American Journal of Mechanics and Applications
2019; 7(1): 10-14
http://www.sciencepublishinggroup.com/j/ajma
doi: 10.11648/j.ajma.20190701.12
ISSN: 2376-6115 (Print); ISSN: 2376-6131 (Online)

Effect on Strength of Concrete by Partial Replacement of Ordinary Portland Cement with Silica Fume

Farhan Hussain Wagan[1, *], Naila Qadir Hisbani[2], Ghulam Hussain Wagan[2]

[1]Irrigation Department, Government of Sindh, Karachi, Pakistan

[2]Civil Engineering, Swedish Engineering College, Raheem Yar Khan, Punjab, Pakistan

Email address:
farhan_hussain_4u@yahoo.com (F. H. Wagan)

[*]Corresponding author

To cite this article:
Farhan Hussain Wagan, Naila Qadir Hisbani, Ghulam Hussain Wagan. Effect on Strength of Concrete by Partial Replacement of Ordinary Portland Cement with Silica Fume. *American Journal of Mechanics and Applications*. Vol. 7, No. 1, 2019, pp. 10-14.
doi: 10.11648/j.ajma.20190701.12

Received: May 9, 2019; **Accepted**: June 13, 2019; **Published**: June 26, 2019

Abstract: Now a days, the increased use of scrap/waste as construction material has proved to be very harmful for the environment particularly in tropical countries like Pakistan. Researchers are trying at their best to reduce the adverse impact of waste material on the required environment but yet until more work is required in this regard. In this research paper authors have tried to reuse Silica Fume as construction material as it is very easily available in market as waste material from raw material /by- product industrial waste materials used in mills. The Authors obtained silica fume after proper screening the concerned industrial waste. These industries are available in grater quantity in the province of sindh. The required waste material is available in huge quantity. Silica is very important construction material and by using this as waste we can protect our environment by reusing or proper use of waste material. Here, researchers took different percentage of silica fume and mixed with concrete in varying ratio as replacement of Ordinary Portland Cement as active material in laboratory. Results were came, very interesting and found Tensile Strength, Compressive Strength and Flexural Strengths near to Ordinary Portland Cement also other properties of concrete like pH value, Slump, Curing and Temperature of Concrete shows satisfactory results at various percentage of Replacement with Ordinary Portland Cement. The research work has yielded the satisfactory results and the silica fume can be used effectively as an active construction material. Different percentage shows different results but at 5% and 10% mixing of silica fume indicated high strength as compare to ordinary cement mix and the controlled temperature 28^0c. Further, Engineering is a vast field and it needs more research with passage of time.

Keywords: Concrete, Silica Fume, By-Product Industrial Waste Materials, Compressive Strength, Tensile Strength, Flexural Strength, Workability of Concrete, Result, Discussion

1. Introduction

Pakistan is world's 7th populous country with growth rate 2.6%, at present it is facing many problems like: education, health but the important and urgent is shelter for its drown trodden peoples in this regard research has been done because the most of the part of the country is arid due to no rain fall or very much erected. The 70% population depend upon agriculture and lives in rural areas, for them shelter is important but must be friendly environmental. The vogue material used in construction as active is cement and inert is hill sand and gravel, that have been proved hot. In province of Sindh Pakistan, have such industries which produce such material that can be used as binding material in place of active material and that has proved a friendly environment in tropics, the authors have tried at the best to get this martial that is silica fume and its particle size have been also maintained.

