cement replacement with wood ash has low sorpitivity values compared to other mixes. Rice husk ash mixed concrete has high sorpitivity compared to other replacements. For M25 and M30 grade concrete sorpitivity value reduces by 53% when compared with conventional mix value. Similarly wood ash replaced mix soritivity values are less than 63% compared to normal mix values in both M30 and M35 grade concrete mix (Gopi Shankar & Rama Rao, 2017).

Experimental investigation has been done to understand the influence of nano materials on the sorpitivity and water absorption of concrete. It is seen that as the percentage replacement of cement with nano cement, nano fly ash and nano silica fume increases the sorpitivity decreases for all grades of concrete. It is also observed that as the percentage replacement of cement with nano cement, nano fly ash and nano silica fume increases the water absorption decreases for all grades of concrete. The coefficient of correlation between the percentage replacement and strength is very close to 1.0 which shows a very strong positive correlation (jemimah Carmichael et al, 2019).

Parameters such as compressive strength, split tensile strength and flexural strength were studied in previous research work. Test results reveal that deterioration factor in compressive strength is 4% at 365days. The deterioration factor of split tensile and flexural strength is 0.96% and 0.6% at 90days respectively. The minimum slip is 1mm and 1.1mm after 28days of testing bond strength for normal water cured and sea water cured samples respectively. The percentage decrease in bond strength is 10.35% for 28days sea water cured samples (Jena & Panda, 2018).

III. MATERIALS USED & MIX DESIGN

Various types of materials used in design mix along with their properties are discussed. Cement, fine aggregates, coarse aggregates and water are used as ingredients in concrete mix. Supplementary cementitious materials such as silica fume are used in this study to replace cement partially by weight to improve the strength of concrete mix.

3.1 Cement

Cement is a key ingredient of concrete. Various types of cement's are used in the construction field according to the requirements of the project site depending on the grade of concrete mix (Sangita, 2016). In this study ordinary Portland cement is used in concrete.
It was obtained from Lafarge Emirates Cement Factory,Oman. The properties of cement is shown in Table 3.1.

Table 3.1 physical properties of OPC

Sl. No.	Properties	Result
1.	Specific Surface area	3403 cm^2/g
2.	Initial setting time Final setting time	152min. 242min.
3.	Soundness: Expansion	0.67mm
4.	Standard consistency	27.5%

3.2 Aggregates

The use of conventional materials in concrete becomes costly day by day hence alternative materials are used as partial or full replacement of naturally available material in the construction field. Sand is a material used in concrete as fine aggregate (Tanveer Ahmed, 2018). Factors such as unavailability of natural coarse aggregates in some parts of the country and high cost in transportation of crushed rock and river gravel from relatively far locations generally lead to increase in construction costs (Hyginus,Uchechi & Chima, 2016). In this study clean dry river sand is used as fine aggregates and crushed rocks in the form of gravel are used as coarse aggregates. Table 3.2 shows the physical properties of fine and coarse aggregates.

Table 3.2: Properties of Aggregates

Material	Specific Gravity	Fineness Modulus
Fine Aggregate	2.5	3.6
Coarse Aggregate	2.7	4.3

3.2 Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. It helps to form the strength giving the cement gel the quantity and quality of water required (Rakesh and Dubey, 2014). In this research normal water which is free from contaminants was used to mix the ingredients of concrete.

3.3 Silica Fume

The addition or replacement of puzzaloanic materials such as silica fume improves the workability, durability, strength and permeability of concrete. In the present study silica fume replaces cement partially by weight. The properties of silica fume (SF) are given in Table 3.3 which was obtained from Oriental Group of Companies, Oman.

Table 3.3 Properties of Silica Fume

Chemical/Physical Property	Content/Results
SiO_2	92.7%
Moisture Content	0.3%
Specific Surface	$19.8m^2/g$
Bulk Density	$648Kg/m^3$
Loss on Ignition	2.1%
Percent retained on 45µm	3.5%

3.4 MIX DESIGN

The process of selecting suitable ingredients of concrete and determining their relative amounts with an objective of producing a concrete of required strength, durability and workability as economical as possible is termed as concrete mix design (Jay Shah and Sachin Shah, 2014). Based on the physical properties of materials the concrete mix design was done using ACI method and the mix proportion was arrived for cement, fine aggregate, coarse aggregate and water. The mix ratio was found to be 1:1.97:2.34 with a w/c ratio of 0.5 for C30 grade of concrete.

