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Effect of Silica Fume and Polymers on Absorption and Some Mechanical Properties of Concrete Contains Waste Aggregates

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Abstract: This research aims to study silica fume and liquid polymers (Styrene Butadiene Rubber (SBR)) on absorption and some mechanical properties of concrete like compressive strength, tensile strength, and flexural strength of concrete containing waste aggregates. The aim for using silica fume powder is to increase the strength of concrete by reaction of this material with silicates hydroxide that liberates from the hydration of cement. This reaction gives additional cement gel that fills the pores inside cement paste and gives higher strength, less absorption concrete, and more durable concrete. Using the waste aggregates in this study has two benefits: the decrease in concrete cost. Secondly, it is higher mechanical properties by using glass aggregates because of its properties that have zero absorption compared with normal aggregates and higher strength of glass that give concrete additional strength and durability. The effect of silica fume only on concrete was given a 61% increment in compressive strength. However, with polymers together give about 72% increment, flexural strength increased from 3.8 MPa for reference mixes to 10.5 MPa for silica fume mixes and 12.3 MPa for polymer-silica mixes. The absorption decreases from 6.01% to 2.85% for silica mixes and to 1.5% for polymer-silica mixes. SBR can give additional bonds between cement particles or gel with external silica of aggregates and decrease voids inside concrete. So, the use of both silica fume and polymers can give extra bond and strength and fewer voids concrete, and these are the main aims of using both materials in this study. Hence, these findings could be beneficial for manufacturers and builders.

Keywords: *Silica fume, polymers, compressive strength, tensile strength flexural strength, absorption, SBR, waste aggregates*

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I. INTRODUCTION

Concrete properties can be improved by using admixtures, there are a lot of admixtures that can improve concrete properties, the reason of using admixtures in concrete can be attributed by the negative properties of ordinary concrete such as low tensile and flexural strength, low impact strength, low or less durability because of concrete nature that have voids and cavities and high permeability that can reduce strength and durability. Admixtures have a wide varieties such as liquid polymers and solid or powder polymers can improve mechanical properties and impact strength and also durability, also super-plasticizers are very important liquid chemicals can reduce water/cement ratio and highly increase strength of concrete. silica fume is a type of admixtures can provide or give higher mechanical properties than ordinary concrete, and also some admixtures like polymers increase mechanical properties and decrease the permeability of

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concrete and increase the durability of concrete. silica fume powder has higher fineness than cement and reacts with some chemicals that liberate from hydration of cement and give less porosity concrete, and that lead to increase values of the compressive, tensile and flexural strength of concrete and increase durability [1, 2, 3]. Polymers like SBR give higher mechanical properties and improves durability for concrete and also increase ductility and low porosity of concrete [4, 5, 6, 7]. Waste aggregate concrete can gives very wide range of benefits such as, low cost concrete, maybe higher strength or additional strength for concrete, such as using glass waste aggregates or slag aggregates and decreasing environmental pollution due to wastes. Waste materials can sometimes decreasing some mechanical properties of concrete like compressive strength but give higher values of tensile and flexural strength such as the using of waste plastics or polyethylene wastes, and some other waste materials can increase the compressive strength, tensile and flexural strength of concrete such as the using of waste marble or waste Gabbro rocks as coarse and fine aggregate [8, 9] and that can be attributed to highly strength of these two materials such as compressive and flexural strength, so that give concrete additional strength. This research aims to improve mechanical properties and decrease absorption for a special type of concrete that has crushed waste glass as coarse aggregate to decrease the cost of concrete and also cleaner environment by using waste glass and using two types of admixtures such as silica fume and liquid polymers.