Silica is one of the important material in construction field, with time researches are working to recycle the silica and one of the recycling example is to reuse on behalf of cement in concrete. Through experiments it was observed the strength of silica is enough to use on behalf of cement. Cement is important ingredient of concrete as it works as binding material between fine and course aggregates. Large scale production of cement is causing environmental problems on one hand and depletion of natural resources on other hand. This threat to ecology has led to researchers to use industrial by products as supplementary cementations material in making concrete. In this study, an attempt has been made to investigate the strength parameters of concrete made with partial replacement of cement by silica fume as industrial waste. The global temperature has impacted the environmental values particularly in low rain fed areas on the other hand the increasing population of Pakistan needs the shelter and for that purpose construction material is required at high level. it has become now indispensible to conduct the research work at high level to find the waste material which gives results of friendly environment. Further it serves two functions its dumping as a problem and its reuse will reduce price escalation of constructing the buildings. this material will prove to be very important cheap material in low caste buildings for such a populous country like Pakistan.

2. Literature Review

The early work done in Norway containing silica fume, had very high strengths and low porosities. Since then silica fume usage and development has continued making it one of the world's most valuable and versatile admixtures and cementations products. [1-2]

Yogendran et al (1987), investigated on silica fume in high strength at a constant water binder action (b/w) of 0.34 and replacement percentages of 0 to 25, with varying dosages of HRWKA. The maximum 28 days compressive strength was obtained at 15% replacement level. [3-5]

Hooten RDC (1993) investigated on influence of silica fume replacement of cement on physical properties and resistance to sulphate attack, freezing and thawing, and alkali silica reactivity. He reported that maximum 28 days compressive strength was obtained at 15% silica fume replacement level, at w/c ratio of 0.35 with variable dosages of HRWRA. [6-7]

The use of good quality silica fume with a high fineness and low carbon content reduces the water demand of concrete and, consequently, the use of silica fume should permit the concrete to be produced at a lower water content when compared to a portland cement concrete of the same workability. Although the exact amount of water reduction varies widely with the nature of the silica fume and other parameters of the mix, a gross approximation is that each 10% of silica fume should allow a water reduction of at least 3%.

A well-proportioned silica fume concrete mixture will have improved workability when compared with a portland cement concrete of the same slump. This means that, at a given slump, silica fume concrete flows and consolidates better than a conventional portland cement concrete when vibrated. The use of silica fume also improves the cohesiveness and reduces segregation of concrete. The spherical particle shape lubricates the mix rendering it easier to pump and reducing wear on equipment (Best 1980). It should be emphasized that these benefits will only be realized in well-proportioned concrete. [8-10] Generally silica fume will reduce the rate and amount of bleeding primarily due to the reduced water demand (Gebler 1986). Particular care is required to determine when the bleeding process has finished before any final finishing of exposed slabs.

An exception to this condition is when silica fume is used without an appropriate water reduction, in which case bleeding (and segregation) will increase in comparison to Portland cement concrete. [11]

The calcium content of the silica fume is perhaps the best indicator of how the silica fume will behave in concrete (Thomas 1999), although other compounds such as the alkalis (Na_2O and K_2O), carbon (usually measured as LOI), and sulfate (SO_3) can also affect the performance of the silica fume. Low-calcium silica fume (< 8% CaO) are invariably produced from anthracite or bituminous coals and are predominantly composed of alumino-silicate glasses with varying amounts of crystalline quartz, mullite, hematite and magnetite. These crystalline phases are essentially inert in concrete and the glass requires a source of alkali or lime (for example, $Ca(OH)_2$) to react and form cementitious hydrates. Such fly ashes are pozzolanic and display no significant hydraulic behavior. [12] The inert material serve the function of interlocking and transferring loads. This composite concrete mix can be used in conventional RCC structures like plain concrete mix. [13] Recently in Pakistan a research conducted regarding mechanical properties of concrete by using inert material from used one, the result shows that the compressive and tensile strength are significantly improved. [14]

3. Objectives of Research

1. Main object of this research is to observe the behavior of Silica with replacement of Cement in (M 20 grade) Concrete with different percentage under 28 days curing. Practical was examined on Flexural, Compressive and tensile strengths.
2. To produce strong and economical concrete.
3. To study the strength development in concrete with different dosage of Silica fume
4. To study the effect on compressive strength, Tensile strength and flexural strength using different dosage of Silica fume cure under 28 days.
5. To compare the results of the concrete containing Silica fume with controlled concrete (without Silica fume)
6. To reduce the environmental problems caused by the large scale production of cement.
7. To reduce the cost of material by using silica fume as partial replacement of cement with high cost material.
8. To improve the strength of concrete.
9. To use the by- product industrial waste materials.
10. To bring awareness to civil engineers regarding advantages of new concrete mix.