IV. METHODOLODY

In this work the ingredients of concrete were mixed according to the mix proportion in a standard mixer machine.15 cubes of standard size (150mm x 150mm x 150mm) and twelve cylindrical samples of 100mm diameter and 50mm thickness were cast. After casting the cube samples were cured for a period of 28days and compressive strength test was done to determine the strength of concrete. Cylindrical samples were also cured for 28days and the sorpitivity test was conducted to find the durability characteristics of concrete mix.

4.1 Casting Process

The cube moulds in a dry condition were applied with oil on the sides and kept ready to fill it with the concrete mix. Concrete was filled in 3 layers and each layer was compacted 25times with a standard tamping rod. The top surface of the moulds were levelled using a trowel (Figure 4.1). The cube samples were labelled with details such as date of casting and percentage replacement of silica fume for identification after the curing process and allowed to dry for 2 to 3 hours at room temperature(Figure 4.2). Similarly the cylindrical samples were cast following the same process with the use of moulds (Figure 4.3 – Figure 4.4).

Figure 4.1 – Levelling Cube Samples with trowel

Figure 4.2 – Labelled Cube Samples

Figure 4.3 – Levelling Cylindrical Samples with trowel

Figure 4.4 – Labelled Cylindrical Samples

4.2 Curing Process

Curing is a process that facilitates maximization of its potential strength. It ensures that concrete experience continued hydration leading to its continued strength gain. Continued hydration is achieved by maintaining satisfactory moisture content and temperature within the concrete for a sufficient period of time (Akinwumi and Abadamosi, 2014). In this study the cube and cylindrical samples were removed from their moulds and immersed in a curing tank for a period of 28 days (Figure 4.5).

Figure 4.5 – Samples cured in a water tank

4.3 Testing of Samples

Testing of hardened concrete plays an important role in controlling and confirming the quality of cement concrete. Compressive strength test is one of major strength tests conducted on concrete. As per Indian Standards 150mm cubes are used for determining the compressive strength of concrete. 100mm cubes are easier to handle and result in material saving, curing space, storage and labour. General specification provides acceptance criteria based on 150mm cube strength (Misbah Gul, 2016). Compressive strength test was done using Universal Testing Machine (UTM) in concrete testing laboratory. The specimen is placed in the testing machine and the bearing surface of the testing machine shall be wiped clean and any loose sand or other material must be removed from the surface of the specimen. The load is applied continuously until the specimen breaks down and no greater load can be sustained. This procedure is repeated for cubes with various mix proportions of concrete replaced with silica fume and the corresponding readings are noted.

Sorpitivity test was conducted on the cylindrical samples after 28days of curing period. Samples were removed from water and kept in an oven at a temperature of 110º C for drying as shown in Figure 4.6. After drying the samples the dry weight

Figure 4.6 - Samples kept in Oven

of samples were measured using a weighing balance nearest to 0.1mg. The side of the samples were sealed with a non-absorbent coating (Figure 4.7) and kept in a tray filled with water such that the water level is not more than 5mm above the base of specimen as shown in Figure 4.8. A stop watch was used to measure the quantity of water absorbed for every 5 minutes until 30 minutes for all the samples. After every 5 minutes the sample is removed and the wet weight is noted. The sorpitivity value for each sample is calculated using suitable formula.

Figure 4.7 – Peripheral surface covered with tape

Figure 4.8 – Sample immersed partially in water

V. RESULTS AND DISCUSSION

The values obtained through compressive strength and sorpitivity tests are used to calculate the compressive strength and sorpitivity results using relevant formula. The compressive strength value for each sample was obtained using the following formula.

$$\text{Compressive strength} = \frac{\text{Ultimate load applied}}{\text{Cross sectional area}}\ (N/mm^2) = \frac{862 \times 10^3}{150 \times 150} = 38.3\ N/mm^2$$

Table 5.1 Compressive Strength Test Results

S.No	Silica Fume Replacement (%)	Ultimate Load (KN)	Average Compressive Strength (N/mm^2)
1	0	862	38.3
2	5	934	41.5
3	10	1026	45.6
4	15	880	39.1
5	20	871	38.7