II. LITERATURE REVIEW FOR WASTE AGGREGATES, WASTE MATERIALS, SILICA FUME, AND POLYMERS

Many researches study the using of waste materials in concrete, waste materials are very high in varieties such as waste concrete due to expire or useless buildings, waste ceramics and tiles, waste glass, waste bricks, furnace slag, waste plastics, papers, woods, etc. Researcher [10] use waste plastics in concrete and got good and higher results in tensile strength of new concrete, researcher [11] had studied the effect of silica fume on some mechanical properties of concrete like compressive strength and got high strength concrete with 74 MPa comparing with reference ordinary concrete mix which was with strength of 63 MPa he also got 18% increment in strength by using 15% silica fume. Polymers used widely in concrete researches, liquid polymers such as SBR used in concrete construction and provide less permeable concrete and more durable concrete, and also give higher mechanical properties of concrete, researcher [12] got 21-26% increment in flexural strength of concrete using polymers as admixture in concrete, also researchers [13] studied the influence of polymers on some mechanical properties of concrete and they got higher compressive and tensile strength for polymer concrete by using polymers. Researcher [14], got excellent increment in flexural strength of concrete by using 15% SBR polymers as percentages of cement weight. [15] studied the effect of SBR polymer on compressive strength and absorption of concrete and he got less absorption concrete by using SBR, compressive strength increased from 35 MPa to about 40 MPa and absorption decreased from 4.5% to 2.5%. Polyvinyl-acetate polymers is a liquid polymers and it can improve some mechanical properties of normal concrete like tensile and flexural strength, [16] used waste vinyl-acetate from paint and got higher values in tensile and flexural strengths up to 1%, polyvinyl-alcohol also used in concrete to increase strength, poly vinyl alcohol is a type of polymers used as admixture in concrete, researcher [17] had used this type of polymer and studied the effect of it on some mechanical properties of concrete like compressive strength and he used this powder polymer as percentages of cement weight ranged from 0 percent, 0.25 percent until 1%, he got about 63% increment in compressive strength. SBR is widely used in concrete construction as admixture and it's a liquid polymer with specific gravity of about 1.1 and it used as percentages of cement weight in concrete, this type of polymer can improve physical and mechanical properties of concrete, some researches were found that 10% is the optimum value for optimum mechanical properties such as compressive strength, flexural strength and tensile strength and other researchers found out that the optimum value is 15%, and that depends on mix proportions of concrete and also types of aggregates and cement and also water/cement ratio used, SBR also increase the impact strength of concrete due to its ball bearing behaviour or action of particles of polymers [18] and this polymer also reduce the voids inside concrete and that leads to less permeability property of concrete and that can make concrete more durable especially when it subjected to water or salty water or when concrete used in piles or piers or foundations that can be attached with salty or chloride water. Some waste materials can be used as fibres in concrete, for example, the saw dust, date palm trunk [19] and that give higher flexural strength and higher tensile strength but less compressive strength, also waste aluminium from coca cola cans can be useful if it used as fibres in concrete and it can be increase compressive strength, tensile strength and flexural strength of concrete. [20] used waste coca cola cans as fiber in concrete [20], they got a lot of benefits when using this waste fibres by

cuttings the cans to small pieces and use it as different percentages in concrete ranged between 0% to 2.5% by volume of the concrete, and by using aluminium strips as fibres, the compressive strength increment by using aluminium fiber was 22%, the tensile strength increment was 187% and flexural strength was highly increased with increment of about 238% with comparison with ordinary concrete that have no fibres.

III. EXPERIMENTAL PROGRAM

A. *Materials*

The sulfate resistance cement used in all mixes, coarse aggregate used in this study with 16 mm maximum size, Table 1 shows grading of coarse aggregate used in the study. The waste glass aggregate was crushed and replaced with 50% from ordinary coarse aggregate then taking the sieve analysis to confirm the specifications, fine aggregate grading is shown in Table 2. both sieve analysis of fine and coarse aggregate confirms Indian standards IS-383 [21].

Table 3 shows the ingredients for each one cubic meter of concrete.

B. *Specimens and Testing*

Cubic steel molds specimens with 100*100*100 mm were used to cast concrete for testing compressive strength, the cubes were tested in compressive testing machine in age of 28 days, 3cubes for each mix were used and then taking the average as final result of compressive strength of specified mix concrete., cylinders with 100*200 used for testing tensile strength (splitting test method), also 3 cylinders were used for each mix and tested after 28 days for tensile strength and taking average of three specimens as final result of concrete mix tensile strength. Small beams (or prisms) with dimensions of 100*100*400 mm for testing the flexural strength of concrete, Fig. 1 shows some specimens before testing. The flexural test done by using third point loading, and the value of flexural strength obtained from equation 1, all specimens tested after 28 days. Fig. 2 shows the beam under testing for the flexural test. Third point loading point done by using the British standards B.S -1881 [22] which used this type of test to calculate the flexural strength of plain concrete and this method used beams that is simply supported subjected to two concentrated loads with equal distances between each support and each force. In this study three beams for each mix casted then left for 1 day to hardened then submerged in water for 27 days, then after these periods (28 days), its ready to be tested for flexural strength. After testing beams, it can be taking the average value of three records of flexural strength of concrete. All beams in this research tested in 28 days, and also for the compressive and tensile strength tests.

