Available online at www.CivileJournal.org

Civil Engineering Journal

Vol. 4, No. 4, April, 2018

Compressive Strength by Incorporating Quarry Dust in Self-Compacting Concrete Grade M35

Mushtaq Ahmad [a*], Sana Ullah [b], Aneel Manan [c], Temple Chimuanya Odimegwu[b], Salmia Beddu [a]

[a] *Department of Civil Engineering, Tenaga Nasional Universiti Malaysia, Kajang Campus, Malaysia.*

[b] *Department of Civil Engineering, Infrastructure University Kuala Lumpur (IUKL) Malaysia.*

[C] *Swedish College of Engineering and Technology, Wah Cantt, Pakistan.*

Received 08 March 2018; Accepted 29 April 2018

Abstract

The study has conducted to determine the workability and compressive strength of the self –compacting concrete. The sand has replaced with quarry dust with the proportion of 10, 20, 30 and 40% and super plasticizer was added 0.9%. The experiments were carried out at the Infrastructure University Kuala Lumpur (IUKL) concrete laboratory. Slump flow, J-Ring tests were carried out to determine the workability of self-compacting concrete and compressive strength test was conducted on 7 days and 28th days of curing period. A finding of the study shows that workability and compressive strength has increased by addition of quarry dust. It is concluded that addition of quarry dust up to 30% improve the workability of the self-compacting concrete and further addition of quarry dust decrease the workability. Additionally, compressive strength of the quarry dust modified self-compacting concrete shows the trend of higher compressive strength up to 30% addition of quarry dust with sand replacement and further addition decrease the compressive strength.

Keywords: Quarry Dust; Self-Compacting Concrete; Workability; Compressive Strength.

1. Introduction

Concrete/cement based product is the most significant composite material in all mankind history. Concrete most commonly use in the building infrastructure from decades and expected to continuously use in the future due to the significance such as abundantly availability across the globe, reasonable cost, easy transportation, placement, compaction, high sustainability, durability, high compressive strength and has ability to use in all kind of environment [1-2]. In the modern concept of building infrastructure the demand for concrete material has increased. Poorly compacted concrete consequently has non-durable concrete structures therefore ordinary concrete need skilled operators to handle in the complex concrete projects. The concrete durability and compaction related problem was addressed by Okamura in 1986 [3] and [4] in the Tokyo University by developing self-compacting concrete (SCC) also called Self-consolidating concrete. In the construction industry self-compacting concrete (SCC) is among the best development [5]. Self-compaction is the fresh concrete to stream under its own weight over a long separation without segregation and without the need to utilize vibrators to accomplish legitimate compaction. SCC has increased more extensive application such as saves labour and compaction noise produced by vibration [6]. The main aim of self-compacting concrete development is to produce compaction free concrete more durable and sustainable concrete that can easily mold in any shape. The consolidation of ordinary concrete is not easy in the complex structure so it was necessary to develop concrete withstand

* Corresponding author: ma_5099@yahoo.com

http://dx.doi.org/10.28991/cej-0309132

under its own weight and does required external energy to vibrate or compact in the molding process [2].

In the result of rocks crushing waste in the form of dust is produced which is known quarry dust. The quarry dust is the waste or by product of crushed rocks which create air pollution therefore the utilization of quarry dust in the building construction may reduce the cost of quarry dust dumping as well reduces the pressure on air pollution. The replacement of fine aggregate with quarry dust as an alternative natural material is practicing in some developing countries [7]. Quarry dust has been used for different activities in the construction industry, such as building materials, road development materials, aggregates, bricks, and tiles. Addition of quarry dust to the construction materials especially in aggregate many enhance the compressive strength properties also may possible replacement of fine aggregate with quarry dust. Addition of quarry dust with the replacement of fine aggregate has recently get attention among construction materials [8]. The limited studies in the area of sand replacement with quarry dust in the Self-compacting concrete are the motivation to conduct this study and followings are the key objectives of the study achieved in the limited time constraint.

- To determine the workability of conventional concrete, Self-compacting concrete and self-compacting concrete containing quarry dust as fine aggregate replacement grade 35 by conducting slump test, Slump flow test, and J-ring test.
- To determine the compressive strength of conventional concrete, self-compacting concrete and self-compacting concrete containing quarry dust as fine aggregate replacement grade 35.
- To determine the optimum dosage of quarry dust in self-compacting concrete grade 35.