Based on the above results a bar chart is drawn and the results are discussed below. From Figure 5.1 it is seen that a maximum strength of 41.1N/mm^2 is achieved at 10 percent replacement of cement with silica fume hence it is considered as optimum replacement level of silica fume in concrete mix. The percentage increase in strength for 5 percent SF replacement is found to be negligible when compared with the normal mix. A substantial increase in strength is observed while comparing the optimum replacement strength value with that of conventional mix value. A further increase in SF content decreases as the silica fume loses

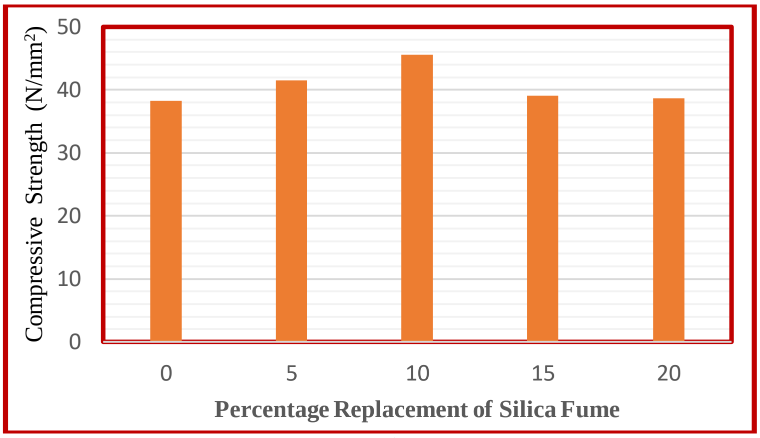

Figure 5.1 – Compressive Strength of Silica Fume Replaced Mix

its void filling effect in concrete. A minimum strength of 38.7N/mm^2 is acquired when 20 percent of cement is replaced with SF. The compressive strength obtained at optimum SF replacement is consistent with previous research work carried out by Faseyemi (2012). In both studies the optimum replacement of SF is found to be 10%. Comparing the optimum SF replaced concrete strength of the present and earlier work it can be noted that the difference is only 7 percent which is within the acceptable limit. Moreover the variation in strength of other replacement levels is meagre while comparing the values of the current study with previous research work. Sopitivity test is done to determine the durability characteristic of concrete mix. Table 5.2 shows the sorpitivity values for all the samples.

Table 5.2 Sorpitivity Test Results

Silica Fume Replacement (%)	Elapsed Time (Minutes)	Dry Weight of Sample (W_1) gm	Wet Weight of Sample (W_2) gm	Sorpitivity Value in 10^{-2} mm/min $^{0.5}$	Sorpitivity mm/hr
0	5	1022.8	1024.4	9.1	5.46
	10	1022.6	1024.7	8.4	5.04
	15	1025	1027.2	7.2	4.32
	20	1024	1026.3	6.5	3.90
	25	1026	1028.3	5.9	3.54
	30	1024	1026	4.6	2.76
5	5	1018	1019.5	8.5	5.12
	10	1020	1022	8.0	4.83
	15	1023	1024.8	5.9	3.54
	20	1026	1028	5.6	3.41
	25	1021	1023	5.0	3.05
	30	1024	1025.5	3.4	2.09
10	5	1010	1011.5	8.5	5.12
	10	1015	1016.7	6.8	4.10
	15	1018	1019.5	4.9	2.95
	20	1021	1020.7	4.8	2.90
	25	1019.5	1021	3.8	2.28
	30	1016	1017.3	3.0	1.80
15	5	1004	1005	5.6	3.41
	10	1009	1010	4.0	2.41
	15	1006	1007	3.2	1.97
	20	1008	1009	2.8	1.70
	25	1010	1011	2.5	1.52
	30	1005	1006	2.3	1.39
20	5	996.2	997.1	5.1	3.06
	10	998.0	998.8	3.2	1.92
	15	1000.5	1001.4	2.9	1.74
	20	1001.6	1002.4	2.3	1.4
	25	1002.8	1003.6	2.0	1.2
	30	1003.3	1004.1	1.6	0.96