$$Fr = P^{*}L/b^{*}d^{2} \tag{1}$$

Tensile strength value obtained from equation 2

$$Ft = 2P/\pi^{*}D^{*}L \tag{2}$$

Absorption test is done by using cylinders and dried in an oven in 100 degrees for 24 hours, then taking the dry weight, then it cooled and submerged in water for 24 hours then taking the saturated weight, Fig. 3 shows cylindrical specimens in the oven for absorption test. The % absorption value is obtained from equation 3.

$$\%ABS = [(WsWd)/Wd] * 100s \tag{3}$$

Where:

Ws = Saturated weight of concrete

Wd = Dry weight of concrete

ABS: Absorption of concrete

Fig. 1. Some specimens before testing

Fig. 2. Concrete beam under testing for flexural strength

Fig. 3. Drying specimens in the oven for absorption test

TABLE 1
GRADING OF COARSE AGGREGATE USED IN THE STUDY

Sieve size, mm	% Passing by weight	IS-383 Standards
20	100	100
16	91.3	90 - 100
10	35.6	30 - 70
5	1.2	0 - 10

TABLE 2
GRADING OF FINE AGGREGATE USED IN THE STUDY

Sieve Size	% Passing	IS-383, Standard for zone 2
10 mm	100	100
5 mm	95.2	90 100
2.36 mm	86.7	75 - 100
1.18 mm	78.8	55 -90
600 mic	58.1	35 -59
300 mic	27.0	8 -30
150 mic	8.1	0 -10

TABLE 3
INGREDIENTS OF CONCRETE REFERENCE MIX USED IN THE STUDY

Ingredient, for each i cubic meter concrete	Cement, KG	Sand, KG	Coarse aggregate, KG	Water	Superplasticizer
	500	740	970	202	0.8 liter for 100 kg cement

IV. RESULTS AND DISCUSSION

Table 4 shows the results of mechanical properties and absorption percentages for concrete does not contain polymers, the compressive strength increased when adding silica fume, the compressive strength increased from 40.23 MPa for reference mixes to 64.8 MPa when adding 15% silica fume, tensile strength also increased from 2.88 to 5.2 MPa, and flexural strength increased from 3.8 to 10.5 MPa, the main reason for this increment is the action of silica fume inside concrete, the silica fume is highly and quickly react with some hydrated particles of cement especially calcium hydroxide and forming additional gel particles that fill the pores and cavities inside concrete, and therefore gives additional strength to concrete [23, 24]. Fig. 4, 5, 6, and 7 show the relationship between compressive, tensile, flexural strength, and absorption with percentages of silica fume used in the study. Absorption decreased highly when using silica fume, it decreased from 6% to 2.8% and the reason attributed to the less porosity of concrete containing silica fume.

Table **??** shows the using both silica fume and 10% SBR polymer, it can be seen from table that compressive, tensile and flexural strengths increased more than using only silica fume, compressive strength increased from 40.23 to 69.2 MPa, tensile strength increased to 5.61 MPa and flexural strength increased to 12.3 MPa, and the reason for this case can be attributed to the formations of polymer films inside concrete [25], those polymer films can bond highly with external silica of aggregates and also bond with gel particles and that give another strength or additional strength to concrete [26, 27], absorption also decrease more than concrete with silica only, the absorption here decrease to only 1.52%. Fig. 8, 9, 10, and 11 show comparison between these two types of concrete for absorption and mechanical properties. Comparing with some previous studies, the compressive strength improvement by using silica fume exceeds 60% in this research, while previous studies show 15-47% increments by using silica fume in ordinary concrete [28, 29] and that may be attributed by using glass aggregates that give additional bond with cement gel in this study. It should be noted that the concrete with silica fume have less values for the mechanical properties such as compressive strength, tensile strength and flexural strength and have higher values for water absorption compared with silica fume concrete modified with SBR, Fig. 11 illustrate the comparison between concrete with silica fume and concrete modified with silica fume and SBR polymer. 2.8% absorption for silica fume concrete, and 1.5% absorption for silica-polymer concrete was found in this research and the improvement is about 86% and that make concrete with less permeability and high durability when using both materials (silica fume and polymers liquid), the new concrete can behave very well for concrete submerged with water or salty water or soil, such as concrete piles, foundations or footings, so even when silica fume and polymers have high costs but the benefits are larger and that was the reason of using both materials as admixtures in concrete in this study. The main reasons of improvement in absorption of concrete and makes concrete with less absorption by using silica fume and SBR can be attributed to the double effect of SBR which fill pores inside concrete and bond very well by polymers films with particles of cement and external silica of aggregates and also the effect of silicafume which react with calcium hydroxides that liberate from reaction of cement compounds with water and that lead to form extra gel that fill the pores inside concrete [30].