2. Literature Review

Self-Compacting Concrete must be as fluid as possible in its fresh state to fill under its own weight. Quarry dust addition or replacement with fine aggregate has received attention not only to cope environmental pollution problem but it may increase the compressive strength of concrete. Partial or full replacement of sand in Self compacting concrete with quarry dust is the recent topic under consideration from the researchers due to limited studies earlier [9]. According to study [9] replacement of sand with quarry dust significantly reduce the cost of self-compacting concrete as well as enhance the compressive strength. Partially replaced cement with quarry dust in SCC found that quarry dust can use in the production of SCC but due to irregular share of quarry dust particles need higher dosage of superplasticizer to achieve similar flow properties [10]. Partially use of quarry dust in the concrete is recommended in the regions where fine aggregate is not available or costly [11]. Study [12] found that 50% replacement of fine aggregate with quarry dust gives the highest compressive strength compare to control concrete. The workability of SSC decreases as the replacement of quarry dust increase. Quarry dust strength characteristics and the chemical composition of fine aggregate are similar. Experimental results indicated that 40% replacement of sand with quarry dust gives better result than normal concrete for M20 grade [14].

The findings indicated that compressive strength increase and workability of concrete decrease by addition or replacement of quarry dust more than 40%. The mechanical properties of self-compacting concrete were improved by incorporating quarry dust 8-10%; the findings indicated that quarry dust added concrete shows better result than normal concrete [14]. Typically, raw materials (Cement, water, fine aggregate, course aggregate and some chemical admixtures) used to produce the SCC is same as normal vibrating concrete (NVC). Chemical admixture utilization is important to increase the workability and minimize the segregation of the SCC. Superplasticizer (SP) is an essential to produce high flowability with small changes in the viscosity of self-compacting concrete. The performance of self-compacting concrete incorporated with different categories of raw materials in various experimental studied is briefly explained.

2.1. Natural Mineral Incorporated With Self-Compacting Concrete

2.1.1. Fly Ash

Cement replaced over fly ash by 40, 50 and 60% to enhance the mechanical properties of self-compacting concrete and the findings shows 28 day compressive strength 26-48 MPa [15]. Authors [16] has investigated the influence of fly ash at high volume on the porosity of Self-Compacting Concrete (SCC) and found that the influence of fly ash content on the porosity is highly depended on the age of SSC. The age of SCC less than 56 days shows high voids and 90 days shows lower voids in the SCC. Portland cement was partially replaced with 0-80% with fly ash by [17] and study found that high volume fly ash incorporated with SCC produce high strength and low shrinkage by replacing 40% cement with fly ash shows highest compressive strength at 56 days.

2.1.2. Silica Fume

Portland cement has replaced with silica fume by [18] to investigate the effect on the performance of SCC. Study found that the top-bar effect of SCC mixtures incorporating silica fume is less intense than in NVC and it is almost eliminated for replacement levels between 8.9% and 10.6% (by weight). High setting time has observed during experiments. Comparative study to investigate the effect (flowability, compressive strength and split tensile strength) of fly ash and silica fume on SCC was conducted by [19] and findings shows the compressive strength as well as split tensile strength increased gradually when only silica fume was used as pozzolanic material as compared to fly ash as pozzolanic material. In general the strength of all mixes with silica fume was found to be on the higher side as compared to fly ash mixes for same w/b ratio. Another comparative study of [20] using silica fume with steel fiber was conducted to improve ductility and reduce the total cost of the SCC. The experimental findings shows that steel fiber improve the mechanical properties of SCC additionally; the silica fume within the entire hybrid mix may possibly adapt the fiber dispersion and strengthen deficits due to the fibers. It could also improve the strength plus the bond between the fiber and the matrix with a dense calcium silicate-hydrate gel in SCC.

2.1.3. Limestone Powder

The physical and mechanical properties and application of limestone powder incorporation with self-compacting concrete was investigated by [21].