Sorpitivity is calculated using the formula (S) = $\frac{I}{t^{0.5}}$

I = Cumulative volume absorbed per unit area of inflow surface = $\frac{\Delta W}{Ad}$

ΔW = Change in weight = $W_2 - W_1$
W_1 = Oven dry weight of cylinder in grams
W_2 = Wet weight of cylinder in grams
A = Surface area of the specimen through which water penetrated = $\frac{\pi D^2}{4}$

D = Diameter of cylindrical sample
d = Density of water
t = Elapsed time in minutes

Sample Calculation

$$I = \frac{\Delta W}{Ad} = \frac{W_2 - W_1}{\pi/4\,(D)^2\, d}$$

$$= \frac{1024.4 - 1022.8}{\pi/4\,(100)^2 \times 10^{-3}}$$

$$S = \frac{I}{t^{0.5}} = \frac{0.203}{(5)^{0.5}} = 0.091 \text{ mm/min}^{0.5} = 9.1 \times 10^{-2} \text{ mm/min}^{0.5}$$

S = 0.091 x 60 = 5.46 mm / hour

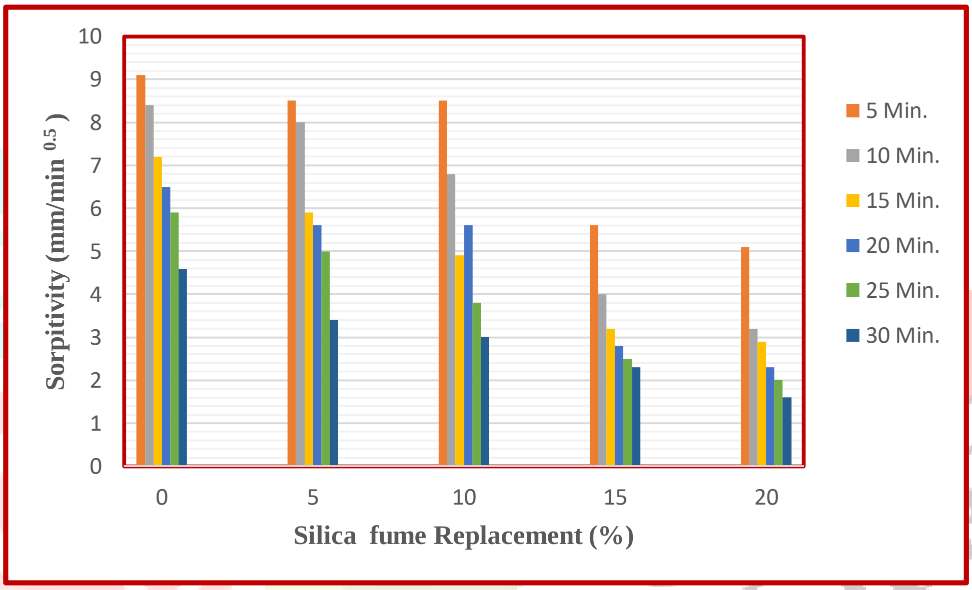

Figure 5.2 – Sorpitivity values of concrete mix

From the above Figure 5.2 it is observed that as the silica fume content increases there is a considerable decrease in the sorpitivity values. Moreover it can be seen that as time lapses the sorpitivity value decreases to a great extent at 15 and 20 percent SF replacement levels due to reduction in the water absorption of cylindrical samples when compared with sorpitivity values of 5 and 10 percent SF replaced mix. Initially there is a proportionate reduction in sorpitivity value with time upto 5% replacement of silica fume. The effect of Silica fume replacement is non-linear at 10% with respect to time and is linear with time at 15 and 20 percent replacement of silica fume in concrete mix. The maximum reduction in sorpitivity value is observed at 20 percent replacement of silica fume with a time duration of 30 minutes. Comparing the conventional mix values with 5% SF replaced mix values the reduction in sorpitivity is maximum at 15 minutes duration and starts to decrease with further time intervals of immersion of sample in water. A similar trend is seen while correlating the values of control mix and other values obtained from SF mixed concrete.