TABLE 4
MECHANICAL PROPERTIES AND ABSORPTION RESULTS OF CONCRETE FOR DIFFERENT RATIOS OF SILICA FUME (FOR MIXES NOT CONTAINING SBR POLYMER)

Mix type	Compressive strength, MPa	Tensile strength, MPa	Flexural strength, MPa	Absorption %
Reference mix (with 50% crushed glass as coarse agg)	40.23	2.88	3.85	6.01
With 5% silica fume	48.92	4.26	5.34	4.50
With 10% silica fume	63.73	5.04	9.46	3.27
With 15% silica fume	64.85	5.23	10.55	2.85

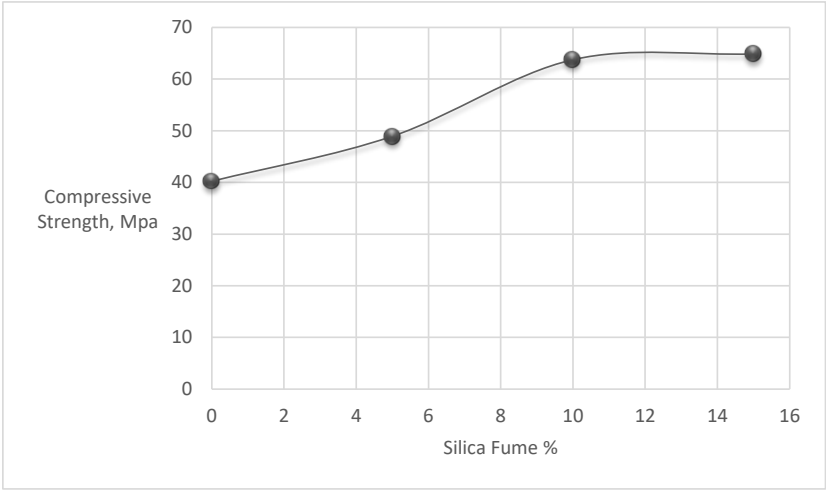

Fig. 4. The relationship between compressive strength and percentages of silica fume, for silica fume concrete (without polymers)

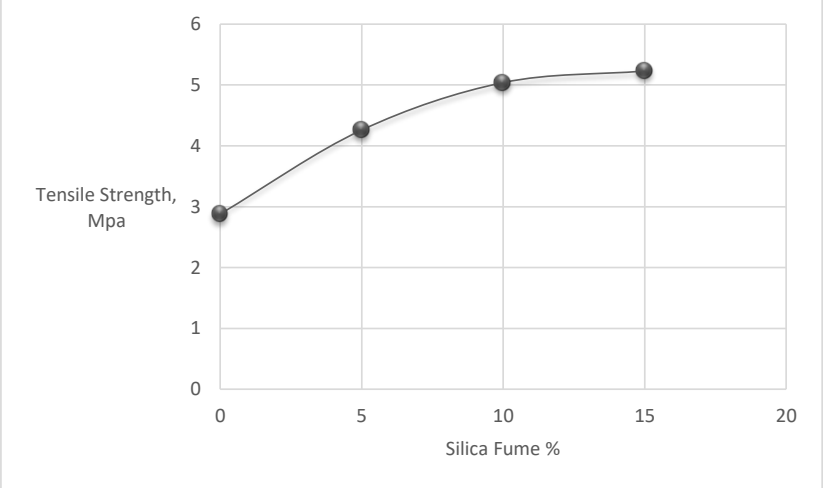

Fig. 5. The relationship between tensile strength and percentages of silica fume, for silica fume concrete (without polymers)