4. Material Used

1. Concrete mix: Characteristic strength at 28 days = 20 MPa
2. Type of cement:O.P.C
3. Type and size of coarse aggregate: Crushed and of max. size = 20mm
4. W/C ratio: constant (0.46 determined from mix design)
5. Mix ratio: 1: 1.38: 3.5

Note: ratio was used after survey with different construction projects in Larkana city.

***Table 1.** Shows the Replacement of Silica with O.P.C.*

Material	Silica Fume 5%	Silica Fume 10%	Silica Fume 15%	Silica Fume 20%	Silica Fume 25%
Cement	361 kg	342 kg	323 kg	304 kg	285 kg
Silica Fume	19 kg	38 kg	57 kg	76 kg	95 kg
Fine Aggregates	523.5 kg	523.5 kg	523.5 kg	523.5 kg	523.5 kg
Course Aggregates	1346.5 kg	1346.5 kg	1346.5 kg	1346.5 kg	1346.5 kg
Water	190 kg	190 kg	190 kg	190 kg	190 kg
Water/Cement Ratio	0.46	0.46	0.46	0.46	0.46
Remarks			On standard conditions.		

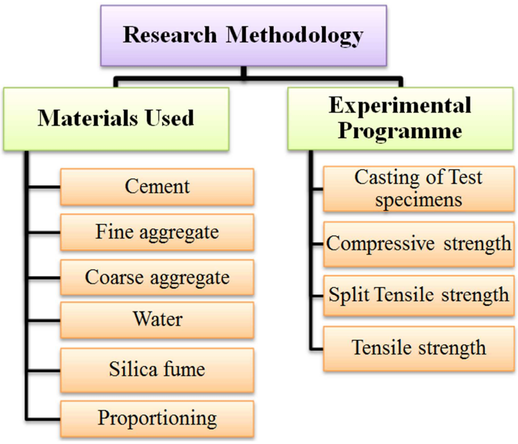

***Figure 1.** Shows Flow Chart of Research Methodology.*

5. Compressive Strength

Compressive strength test through Universal Testing Machine is one of the best way to find out the strength property of concrete at standard level.

Formula for compressive strength

Compressive Strength=Crushing Load/Cross sectional area.

Unit: N/mm^2

***Table 2.** Compressive Strength of cube.*

S.No	1	2	3	4	5	6
S.F Ratio	0	5	10	15	20	25
Specimen1	27.5	19.5	33.5	28	26.7	24.75
Specimen	28.3	21.3	32.3	27	26.5	24.3
Specimen	29	21	32	31	27	25
Average Value	28.17	20.55	32.54	28.6	26.5	24.9

***Table 3.** Compressive Strength of Cylinder.*

S.No	1	2	3	4	5	6
S.F Ratio	0	5	10	15	20	25
Specimen1	19.05	15.15	26.25	21.23	18.79	19.75
Specimen2	20.01	16.3	24.45	21.45	22.25	20.03
Specimen3	19.28	15.9	28.89	21.11	21.68	20.16
Average Value	19.44	15.79	26.51	21.04	20.16	20.06

