National Journal of Advanced Research
ISSN: 2455-216X; Impact Factor: RJIF 5.12
Received: 21-11-2018; Accepted: 22-12-2018
www.allnationaljournal.com
Volume 5; Issue 1; January 2019; Page No. 22-27

Utilization of silica fume and steel powder in concrete

Boskee Sharma
Civil Engineering Department, M.I.T.R.C, Alwar, Rajasthan, India

Abstract
Cement concrete are designed to resist the disastrous surrounding effects such as high temperature variations, high humid environments, coastal areas, industrial areas and other pollutant types. The major advantage of these materials is the replacement of cement or other ingredients. The use of waste material can consume these. This can also improves the properties of concrete in fresh and hydrated.
In the current study a set of experiments had been performed to compare the use of 3 different types of mixes formed by replacing cement by silica fume, sand by steel powder and in third mix both the materials are used together for M25 grade of concrete. Cement and sand were replaced in different proportions such as 10%, 15%, 20%, 25%, and 30% by these materials. The ingredients are mixed in 1:1:2 proportions. The properties studied are 3 days, 21 days and 28 days compressive strengths and workability by compaction factor. The main conclusions drawn are inclusion of silica fume increases the compressive strength up-to a certain proportions and then reduces the strength, it also effects the setting time and consistency. Steel powder increases the strength but reduces the compaction factor. Comparatively higher early strength gain (3-days) is obtained with steel powder concrete.

Keywords: cement concrete, silica fume, steel powder, compressive strength etc

1. Introduction

Several researchers investigated the suitability of these waste materials as construction materials by partially replacing cement, sand or aggregate in concrete and mortar with these materials.

Many works have been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete. Thomas and Shehata [1] have studied the ternary cementitious blends of Portland cement, silica fume, and fly ash offer significant advantages over binary blends and even greater enhancements over plain Portland cement. Sandor [2] have studied the Portland cement-fly ash – silica fume systems in concrete and concluded several beneficial effects of addition of silica fume to the fly ash cement mortar in terms of strength, workability and ultra sonic velocity test results

Lam, Wong, and Poon [4] in their studied entitled Effect of fly ash and silica fume on compressive and fracture behaviors of concrete had concluded enhancement in strength properties of concrete by adding different percentage of fly ash and silica fume.

Replacement of sand with waste powder as a fine aggregate in concrete draws severe awareness of researchers and investigators. The utmost compressive and flexural strengths were experimented for specimens containing a 6% dissipate mud when compared with ordinary mix and it has been also instigate that mixing of waste powders up to 9% could efficiently be used as a preservative material in civil materials (Singh and Nanda) [5].

With the addition of obtained waste marble powder the characteristics of concrete steadily increases up to certain bound. With the addition of Marble powder early strength increase in concrete is elevated. It has been revealed that the best percentage for substitution of marble powder with cement and it is approximately 10% binder for both casted cubes and cylinders (Valeria *et al.*) [6].

According to Hendriks and Janssen (2003) [7] there are numerous alternatives for the reuse of recycled materials in structures. For each alternative a number of scientific and environmental aspects are applicable. Also, explains numerous models which can be utilized to take the optimal assessment. In common the world-wide used Life Cycle Assessment can be applied as a multi-parameter model for the ecological effects.

Khari *et al.* (1995) [8] explained that minimum essential mixing time has been determined from the development of the power applied to the tool during mixing. It has been concluded that high w/c values resulted in short stabilization times. In addition, the contents of silica fume and quartz flour as well as the type of cement and super plasticizer affected the stabilization time considerably.

Concrete prepared using recycled aggregates have been used for many years in several countries which go ahead the way in this concept (Kwan *et al*., 2012) [9]. Many major projects have been completed in these countries with cheering results. Its utilization is so widely spread worldwide, so, that several countries have adopted it and are preparing regulatory documents about its use.