The results showed that limestone powder produce normal strength in SCC and mechanical properties has improved. Study of [22] has investigated the effect of limestone powder incorporated with SCC using Portland cement and water cement ratio 0.38 by weight. The limestone powder was added 5, 10 and 15%. The study found that slump flow, V funnel flow time and marsh cone flow has increased by increasing the limestone powder content and the compressive strength decreased by increasing the limestone powder contents. Fine aggregate was replaced 100% with limestone powder at the study of [23] and the result indicated that limestone powder has potential to improve the SCC by partial replacement of fine aggregate.

2.1.4. Marble Dust

Likewise other natural waste materials marble dust is also most commonly use in the building material. Marble waste is the by-product and can significantly use in the concrete but incorporation with self-compacting concrete there is few studies have conducted showing positive and great potential to improve the properties of SCC. Paper [24] has examined the effect of marble dust incorporated with SCC by replacing the Portland cement partially at (10-40%). The result of the study shows significant improvement in the workability and compressive strength. Partial replacement of fine aggregate with marble dust investigated by [25] and study found that high percentage of fine aggregate reduce the compressive strength however mechanical properties of SCC has improved by using marble dust. Study of [26] developed SCC with incorporation with marble dust using response surface methodology. Multi objective optimization technique used to find eco efficient SCC mixture by adding maximum marble dust content. The eco efficient SCC was obtained with the water-to-cement-ratios less than 0.55 and the marble powder-to-cement-ratios of up to 0.6.

2.1.5. Palm Oil Fuel Ash

Palm oil fuel ash (POFA) is produced by the palm oil industry as a result of the burning of empty fruit bunch (EFB), fiber and oil palm shell (OPS) as fuel to generate electricity at temperatures of about 800-1000 C. In the result, the waste is collected in the form of ash called palm oil fuel ash (POFA). Malaysia produced about 3 million tons of POFA in 2007 while 100,000 tons of POFA is being produced annually in Thailand, and this production rate is likely to increase due to increased plantation of palm oil trees [27]. The effect of POFA incorporation with SCC studied [27] and Portland cement is replace 10, 15 and 20% with POFA. The result shows that palm oil fuel ash enhance the acid and sulphate resistance, reduce the shrinkage and surface water absorption of the SCC without effecting compressive strength of the self-compacting concrete. POFA used in the replacement of cement 5, 10 and 15% incorporation with SCC and the result found that slum flow, J-ring flow decreased and T 50 cm spread time and V-funnel flow time increased with higher POFA content [28]. The presence of POFA improved the stability of concrete mixture and provided a lower visual stability index. Study [29] has encouraged the use of palm oil fuel ash to improve the performance of self-compacting concrete.

2.1.6. Rice Husk Ash

Rice husk ash (RHA) is a pozzolanic material and used to enhance the microstructure of the interfacial transition zone between cement paste and aggregate in the self-compacting concrete. Study [30] has reported the rice husk ash positively improve the mechanical properties of SCC at age of 60 days by 20% addition in the replacement of cement. The cost factor using rice husk ash as a superplasticizer in self-compacting concrete was studied [31] where cement, fine aggregate, W/R and coarse aggregate was kept constant. Study found satisfactory result to meet the European federation of national trade associations representing producers and applicators of specialist building products (EFNARC) guide for making SCC.

2.2. Fibers Incorporated with Self-Compacting Concrete

2.2.1. Steel Fiber

Fibers are well known in the improvement of concrete properties and in the case of self-compacting concrete steel fibers were used to investigate the effect of steel fibers. A study conducted by [32] has compare control SCC with SCC incorporated with steel fibers. Steel fibers did not have significant effect on the durability of the SCC in the sulphate environment [33].

2.2.2. Polymer

The polymer use incorporation with self-compacting concrete has investigated [34] used waste tyre rubber to examine the mechanical and microstructural properties SCC. The result shows enhancement in the properties by using polymer incorporation with SCC. Acrylic polymer and micro-SiO_2 does not have a significant negative effect on the mechanical properties of self-compacting concrete [35]. In addition using these materials leads to improving them.

3. Materials and Methods

Fine aggregate is replaced with quarry dust with the proportion of 10, 20, 30 and 40%.Slump test, J-Ring test and compressive strength experimental tests followed British (BS) and Malaysian JKR (Public Works Department) standards were conducted at Infrastructure University Kuala Lumpur Malaysia (IUKL) to achieve the objective of the study. The materials used in the experimental study are listed.