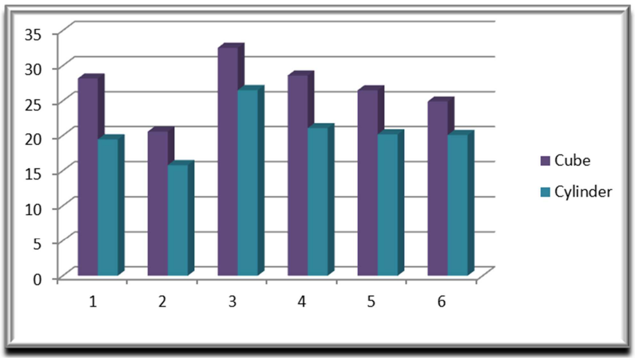

***Figure 2.** Shows Compression Between (Average Values) Compressive strength of Cube and Cylinder.*

6. Tensile Strength Test

Through UTM tensile strength was found with the formula

$$\text{Tensile Strength} = 2P / \pi DL$$

P = crushing load, D = diameter of the cylinder, L = length of cylinder

Unit= N/mm^2

***Figure 3.** Shows Testing Strength Flexural Specimen in UTM.*

Table 4. *Tensile Strength of Cylinder.*

S.No	1	2	3	4	5	6
S.F Ratio	0	5	10	15	20	25
Specimen1	2.08	1.93	2.85	2.6	2.20	2.29
Specimen2	2.45	1.95	2.54	2.22	2.45	2.53
Specimen3	2.34	2	3.03	2.45	2.15	2.35
Average Value	2.3	2	3	2.5	2.25	2.4

7. Flexural Strength Test

Flexural strength test (Modulus of Rupture) is same as tensile strength if material is same. In our research we use dimensions of beam as 500X100X100 (mm). its formula is $\sigma = PL/bd^2$

P= load on beam, L= length of beam, b= breadth of beam, d= depth of beam.

Table 5. *Shows Flexural Strength of Beam.*

S.No	1	2	3	4	5	6
S.F Ratio	0	5	10	15	20	25
Specimen1	6.01	8.6	5.90	8.9	3.5	4.8
Specimen2	5.65	6.51	5.37	8.72	4.32	3.00
Specimen3	4.5	7.3	6.71	7.41	3.81	4.18
Average Value	5.33	7.45	6.02	8.3	3.8	4.01

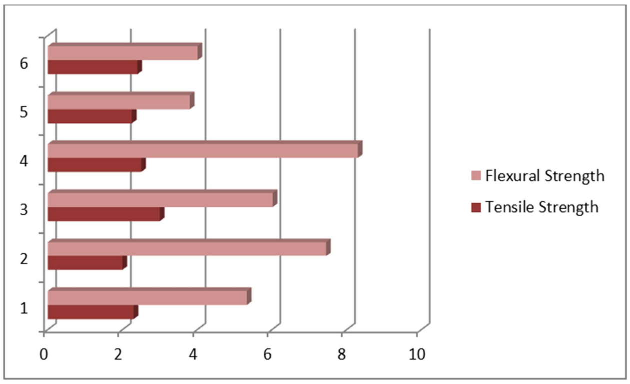

Figure 4. *Shows Compression Between (Average Values) Tensile Strength of Cylinder and Flexural Strength of Beam.*

8. Results and Discussions

8.1. Tensile Strength

The maximum Tensile Strength was observed at 10% replacement of silica fume with cement.

8.2. Flexural Strength

Maximum Flexural Strength was observed at 15% replacement of silica fume with cement.

8.3. Compressive Strength

The cube compressive strength, cylindrical compressive strength, spilt tensile strength and flexural strength are 15.19%, 36.36%, 23.24% and 55.53%, more than those of normal concrete respectively

Silica fume seems to have a more pronounced effect on the flexural strength than the spilt tensile strength.

8.4. Slump

Workability of Concrete is measured to ensure that concrete is workable and can be easily transport, lay at proper position and proper compaction will be done. In our research average slump value came out of 45 mm. where maximum value is 55 mm and minimum value is 40 mm.

8.5. Temperature of Concrete

The high temperature of concrete mix enhanced heat of hydration which impacts the plastic state of concrete. therefore the controlled specific temperature 28°C proved to give required results. the temperature was controlled by mixing cold water to the concrete mix.