VI. CONCLUSION

Based on the above study the following conclusions are arrived :

- Tests carried out on concrete cube samples reveal that maximum strength is attained at 10 percent replacement of cement with silica fume which is considered as optimum SF replacement in the concrete mix.
- The compressive strength of 10 percent SF replaced mix is 19 percent higher than the conventional mix strength which is found to be 45.6 N/mm^2
- It is also evident that compressive strength values of concrete mixed with various proportions of silica fume is higher than the control mix values.
- The variation of strength between control mix and 20% SF replaced mix is negligible since it produces minimum strength.

- The control mix has the highest sorpitivity values when compared with SF replaced mix values of various proportions irrespective of the time duration.
- The discrepancy between the sorpitivity values of control mix and 5% SF replaced concrete mix is found to be less up to 10minutes duration and rise up to 55% for immersing samples for a period of 15 minutes.
- The maximum rate of water absorption due to capillary suction occurs in 5% SF replaced mix while comparing it with other mixes.
- The rate of reduction in sorpitivity in control mix and 10% SF replaced mix is similar to that of 15% and 20% silica fume replaced concrete mixes.
- The sorpitivity results of all mixes for all time durations is within the acceptable limits for durability index of laboratory concrete.

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REFERENCES

[1] Akinwumi I.I., Gbadamosi Z.O. (2014) Effects of Curing Condition and Curing Period on Compressive Strength Development of Plain Concrete. International Journal of Civil and Environmental Research, 1(2): 83-99.

[2] Gopi Shankar K., Rama Rao G.V. (2017) Variation of Sorpitivity in Diverse Grades of Concrete Proportioned with Fly Ash Wood Ash and Rice Husk Ash. International Research Journal of Engineering and Technology, 4(12): 1626-1633.

[3] Hyginus E. Opara, Uchechi G. Ezeifula, Chima C. Ugwuegbu (2016) Experimental Study of Concrete using Recycled Coarse Aggregate. International Journal of Materials and Structural Integrity, 10(4): 123-132.

[4] Jay H. Shah, Sachin B. Shah (2014) Comparative Study of Concrete Mix Design by Adding various Types of Admixtures. National Conference on Recent Advances in Civil and Structural Engineering, 1: 225-229.

[5] Jayesh Kumar Pitroda, Umrigar F.S. (2013) Evaluation of Sorpitivity and Water Absorption of Concrete with Partial Replacement of Cement by Thermal Industry Waste. International Journal of Engineering and Innovative Technology, 2(7): 245-249.

[6] Jemimah Carmichael M., Prince Arulraj G., Swetha Elizabeth, Jincy K. Johnson, Arunima Tomy, Irene Joy (2019) Assessment of Sorpitivity and Water Absorption of Concrete with Nano Sized Cementitious Materials. International Journal of Engineering and Advanced Technology, 8(3): 847-851.

[7] Jena T., Panda K.C. (2018) Mechanical and Durability Properties of Marine Concrete using Fly Ash and Silpozz. Advances in Concrete Construction, 6(1): 47-68.

[8] Misba Gul (2016) Effect of Cube Size on the Compressive Strength of Concrete. International Journal of Engineering Development and Research, 4(4): 956-959.

[9] Prakash B., Agadi Kishan, Prem Kumar W.P. (2019) Comparative Study on the Strength and Durability Characteristics of M35 Concrete with Partial Replacement of Cement by Mineral Admixtures. International Journal of Scientific Research and Reviews, 8(2): 3390-3402.

[10]Rakesh A. More, Dubey S.K. (2014) Effect of Different Types of Water on Compressive Strength of Concrete. International Journal on Emerging Technologies, 5(2): 40-50.

[11]Sangita Bhamere (2016) Comparison of Compressive Strength of Various Brands of Cement. International Journal of Advances in Mechanical and Civil Engineering, 3(3): 110-112.

[12]Tanveer Ahmed, Pratiksha Malviya, Vikash Kumar Singh (2018) Experimental Study on Concrete by Partial Replacement of Fine Aggregate with Stone Dust and Cement by Glass Powder for M30 Grades of Concrete. International Journal of Engineering Development and Research, 6(1): 386-393.

[13]Turk K., Turgut P., Karatas M., Benly A. (2010) Mechanical Properties of Self Compacting Concrete with Silica Fume/ Fly Ash. 9th International Congress on Advances in Civil Engineering, 1-7.