Application of fine recycled aggregates in concrete improves the properties of cement concrete. Several researchers determined effect over most vital properties of concrete compressive and tensile strength; modulus of elasticity; water absorption; shrinkage; carbonation and chloride penetration. For the long-term durability of reinforced or pre-stressed concrete carbonation and chloride penetration are significant properties. Experiments have been performed by preparing concrete mixes with different rates of substitution of fine aggregates with fine recycled aggregates obtained from crushed concrete. Testing results had been compared with concrete of same mix proportions without any recycled aggregates.

Reuse of waste materials from construction industry is a creative step towards sustainable and green construction (Uygunoğlu, 2011) [10]. Usage of waste materials in construction has been considered as good thought; however, this thought has been not accepted widely between the researchers. But, through proper concrete mix design the concrete having recycled aggregate can achieve target strength and is appropriate for broad variety of applications in construction. Good knowledge regarding durability and properties influencing durability is required for applying recycled aggregate in construction.

Pacheco-Torgal and Jalali S, 2011 [11] presented important information over the robustness and design methodology for recycled aggregates. Parameters investigated in this study are compressive strength, ultrasonic pulse velocity, shrinkage, water absorption and intrinsic permeability. It has been observed from results that the in recycled aggregates concrete ultrasonic pulse velocity is higher, and it contains low water absorption intrinsic permeability. By replacing 80% of the total coarse aggregate with recycled aggregates and by following mix design method proposed by the Department of Environment, target crushing strength can be achieved.

Radlinski, Olek and Nantung [12] in their experimental work entitled effect of mixture composition and Initial curing conditions on the scaling resistance of ternary concrete have find out effect of different proportions of ingredients of ternary blend of binder mix on scaling resistance of concrete in low temperatures.

Barbhuiya, Gbagbo, Russeli and Basheer [13] studied the properties of fly ash concrete modified with hydrated lime and silica fume concluded that addition of lime and silica fume improve the early days compressive strength and long term strength development and durability of concrete.

Accumulation of waste marble dust in cement has been presented by Aliabdo [14], in this work cement mortar and concrete composed by applying marble dust have been found to be improved, with the addition of marble dust. Concrete composed adding of marble dust as replacement of sand reveals improved act compared to replacement of cement. The chief idea of this investigation has been found to be examine the opportunity of utilizing waste marble dust in cement and concrete making.

The usefulness of waste marble dust as preservative material combine together with cement is examined by Aruntaş *et al*. [15]**.** For this plan, waste marble dirt added cements were attained by inter blending with marble dust with Portland cement ashes at dissimilar combine ratios at different percentages by weight. Standard cube size of mortar prisms has been artificial with the obtained cements. On these mortar prisms, strength tests have been accepted sample on different days of curing.

Emre and Şükrü in 2015 [16] examined the blended cements produced by using the building stone powder were out to sulfate concentration for unusual properties. Prepared mortar specimens had been cured under water for 28 days and then exposed to several different extents of sodium sulfate solution for large number of days. Performances of cements had been determined by testing properties like compressive and tests. In mixed binders exclusively cements produced by substituting waste provides like strength data when compared with ordinary Portland cement at the ages of different curing days.

Shayan and Xu (2006) [17] studied the presentation of glass powder in concrete in the real situations, a field examination has been performed by means of a 40 MPa concrete combination, including and considering a range of proportions of glass powder in and as cement replacement. Several blends were formed and most of the mixtures also involves sand-size meshed glass collective substance, were used to cast several concrete slabs. Concrete casted has been tested for the compressive and separating tensile strength, shrink and rise, ultrasonic pulse velocity, and permeability of chloride. Basic models had been cut from the slabs of various life spans for the same as well as for micros assessment. Mixtures with glass powder blend showed acceptably when compared in drying shrinkage and alkali reactivity. The outcomes revealed that GLP can be incorporated into high strength concrete at considerable proportions such as 20 – 30% to substitute of cement. Application of glass powder provides for substantial well utilization of waste glass in prepared mixes and noteworthy changes in the production of harmful gases to environment.