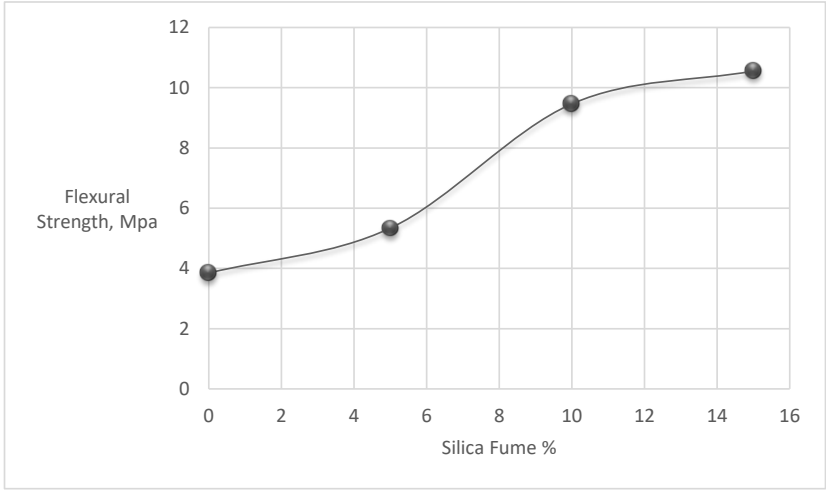

Fig. 6. The relationship between flexural strength and percentages of silica fume, for silica fume concrete (without polymers)

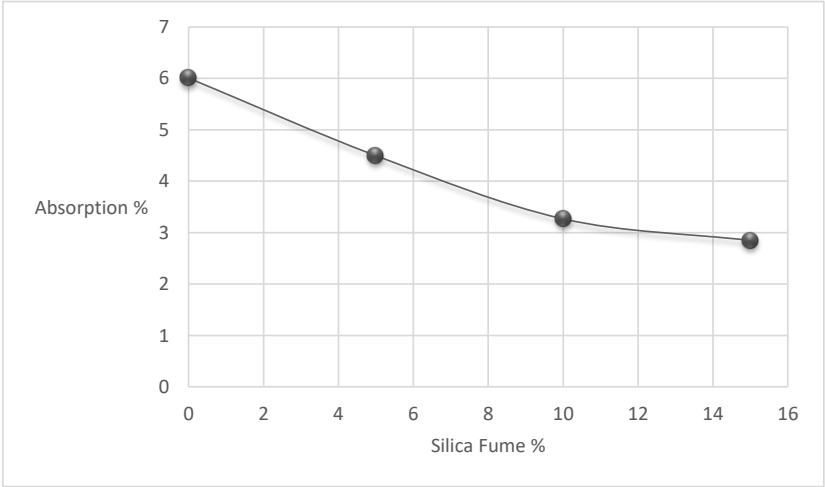

Fig. 7. The relationship between absorption and percentages of silica fume, for silica fume concrete (without polymers)

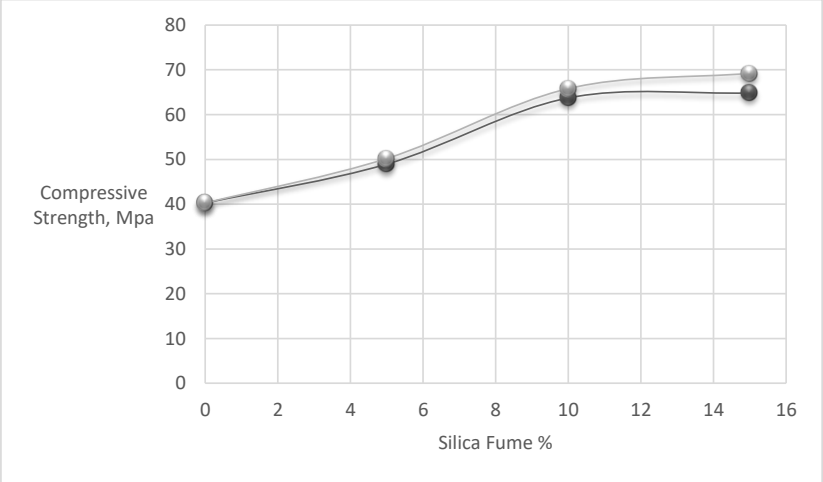

Fig. 8. Comparison between silica-polymer concrete (above) and silica concrete for the compressive strength test