3.1. Cement

Ordinary Portland cement (OPC) of BS-Grade 35 has used and the properties of the cement has given in Table 1.

Table 1. BS-35 cement properties

Specific gravity	3.11
Standard consistency (%)	30.60
Initial setting time (min.)	89
Final setting time (min.)	260
Average compressive strength (MPa) on 28th Days	30.20

3.2. Fine Aggregate

The grading of fine aggregate used is shown in the Table 2.

Table 2. Fine aggregate grading

Sieve Size	Weight Retained (g)	% passing
10 mm	0.04	98.6
5 mm	0.16	93.2
2.36 mm	0.88	63.2
1.18 mm	1.44	14.2
600 mc	0.18	8.08

3.3. Course Aggregate

Crushed granite stone used a course aggregate and course aggregate grading is shown in Table 3.

Table 3. Course Aggregate grading size

Sieve Size	Weight Retained (g)	% passing
20 mm	0.84	90
14 mm	4.40	37
10 mm	0.76	28
5 mm	1.42	11

3.4 .Mix Design

Self- compatibility can be a great extent influenced by the qualities of materials and the mix proportion. In the present investigation, Su [37] technique used to calculate the material proportions and propose mix design.

Table 4. Mix Design

NO.	Mixture Designation	Cement (Kg/m^3)	Sand (Kg/m^3)	Water (Kg/m^3)	Aggregate (Kg/m^3)	Quarry dust (Kg/m^3)	SP (Kg/m^3) (0.9%)
1	Control	420	850	213	920	_	_
2	SP	420	850	213	920	_	3.8
3	QD10	420	765	213	920	85	3.8

4	QD20	420	680	213	920	170	3.8
5	QD30	420	595	213	920	255	3.8
6	QD40	420	510	213	920	340	3.8

4. Finding and Discussion

4.1. Workability

Self- Compacting Concrete is characterized by filling ability, passing ability and resistance to segregation. European federation of national trade associations representing producers and applicators of specialist building products (EFNARC) [38-39] and ASTM [40] recommended values for slump and J Ring test is given in Table 5.

Table 5. Recommended values

No	Property	Range
1.	Slump Flow Diameter	500-700 mm
2.	J-Ring	0-10 mm

Table 6 indicated the slum flow test; J ring and J ring flow. The study has recorded the superplasticizer SP addition to the concrete has the slump flow 545 mm J ring 6.25 mm and J Ring flow 510 mm. These values are in the range of recommended values of EFNARC [38] and ASTM [40] standards. In the second stage sand/fine aggregate is replaced with quarry dust 10, 20, 30 and 40% in the result slump flow shows 550, 600, 670 and 630 mm respectively. Moreover, J ring values 7.5, 7.75, 9.25 and 8.5 mm respectively also J ring flow 515, 550, 620 and 580 mm respectively. The findings shows that addition of quarry dust 10-30% enhances the workability of the self-compacting concrete further addition decrease the slump flow shows the lower workability. The obtained slump flow; J-Ring and J Ring flows (mm) values shown in Table 6 are within EFNARC and ASTM standards.

Table 6. Fresh concrete properties of SCC

ID	SLUMP FLOW (500-700 mm)	J-Ring (0-10 mm)	J-Ring Flow (mm)
SP	545	6.25	510
10%	550	7.5	520
20%	600	7.75	575
30%	670	9.25	650
40%	630	8.5	600

4.2. Compressive Strength Test

Compressive strength test of SCC cubes is carried out at Infrastructure University Kuala Lumpur Malaysia (IUKL). The second objective of the study is to determine the compressive strength of the self-compacting concrete in the comparison of control samples. Test was designed for 7th days and 28th days where samples were cured. Compressive test were repeated 3 times for each batch mean compressive strength has determined and shown in the Table 7. Mean Compressive strength of control samples for the day 7th and 28th as recorded 27.03 and 36.15 MPa respectively. The result indicated that by addition of superplasticizer in the concrete has improved the compressive strength for day 7th and 28th as 27.96 and 36.39 MPa. With the effect of sand replacement with quarry dust of 10, 20, 30 and 40% the compressive strength of 7th days is 23.27, 24.89, 28.75 and 27.64 MPa respectively. The compressive strength on 28th days shows 33.73, 35.34, 37.46 and 36.27 MPa respectively. The findings shows that replacement of sand with of quarry dust of 10-30% improves the compressive strength and further addition decrease the compressive strength. Figure 1 and Table 8 indicate the compressive strength of the self-compacting concert in the comparison of 7-day and 28 days curing of SSC cubes.