Mehmet (2014) [18] discussed the result of chemical over few good strength gains of mixed cement mortars in order to expand a enhanced consideration for enhancement of hydration and strength of newly mixed cements. Pastes and mortars, containing the mixed blends and the ordinary cement had been also formed and they had been cured within water to pending tests. Experimentations including test of chemical compositions of mixtures and strengths after different curing periods have been performed according to standard codes.

2. Materials and methods

Fractional replacement of cement or sand in concrete with waste materials affects variety of physical and chemical properties of the concrete and mortar. In the present work, several properties of concrete and mortar mixes are identified to evaluate the effect of waste materials on the performance of concrete. Following table 2, will presents theses parameters along with testing techniques.

Table 1

Parameters	Significance	Testing
Compressive Strength (3 Days)	In 3 days concrete can gain almost 40% of the 28 days compressive strength.	Compression testing machine
Compressive Strength (21 Days)	7-day test may be help to detect potential problem with concrete or testing procedure at the lab. In 7 days compressive strength is almost 65% of the 28 days strength.	Compression testing machine
Compressive Strength (28 Days)	To evaluate quality and characteristics of concrete. Concrete mixes are recognised by their respective 28 days strength.	Compression testing machine
Initial Setting Time	Time period available for the transportation and placing of concrete after mixing. It marks roughly the end of the period when the wet mix can be moulded into shape.	Vicat's Apparatus
Final Setting Time	The final setting time is the point at which the set cement has acquired a sufficient firmness to resist a certain defined pressure.	Vicat's Apparatus
Workability	Workability represents the effort which is to be done to compact the concrete in a given module.	Slump Test

Compressive Strength

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not.

For cube test two types of specimens either cubes of 15 cm x 15 cm x 15 cm or 10 cm x 10 cm x 10 cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15 cm x 15 cm x 15 cm are commonly used. This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimens should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.

These specimens are tested by compression testing machine after 3, 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

The test specimens are stored in moist air for 24 hours and after this period the specimens are marked and removed from the molds and kept submerged in clear fresh water until taken out prior to test.

Initial and final setting time

We need to calculate the initial and final setting time as per IS: 4031 (Part 5) – 1988. To do so we need Vicat's apparatus conforming to IS: 5513 – 1976, Balance, whose permissible variation at a load of 1000g should be +1.0g, Gauging trowel conforming to IS: 10086 – 1982.

Initial setting time

Place the test block under the rod bearing the needle. Lower the needle gently in order to make contact with the surface of the cement paste and release quickly, allowing it to penetrate the test block. Repeat the procedure till the needle fails to pierce the test block to a point 5.0 ± 0.5 mm measured from the bottom of the mould. The time period elapsing between the time, water is added to the cement and the time, the needle fails to pierce the test block by 5.0 ± 0.5 mm measured from the bottom of the mould, is the initial setting time.

Final setting time

Replace the above needle by the one with an annular attachment. The cement should be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression therein, while the attachment fails to do so. The period elapsing between the time, water is added to the cement and the time, the needle makes an impression on the surface of the test block, while the attachment fails to do so, is the final setting time.

Workability

The behavior of green or fresh concrete from mixing up to compaction depends mainly on the property called "workability of concrete". Workability of concrete is a term which consists of the following four partial properties of concrete namely, Mixability, Transportability, Mouldability and Compact ability. The slump is a measure indicating the consistency or workability of cement concrete. It gives an idea of water content needed for concrete to be used for different works. Slump cone apparatus is required to evaluate workability of concrete.

3. Results & Discussion

Experiments had been conducted to determine the suitability of silica fume and steel powder as alternative construction materials. Several Concrete mixes have been prepared by replacing cement with these materials, to determine compressive strength and slump values. It has been observed from experimental results that compressive strength increases up-to a certain point by replacing chief ingredients with supplementary materials and workability decreases with the increase in percentage of replacement. Setting time increases with increase in percentage of replacement.