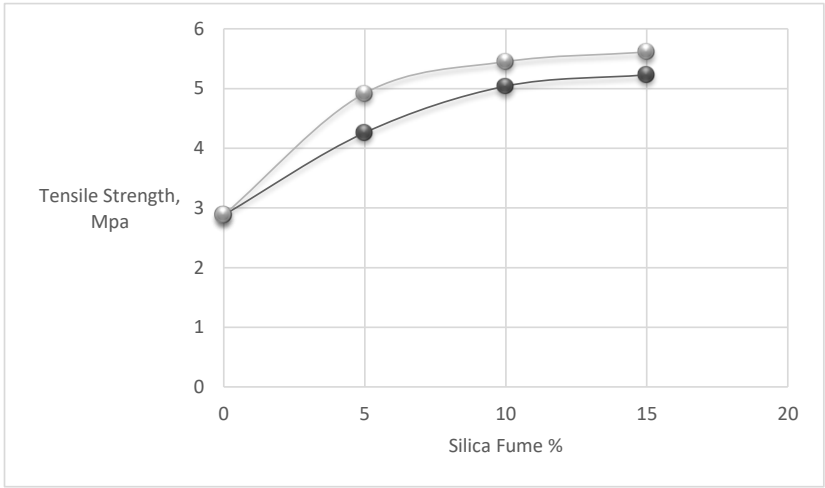

Fig. 9. Comparison between silica-polymer concrete (above) and silica concrete for the tensile strength test

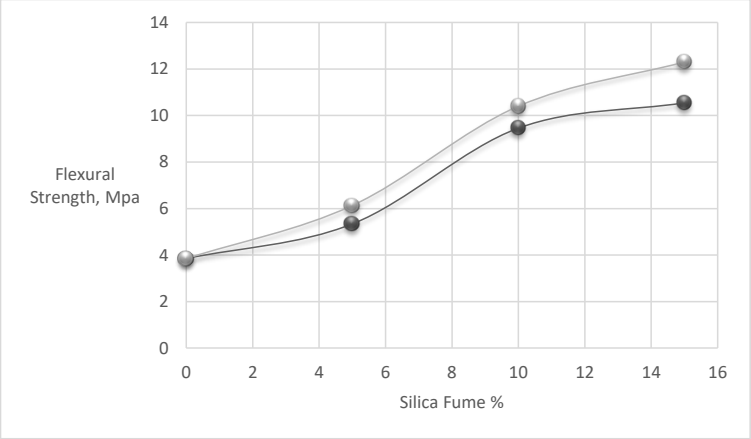

Fig. 10. Comparison between silica-polymer concrete (above) and silica concrete for the flexural strength test

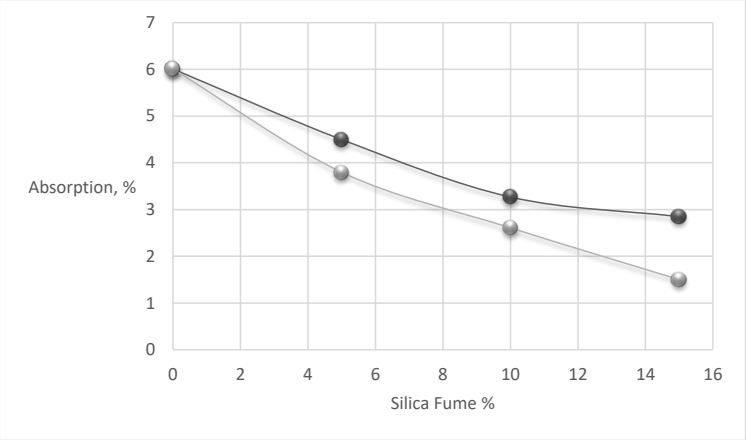

Fig. 11. Comparison between silica-polymer concrete (lower curve) and silica concrete (upper curve) for absorption test

V. CONCLUSION AND RECOMMENDATIONS

1- Silica fume give higher mechanical properties compared to ordinary mixes, compressive strength increased from 40.2 to 64.8 MPa by adding 15% silica fume, flexural and tensile strengths also increased by adding silica fume, tensile strength increased from 2.8 MPa to 5.2 MPa (increment equal about 85%), flexural strength increased from 3.8MPa to 10.5 MPa and that was very high increment in third point flexural strength (the increment about 176%), and the absorption decrease from about 6% to 2.8% and that is very significant effect that leads to reduce permeability and increase durability of concrete.