Past studies of [2, 6, 10, 12, 41 and 42] has found average 7 days compressive strength of SSC 24-29 MPa and 28 days compressive strength of SSC has found 31-40 MPa. [41] Postulated the recommended values of 7 and 28 days compressive strength of SSC is 27.85 and 39.56 MPa. In this regards, study has determined the compressive strength of 7 days and 28 days are in the range as the past studies found 10-30% addition of quarry dust with the replacement of sand gives the higher compressive strength.

Table 7. Compressive strength results of various concrete mixtures

percentage of replacement	Age (Days)			
	7 days		28 days	
	Compressive Strength (MPa)	Average value (MPa)	Compressive Strength (MPa)	Average value (MPa)
Control	26.12		36.31	
	26.53	27.03	35.87	36.15
	28.44		36.27	
SP (0%)	27.43		36.63	
	28.21	27.96	36.73	36.39
	28.24		35.81	
(10%)	24.58		33.43	
	22.91	23.27	34.59	33.73
	23.66		33.17	
(20%)	25.14		35.93	
	24.2	24.89	34.66	35.34
	25.33		35.43	
(30%)	26.48		37.9	
	30.12	28.75	36.83	37.46
	29.66		37.65	
(40%)	27.43		36.74	
	28.21	27.64	35.83	36.27
	27.28		36.24	

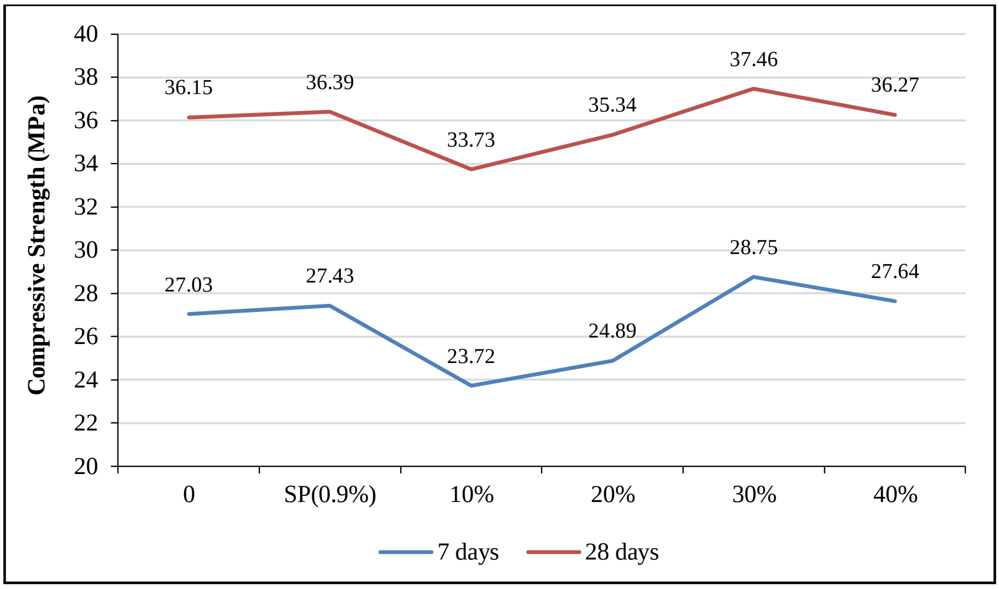

Figure 1. Comparison of compressive strength between 7 and 28day (Primary Result data)

4.3. Discussion

The aim of the study is to determine compressive strength and workability of the self-compacting concrete by addition of quarry dust with replacement of sand over different design proportion 10-40%. In the first phase of concrete design and placement to the mold workability and J ring flow test findings shown significant improvement in the self-compacting concrete. Compressive strength of 7 days and 28th days indicated significant improvement of the addition of quarry dust up to 30% further addition shows compressive strength decrease. Super plasticizer is a chemical admixture which was used in our project. Poly Carboxylate Ester (PCE) type super plasticizer used to easy flow of concrete without external vibration. Replacement of sand by QD as 10, 20, 30 and 40% from that replacement, the compressive strength is achieved in 30% replacement of quarry dust. The compressive strength value is 37.46 MPa at the age of 28 days.