In the present study usefulness of silica fume and steel powder as construction materials has been investigated through laboratory experiments. Various Concrete blocks have been casted using these materials to investigate compressive strength and slump values. The results show that silica fume may be used in concrete upto 15 to 20% of weight of cement and steel powder can be used upto 15% for optimum values of strength and workability.

Utility of materials such as silica fume and steel powder in construction industry reduces the use of Portland cement and thus reduces the construction cost.

In the present concrete mixes have been prepared by adding these materials in different percentage. Concrete mixes formed are tested for compressive strength and slump values and compared with ordinary Portland cement concrete values.

4. Tables and Figures

Table 2: Ratio of weight of each constituent (Kg) in concrete for preparing mixes

Water	Cement	Sand	Course aggregate
0.5	1	1	2

Table 3: Proportion of ingredients for M1 mixes after replacing cement by Silica fume

Weight of Materials (Kg)				
% Replacement	**Cement**	**Silica Fume**	**Aggregate**	**Sand**
0	4	0	8	4
10	3.60	0.40	8	4
15	3.40	0.60	8	4
20	3.20	0.80	8	4
30	2.80	1.20	8	4

Table 4: Proportion of ingredients for M2 mixes by replacing sand by steel powder

Weight of Materials (Kg)				
% Replacement	**Cement**	**Sand**	**Aggregate**	**Steel Powder**
0	4	4	8	0
10	4	3.6	8	0.40
15	4	3.4	8	0.60
20	4	3.2	8	0.80
30	4	2.8	8	1.20

Table 5: Proportion of ingredients for M3 mixes after replacing cement and sand

Weight of Materials (Kg)					
% Replacement	**Cement**	**Silica Fume**	**Aggregate**	**Sand**	**Steel Powder**
0	4	0	8	4	0
10	3.60	0.40	8	3.60	0.40
15	3.40	0.60	8	3.40	0.60
20	3.20	0.80	8	3.20	0.80
30	2.80	1.20	8	2.80	1.20

Compressive Strength Test
Cement and sand in cement concrete has been replaced in 10, 15, 20, 30% with silica fume and steel powder respectively, and in third mix both the ingredients have been replaced simultaneously. Their compressive strength has been tested after different curing periods such as 3 days, 21days and 28 days standard curing conditions. Results of compression tests had been showed in table 6 0% replacement represents the original OPC concrete mix. Hence, this table compares concrete prepared by OPC concrete with concrete formed by replacing cement with steel powder for concrete mix M1.

Table 6: Results of compression tests for M1concrete mix in MPa

S. No.	Days	% of Replacement				
		0%	10%	15%	20%	30%
1	3	16.2	16.5	16.9	17.2	16.8
2	21	20.1	20.4	20.6	21.1	20.7
3	28	24.7	25.2	25.4	25.9	24.9

Table 7: Results of compression tests for M2 concrete mix in MPa

S. No.	Days	% of Replacement				
		0%	10%	15%	20%	30%
1	3	16.2	16.7	17.2	17.8	18.2
2	21	20.1	20.7	21.3	21.8	22.3
3	28	24.7	25.4	25.9	26.5	27.1

Table 8: Results of compression tests for M3concrete mix in MPa

S. No.	Days	% of Replacement				
		0%	10%	15%	20%	30%
1	3	16.2	16.6	16.8	17.1	17.4
2	21	20.1	20.5	20.8	21.1	21.3
3	28	24.7	25.1	25.5	25.9	26.3

It has been observed that from above tables that
1. Maximum compressive strength is found at 20% replacement of cement with silica fume after 3, 7 and 28 days of curing.
2. Maximum compressive strength is found at 30% replacement of sand with steel powder after 3, 7 and 28 days of curing.
3. Maximum compressive strength is found at 30% replacement of both cement and sand after 3, 7 and 28 days of curing.
4. Compressive strength of concrete mix increases with high percentage when sand is replaced with steel powder.
5. Compressive strength of concrete mix were increased slowly when both the chief ingredients were replaced by silica fume and steel powder.
6. Variation of compressive strength with change in proportions of ingredients in all the three mixes has been presented in following figures.