8.6. pH Value of Water

pH value show the nature of water used for Batching of Concrete. Particularly for this research the water was potable extracted from ground and its average pH value was 7.54. which satisfy the standard of ACI and BS.

9. Suggestions

1. Research may be carried by using sand stone and lime stone as binding material.
2. The use of port land cement as active material in construction of the buildings has proved to be too hot in tropical countries.
3. The port land cement can be used in insular environmental conditions

10. Conclusion

1. Since the strength of silica fume concrete is more than normal concrete so this type of concrete may be used where high strength is required.
2. To save the quantity of cement, silica fume concrete may be used.
3. To reduce environment problems on one hand and to utilize by product industrial waste material on the other hand, this type of concrete may be used.
4. The used material is cheap and easily available industrial waste as compared to Port land Cement.
5. The silica fume has proved to be the best construction material in continental climate.
6. The silica fume proved to be the best binding material in a concrete mix.

References

[1] Yunsheng Xu and D. D. L. Chung, "Improving the workability and strength of silica fume concrete by using saline treated silica fume" cement and concrete research Journals published (on line), 1999.

[2] Kanstad, Biontegard, O, sellevold, EJ, Hammer, T. A and Fidgestol, P, “Effect of silica fume on crack sensitivity”, concrete International Journal, December 2001 pp 53-59.

[3] Hooten RDC, “Influence of silica fume replacement of cement on physical properties and resistance to sulphate attack freezing and Thawing, and Alkali silica reactivity, Aci Material Journal, No. 2 90 (1993) 143-151

[4] Bhanja, S and Sengupta, B, “Influence of Silica fume on the tensile strength of concrete”, cement and concrete research, 35, (2005) pp 743-747.

[5] Banja S, Sengupta B, “Optimum silica fume content and its mode of action on concrete” Acimaterials Journal, September – October 2003. pp, 407-412.

[6] Tiwari A, Momin I, “Improving early age strength of PSC with indigenous silica fume”, The Indian Concrete Journal, October 2000, pp, 595,98.

[7] Yogendran V, Langen BW, Haque MN, Ward MA, “ Effect of silica fume on high strength concrete”, ACD Material Journal, No. 2, 84 (1987) 124-9.

[8] AASHTO M 295, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete, American Association of State Highway and Transportation Officials, Washington, DC, 2007.

[9] Barrow, R. S., Hadchiti, K. M., Carrasquillo, P. M. and Carrasquillo, R. L., "Temperature Rise and Durability of Concrete Containing FlyAsh," Proceedings of the Third International Conference on theUse of Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, (Ed. V. M. Malhotra), ACI SP-114, Vol. 2, American Concrete Institute, Detroit, 1989, pages 331 to 347.

[10] Carette, G., Bilodeau, A., Chevrier, R. L. and Malhotra, V. M., "Mechanical Properties of Concrete Incorporating High Volumes of Fly Ash from Sources in the U. S.," ACI Materials Journal, Vol. 90, No. 6, 1993, pages 535 to 544.

[11] Concrete Society, The Use of GGBS and PFA in Concrete,” Technical Report No. 40, The Concrete Society, Wexham, Slough, 1991, 142 pages.

[12] Cross, D., Stephens, J. and Vollmer, J., “Field Trials of 100% Fly AshConcrete,” Concrete International, September, 2005, pages 47 to 51.

[13] Rizwan Hussain Wagan, Farhan Hussain Wagan & others, "The Effect of Waste Tyre Steel Fibers distributionCharacteristics on the Flexural Strength of Concrete with Improving Environmental Impact in Pakistan" American Journal of Applied Scientific Research, ISSN 2471-9722 (2017).

[14] Rizwan Hussain Wagan, Farhan Hussain Wagan & others, " Study on flexural Strength of Concrete Beams by Using Steel Fibers Extracted from Wasted Tyres in Pakistan " East African Scholars Journal of Engineering and Computer Sciences volume I, Issue I, ISSN - 2617-4480 (2018).