5. Conclusion

This study concluded that replacement of sand/fine aggregate with quarry dust proportion ratio of 10, 20, 30 and 40% slightly improve the compressive strength and workability of the self-compacting concrete (SCC). However, the workability of SCC was increased with percentage of quarry dust with the value replacement of 10-30% of quarry dust, the optimum workability on 30% and highest compressive strength of SCC is achieved on 7-28 days by the replacement of 10-30% further addition or replacement of sand reduce the compressive strength of the SCC. Quarry dust has potential to use in the SCC by the replacement of fine aggregate. Due to time constraint many other properties testing has been avoided and this study recommend that some other mechanical testing has carried out. Quarry dust combination with husk rice is suggested to adopt in the future study to determine the compressive strength also utilize the rice waste with concrete. Some other long term mechanical properties is suggested to study in the future such as weather/environment effect on the self-compacting concrete and compressive strength on 60th days of curing.

6. References

[1] N. Krishna Murthy, A. Narsimha Rao, I. Ramana Reddy, and M. Vijay Sekhar Reddy, "Mix Design procedure for self-compacting concrete," IOSR Journal of Engineering, vol. 2, no. 9, pp. 33-41, 2012.

[2] Alyhya, Wajde S. "Self-compacting concrete: mix proportioning, properties and its flow simulation in the V-funnel." PhD diss., Cardiff University, 2016.

[3] H. Okamura, "Self-compacting high-performance concrete," Concrete international, vol. 19, no. 7, pp. 50-54, 1997.

[4] H. Okamura and M. Ouchi, "Self-compacting concrete," Journal of advanced concrete technology, vol. 1, no. 1, pp. 5-15, 2003.

[5] H. Brouwers and H. Radix, "Self-compacting concrete: theoretical and experimental study," Cement and Concrete Research, vol. 35, no. 11, pp. 2116-2136, 2005.

[6] R. D. Kumar, "Self-Compacted Concrete Mix Design and its Comparison with Conventional Concrete (M-40)," Journal of Civil & Environmental Engineering, vol. 5, no. 3, p. 1, 2015.

[7] K. Shyam Prakash and C. Rao, "Study on compressive strength of quarry dust as fine aggregate in concrete," Advances in Civil Engineering, vol. 2016, 2016.

[8] B. Rai, S. Kumar, and K. Satish, "Effect of fly ash on mortar mixes with quarry dust as fine aggregate," Advances in materials Science and Engineering, vol. 2014, 2014.

[9] B. Rai, S. Kumar, and K. Satish, "Effect of quarry waste on self-compacting concrete containing binary cementitious blends of fly ash and cement," Advances in Materials Science and Engineering, vol. 2016, 2016.

[10] D. Ho, A. Sheinn, C. Ng, and C. Tam, "The use of quarry dust for SCC applications," Cement and Concrete Research, vol. 32, no. 4, pp. 505-511, 2002.

[11] H. Dehwah, "Corrosion resistance of self-compacting concrete incorporating quarry dust powder, silica fume and fly ash," Construction and Building Materials, vol. 37, pp. 277-282, 2012.

[12] N. Khan and R. Chandrakar, "An Experimental study on uses of Quarry Dust to replace sand in concrete," 2017.

[13] K. S. Prakash and C. H. Rao, "Strength Characteristics of Quarry Dust in Replacement of Sand," in IOP Conference Series: Materials Science and Engineering, 2017, vol. 225, no. 1, p. 012074: IOP Publishing.

[14] H. Dehwah, "Mechanical properties of self-compacting concrete incorporating quarry dust powder, silica fume or fly ash," Construction and Building Materials, vol. 26, no. 1, pp. 547-551, 2012.