Slump cone test
Along with compressive strength workability of concrete is major parameter required for testing the quality of concrete mix, again by mixing steel powder and silica fume in cement concrete in different proportions such as in 10, 15, 20, 30% and performing slump cone test following results were obtained. It has been observed from above table that slump value reduces with the increase in values of percentage replacement following changes are presented in following figures. However, It has been observed that workability of concrete increases with the combined use of silica fume and steel powder.

Table 9: Results of workability test

MIX	% Replacement	Slump Value
M1	0	98
	10	91
	15	83
	20	74
	30	67
M2	0	100
	10	92
	15	87
	20	79
	30	71
M3	0	110
	10	102
	15	96
	20	89
	30	81

Setting time
Along with compressive strength and workability of concrete, setting time of cement is major parameter required for testing the quality of concrete mix, again by mixing steel powder in cement mortar in different proportions such as in 10, 20 and 30% and testing setting time by Vicat's apparatus following results were obtained and from results it has been observed that setting time delays by mixing the steel powder.

Table 10: Setting time of blended cement mix for M1 mix

S. No.	Percentage of replacement	Setting time (minutes)
Initial setting time	0	32
	10	36
	20	38
	30	42
Final setting time	0	608
	10	615
	20	622
	30	627

Fig 1: Compressive strength test

Fig 2: Slump Cone Apparatus

5. Conclusions

Following are the conclusions of the present work –

1. By replacing cement with silica fume in M1 mix compressive strength increases up-to 20% and then decreases with increase in percentage replacement of cement.
2. Compressive strength has been found to be highest at 20% replacement of cement by silica fume in M1 mixes.
3. Slump value is decreased by increasing the percentage of silica fume.
4. Compressive strength increases and slump value decreases by increasing the percentage of replacement of sand by steel powder in M2 mixes.
5. Hence, from above results it has been recommended to replace cement about 20% with silica fume for higher compressive strength and optimum workability.
6. Results indicate that compressive strength increases with the combined use of steel powder and silica fume in concrete.
7. Slump value is higher in case of M3 concrete mix when compared with M1 and M2 mixes. However, with the increase in percentage of replacement value of slump cone decreases in all the three concrete mixes M1, M2 and M3.