2- By using both SBR latex and silica fume, the mechanical properties of concrete increased highly or in higher values compared with silica-concrete, the compressive strength increased from 40.2 MPa to 69.2mpa (about 72%), tensile strength increment was about 94.8%, flexural strength increment was very high (about 219%), and absorption reduced to only 1.5%.

3- For future studies it can be recommend to study different types of polymers such as polyvinyl-acetate or polyvinyl-alcohol polymers and effect of them on behaviour of concrete and silica fume concrete.

Declaration of Conflicting Interests

The authors conform that there are no conflicts of interests.

REFERENCES

[1] N. Amudhavalli and J. Mathew, “Effect of silica fume on strength and durability parameters of concrete,” *International Journal of Engineering Sciences & Emerging Technologies*, vol. 3, no. 1, pp. 28–35, 2012.

[2] A. Jain and P. Pawade, “Characteristics of silica fume concrete,” *International Journal of Computer Applications*, vol. 975, pp. 23–26, 2015.

[3] L. Jeeyoung, G. Habimana, H. Kyungbo, K. T. Jeong, and K. Sunkuk, “Panelizing algorithms for free-form concrete panels considering esthetic surfaces,” *International Journal of Technology and Engineering Studies*, vol. 1, no. 3, pp. 81–86, 2015. doi: https://doi.org/10.20469/ijtes.40003-3

[4] K. Soni and Y. Joshi, “Performance analysis of

styrene butadiene rubber-latex on cement concrete mixes," *Journal of Engineering Research and Applications*, vol. 3, no. 1, pp. 838–844, 2014.

[5] N. H. A. Rahim, K. Kamaruddin, and H. M. Saman, "Properties of micro fine quarry dust concrete," *International Journal of Technology and Engineering Studies*, vol. 1, no. 1, pp. 8–13, 2015. doi: https://doi.org/10.20469/ijtes.40002

[6] S. Sung, J. Lim, S. Palikhe, K. Han, and S. Kim, "Development of the system form for concrete casting in the girder bridge slab-purlin hanging system," *Journal of Advances in Technology and Engineering Research*, vol. 2, no. 2, pp. 18–21, 2016. doi: https://doi.org/10.20474/-jater2.1.4

[7] T. H. K. Kang and J. Ki Hong, "Detailed analytical methods for simulation of concrete, target resistance against F-4D jet impact," *Journal of Advances in Technology and Engineering Studies*, vol. 4, no. 1, pp. 1–8, 2018. doi: https://doi.org/10.20474/jater-4.1.1

[8] T. Mezher, Q. Jabal, and A. Zwain, "Some mechanical properties of waste marble aggregate concrete reinforced with local steel pins as steel fibers," *International Journal of Civil Engineering and Technology (IJCIET)*, vol. 10, no. 1, p. 105111, 2019.

[9] Wikipedia. Gabbro. [Online]. Available: https://bit.ly/1SaD2kC

[10] M. Hossain, P. Bhowmik, and K. Shaad, "Use of waste plastic aggregation in concrete as a constituent material," *Progressive Agriculture*, vol. 27, no. 3, pp. 383–391, 2016. doi: https://doi.org/10.3329/pa.v27i3.30835

[11] O. A. Ahmad, "Production of high-performance silica fume concrete," *American Journal of Applied Sciences*, vol. 14, no. 11, pp. 1031–1038, 2017. doi: https://doi.org/10.3844/ajassp.2017.1031.1038

[12] P. Palson, "Mechanical properties of latex modified concrete with silica fume," *International Journal of Civil Engineering and Technology*, vol. 8, no. 9, pp. 701–710, 2017.