[15] N. Bouzoubaa and M. Lachemi, "Self-compacting concrete incorporating high volumes of class F fly ash: Preliminary results," Cement and concrete research, vol. 31, no. 3, pp. 413-420, 2001. doi:https://doi.org/10.1016/S0008-8846(00)00504-4

[16] S. Kristiawan and G. Murti, "Porosity of Self-Compacting Concrete (SCC) incorporating high volume fly ash," in IOP Conference Series: Materials Science and Engineering, 2017, vol. 176, no. 1, p. 012043: IOP Publishing. http://doi.org/10.1088/1757-899X/176/1/012043

[17] J. Khatib, "Performance of self-compacting concrete containing fly ash," Construction and Building Materials, vol. 22, no. 9, pp. 1963-1971, 2008. https://doi.org/10.1016/j.conbuildmat.2007.07.011

[18] K. G. Trezos, I. P. Sfikas, and K. Orfanopoulos, "Bond of self-compacting concrete incorporating silica fume: Top-bar effect, effects of rebar distance from casting point and of rebar-to-concrete relative displacements during setting," Construction and Building Materials, vol. 73, pp. 378-390, 2014. https://doi.org/10.1016/j.conbuildmat.2014.09.113

[19] K. Satish, S. Kumar, and B. Rai, "Self Compacting Concrete Using Fly Ash and Silica Fumes as Pozzolanic Material," Journal of Engineering Technology (ISSN: 0747-9964), vol. 6, no. 2, pp. 394-407, 2017.

[20] A. F. Mohamed, N. Shafiq, M. Nuruddin, and A. Elheber, "Effect of Silica Fume on the Properties of Steel-Fiber Reinforced Self-compacting Concrete," World Academy of Science, Engineering and Technology, International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, vol. 7, no. 10, pp. 754-758, 2013

[21] B. Felekoglu, "Utilisation of high volumes of limestone quarry wastes in concrete industry (self-compacting concrete case)," Resources, Conservation and Recycling, vol. 51, no. 4, pp. 770-791, 2007. https://doi.org/10.1016/j.resconrec.2006.12.004

[22] G. Sua-Iam and N. Makul, "Use of Limestone Powder to Improve the Properties of Self-Compacting Concrete Produced Using Cathode Ray Tube Waste as Fine Aggregate," in Applied Mechanics and Materials, 2012, vol. 193, pp. 472-476: Trans Tech Publ. https://doi.org/10.4028/www.scientific.net/AMM.193-194.472.

[23] G. Sua-iam and N. Makul, "Utilization of limestone powder to improve the properties of self-compacting concrete incorporating high volumes of untreated rice husk ash as fine aggregate," Construction and Building Materials, vol. 38, pp. 455-464, 2013. https://doi.org/10.1016/j.conbuildmat.2012.08.016

[24] A. Belaidi, L. Azzouz, E. Kadri, and S. Kenai, "Effect of natural pozzolana and marble powder on the properties of self-compacting concrete," Construction and Building Materials, vol. 31, pp. 251-257, 2012. https://doi.org/10.1016/j.conbuildmat.2011.12.109

[25] M. Gesoğlu, E. Güneyisi, M. E. Kocabağ, V. Bayram, and K. Mermerdaş, "Fresh and hardened characteristics of self compacting concretes made with combined use of marble powder, limestone filler, and fly ash," Construction and Building Materials, vol. 37, pp. 160-170, 2012. https://doi.org/10.1016/j.conbuildmat.2012.07.092

[26] K. E. Alyamac, E. Ghafari, and R. Ince, "Development of eco-efficient self-compacting concrete with waste marble powder using the response surface method," Journal of Cleaner Production, vol. 144, pp. 192-202, 2017.https://doi.org/10.1016/j.jclepro.2016.12.156

[27] N. Ranjbar, A. Behnia, B. Alsubari, P. M. Birgani, and M. Z. Jumaat, "Durability and mechanical properties of self-compacting concrete incorporating palm oil fuel ash," Journal of Cleaner Production, vol. 112, pp. 723-730, 2016.

https://doi.org/10.1016/j.jclepro.2015.07.033

[28] M. Safiuddin and M. Jumaat, "Fresh properties of self-consolidating concrete incorporating palm oil fuel ash as a supplementary cementing material," Chiang Mai Journal of Science, vol. 38, no. 3, pp. 389-404, 2011.