6. References

1. Thomas MDA, Shehata MH. Use of ternary cementitious systems containing silica fume and fly ash in concrete; cementand concrete research, 1999, 29.
2. Sandor P. Portland Cement- Fly ash- Silica fume Systems in concrete Department of civil and Architectural Engineering, Drexel University, Philadelphia, Pennsylvania.
3. Aalok Sakalkale D. Experimental Study on Use of Waste Marble Dust in Concrete Int. Journal of Engineering Research and Applications. 2014; 4(10):44-50.
4. Lam, Wong, Poon. Utilization of Fly Ash, Rice Husk Ash, and Palm Oil Fuel Ash in Glass Fiber–Reinforced Concrete J. OF MAT. IN CIVIL ENGG. , Sep. 2012, 1281-1288.
5. Singh T, Nanda AK. Influence of Marble Powder on Mechanical Properties of Mortar and Concrete Mix NMBCW, 2012.
6. Valeria Corinaldesi, Giacomo Moriconi, Tarun R. Naik, Characterization of marble powder for its use in mortar and concrete, Construction and Building Materials. 2010; 24(1):113-117, ISSN 0950-0618,
7. Hendriks F, Janssen GMT. Use of recycled materials in constructions Materials and Structures. 2003; 36(9):604-608.
8. Khatri RP, Sirivivatnanon V, Gross W. Effect of different supplementary cementitious materials on mechanical properties of high performance concrete Cement and Concrete Research 1995; 25(1):209-220.
9. Kwan WH, Ramli M, Kam KJ, Sulieman MZ. Influence of the amount of recycled coarse aggregate in concrete design and durability properties Construction and Building Materials. 2012; 26:565-573.
10. Uygunoğlu T. Use of hydrated mortar as partial replacement material in cement, Advances in Cement Research. 2011; 23(3):113-122.
11. Pacheco-Torgal F, Jalali S. Compressive strength and durability properties of ceramic wastes based concrete Materials and Structures. 2011; 44:155-167.
12. Radlinski, Olek. Nantung Durability performance of concrete made with fine recycled concrete aggregates Cement & Concrete Composites. 2010; 32:9-14.
13. Barbhuiya SA, Gbagbo JK, Russell MI, Basheer PAM. Properties of fly ash concrete modified with hydrated lime and silica fume. Construction and Building Materials. 2009; 23(10):3233-3239.
14. Aliabdo Ali A, Elmoaty Abd, Elmoaty M, Abd Esraa M. Auda Re-use of waste marble dust in the production of cement and concrete. Construction and Building Materials. 2014, 28-41, ISSN 0950-0618.
15. Aruntaş HY, Gürü M, Day M, Tekin I. Utilization of waste marble dust as an additive in cement production, Materials and Design. 2010; 31(8):4039-4042.
16. Emre Sancak, Şükrü Özkan. Sodium Sulphate Effect on Cement Produced with Building Stone Waste, Journal of Materials. Article ID 813515, 2015. doi:10.1155/2015/81351
17. Shayan Xu. Performance of glass powder as a pozzolanic material in concrete: A field trial on concrete slabs Cement and Concrete Research. 2006; 36:457-468.
18. Mehmet Serkan Kirgiz. Effects of Blended-Cement Paste Chemical Composition Changes on Some Strength Gains of Blended-Mortars, The Scientific World Journal, Article ID 625350, 2014.
19. Xianwei Ma, Zhenyu Wang. Effect of Ground Waste Concrete Powder on Cement Properties, Advances in Materials Science and Engineering, 2013, Article ID 918294.
20. Bijen J. Benefits of slag and fly ash construction and building materials. 1996; 10(5):309-314.
21. Lam L, Wong YL, Poon CS. Effect of fly ash and silica fume on compressive and fracture behaviors of concrete Cement and Concrete research. 1988; 28(2):271-283.
22. Gonen T, Yazicioglu S. The influence of mineral admixtures on the short and long term performances of concrete department of construction education, Firat University, Elazig, 2009.
23. Mateusz RJO, Tommy N. Effect of composition and Initial Curing Conditions of Scaling Resistance of Ternary(OPC/FA/SF) concrete, Journal of Materials in Civil Engineering ASCE/. 2008, 668-677.
24. Cabrera JG, Linsdale CJ. A new gas parameter for measuring the permeability of mortar and concrete. magazine of concrete research. 1988; 40:177-182.
25. Jigar Patel P. Broader use of steel slag aggregates in concrete, M. Tech. thesis, Cleveland State University, December, 2008.
26. Thanongsak N, Watcharapong W, Chaipanich A. Utilization of fly ash with silica fume and properties of Portland cement–fly ash–silica fume concrete. Fuel. 2009; 89(3):768-774**.**
27. Patel A, Singh SP, Murmoo M. Evaluation of strength characteristics of steel slag hydrated matrix Proceedings of Civil Engineering Conference-Innovation without limits (CEC-09), 2009.
28. Li Yun-feng, Yao Yan, Wang Ling. Recycling of industrial waste and performance of steel slag green concrete, J. Cent. South Univ. Technol. 2009; 16:8-0773, DOI: 10.1007/s11771-009-0128-x.
29. Velosa AL, Cachim PB. Hydraulic lime based concrete: Strength development using a pozzolanic addition and different curing conditions Construction and Building Materials. 2009; 23(5):2107-2111.

30. Turkmen I. Influence of different curing conditions on the physical and mechanical properties of concrete with admixtures of silica fume and blast furnace slag, Materials Letters. 2003; 57:4560-4569.