[13] M. Yahya, B. Zhang, and M. Barker. Influence of Styrene-Butadiene-Rubber latex (SBR) and Polyvinylidene Chloride (PVDC) on mechanical properties of HPC. [Online]. Available: https://bit.ly/2Wic7hf

[14] B. Al Numan, F. Ahmed, and K. Hamad, "Effect of styrene butadiene rubber latex on mechanical properties of eco concrete: Limestone powder concrete," *ARO-The Scientific Journal of Koya University*, vol. 6, no. 1, pp. 1–6, 2018. doi: https://doi.org/10.14500/aro.10212

[15] G. Shete and K. Upase, "Evaluation of compressive strength and water absorption of Styrene Butadiene Rubber (SBR) latex modified concrete," *International Journal of Modern Engineering Research (IJMER)*, vol. 4, no. 10, pp. 40–44, 2014.

[16] M. Ismail, A. Bhutta, and A. H. Noruzman, "Mechanical properties of polymer modified concrete with addition of vinyl acetate waste," in *The Seventh International Structural Engineering and Construction Conference*, Honolulu, HI, 2013. doi: 10.3850/978-981-07-5354-2_M-44-392

[17] S. R. Warghane, "Use of polyvinyl alcohol in pervious concrete to increasing the strength," *International Journal for Research in Applied Science and Engineering Technology*, vol. 6, no. 5, pp. 1336–1340, 2018. doi: https://doi.org/10.22214/ijraset.2018.5219

[18] J. J. Assaad, "Development and use of polymer-modified cement for adhesive and repair applications," *Construction and Building Materials*, vol. 163, pp. 139–148, 2018. doi: https://doi.org/10.1016/j.conbuildmat.2017.12.103

[19] H. Gil, A. Ortega, and J. Pérez, "Mechanical behavior of mortar reinforced with sawdust waste," *Procedia Engineering*, vol. 200, pp. 325–332, 2017. doi: https://doi.org/10.1016/j.proeng.2017.07.046

[20] R. Muwashee, H. A. Al-jameel, and Q. A. Jabal, "Investigating the behavior of mortar and concrete reinforced with aluminum waste strips," *International Journal of Engineering and Technology*, vol. 7, pp. 211–213, 2018.

[21] Burea of India Standard. (1971) Indian standards specifications for coarse and fine aggregates from natural sources for concrete. [Online]. Available: https://bit.ly/2EFUaPJ

[22] British Standards Specifications, "method for determination of flexural strength for concrete," BSI - Standards for Testing Concrete, London, UK, Tech. Rep., 1881.

[23] M. A. Rasol, "Effect of silica fume on concrete properties and advantages for Kurdistan Region, Iraq," *International Journal of Scientific & Engineering Research*, vol. 6, no. 1, pp. 170–173, 2015.

[24] D. King, "The effect of silica fume on the properties of concrete as defined in concrete society report 74, cementitious materials," in *37th Conference on Our World in Concrete and Structures*, Singapore, 2012, pp. 29–31.

[25] X. Qu and X. Zhao, "Influence of SBR latex and HPMC on the cement hydration at early age," *Case studies in construction materials*, vol. 6, pp.

213–218, 2017. doi: https://doi.org/10.1016/j.cscm.2017.04.006

[26] Y. Ohama, "Recent progress in concrete-polymer composites," *Advanced Cement Based Materials*, vol. 5, no. 2, pp. 31–40, 1997. doi: https://doi.org/10.1016/s1065-7355(96)00005-3

[27] Y. Ohama, "Polymer-based admixtures," *Cement and Concrete Composites*, vol. 20, no. 2-3, pp. 189–212, 1998. doi: https://doi.org/10.1016/s0958-9465(97)00065-6

[28] V. Srivastava, R. Kumar, V. Agarwal, and P. Mehta, "Effect of silica fume on workability and compressive strength of OPC concrete," *Journal of Environmental Nanotechnology*, vol. 3, no. 3, pp. 32–35, 2014. doi: https://doi.org/10.13074/jent.2014.09.143086

[29] R. koul, S. Sharma, D. Raina, S. Singh, V. kumar, B. Singh, P. Sharma, H. Khajuria, A. Dewangan, E. R. Magotra, and E. I. Lidoo, "Effect of silica fumes on the compressive strength of concrete," *International Journal of Engineering Research And Management*, vol. 5, no. 3, pp. 19–24, 2018.

[30] S. Muralidharan, A. Parande, V. Saraswathy, K. Kumar, and N. Palaniswamy, "Effect of silica fume on the corrosion performance of reinforcements in concrete," *Zaštita Materijala*, vol. 49, no. 4, pp. 3–8, 2008.