[29] M. Safiuddin, M. Abdus Salam, and M. Z. Jumaat, "Utilization of palm oil fuel ash in concrete: a review," Journal of Civil Engineering and Management, vol. 17, no. 2, pp. 234-247, 2011.

[30] M. Ahmadi, O. Alidoust, I. Sadrinejad, and M. Nayeri, "Development of mechanical properties of self compacting concrete contain rice husk ash," International Journal of Computer, Information, and Systems Science, and Engineering, vol. 1, no. 4, pp. 259-262, 2007.

[31] S. A. Memon, M. A. Shaikh, and H. Akbar, "Utilization of rice husk ash as viscosity modifying agent in self compacting concrete," Construction and building materials, vol. 25, no. 2, pp. 1044-1048, 2011. https://doi.org/10.1016/j.conbuildmat.2010.06.074

[32] S. Grünewald and J. C. Walraven, "Parameter-study on the influence of steel fibers and coarse aggregate content on the fresh properties of self-compacting concrete," Cement and Concrete Research, vol. 31, no. 12, pp. 1793-1798, 2001.

https://doi.org/10.1016/S0008-8846(01)00555-5

[33] A. S. El-Dieb, "Mechanical, durability and microstructural characteristics of ultra-high-strength self-compacting concrete incorporating steel fibers," Materials & Design, vol. 30, no. 10, pp. 4286-4292, 2009. https://doi.org/10.1016/j.matdes.2009.04.024

[34] M. Bignozzi and F. Sandrolini, "Tyre rubber waste recycling in self-compacting concrete," Cement and concrete research, vol. 36, no. 4, pp. 735-739, 2006.https://doi.org/10.1016/j.cemconres.2005.12.011

[35] A. Heidari and M. Zabihi, "Self-Compacting Concrete Incorporating Micro-and Acrylic Polymer," Advances in Civil Engineering, vol. 2014, 2014. http://dx.doi.org/10.1155/2014/652362

[36] F. Aslani and S. Nejadi, "Self-compacting concrete incorporating steel and polypropylene fibers: compressive and tensile strengths, moduli of elasticity and rupture, compressive stress–strain curve, and energy dissipated under compression," Composites Part B: Engineering, vol. 53, pp. 121-133, 2013.

[37] N. Su, K.-C. Hsu, and H.-W. Chai, "A simple mix design method for self-compacting concrete," Cement and concrete research, vol. 31, no. 12, pp. 1799-1807, 2001.

[38] EFNARC"The European Guidelines for Self-Compacting Concrete," 2005.

[39] H. G. Russell, "ASTM Test Methods for Self-Consolidating Concrete," HPC Bridge Views, vol. 50, 2008.

[40] ASTM, "C1611 Standard test method for slump flow of self-consolidating concrete," US: ASTM, 2014.

[41] M. Mallesh, G. Shwetha, and K. Reena, "Madhukaran,"Experimental Studies on M30 Grade Self Compacting Concrete"," International Journal of Science, Engineering and Technology Research (IJSETR), vol. 4, no. 9, 2015.

[42] G. Balamurugan and P. Perumal, "Use of quarry dust to replace sand in concrete–An experimental study," International Journal of Scientific and Research Publications, vol. 3, no. 12, p. 1, 2013.

7. Appendix

Figure 1A .Self-compacting concrete volume details

Characteristic Strength	35 N/mm^2
Proportion defective	5 N/mm^2
Margin (k=1.64)	1.64 x 8 = 13.12 N/mm^2
Target mean strength	35 + 13.12 = 48.12 N/mm^2
Cement type	OPC
Cement strength class	42.5
Coarse aggregates	Crushed
Fine aggregates	Uncrushed
Free water/cement ratio	0.51
Slump	30-60 mm
Maximum aggregates size	10 mm
Free water content	213 kg/m^3
Cement content	213 / 0.51 = 418 kg/m^3
Specific gravity	2.7
Concrete density	2400 kg/m3
Total aggregate content	2400 -418 -213 = 1769kg/m^3
Grading of aggregate	% pass 600µm sieve = 40%
Proportion of fine aggregate	48 %
Fine aggregate content	1769 x 0.48 = 849 kg/m^3
Coarse aggregate content	1769-849 = 920kg/m^3