Malaysian Journal of Civil Engineering 30(3):415-428 (2018)

THE EFFECT OF QUARRY DUST WITH CEMENT BY-PRODUCTS ON PROPERTIES OF CONCRETE

Jaharatul Dini Karen Lee Abdullah[1]*, Nazri Ali[1], Roslli Noor Mohamed[1] & Mohammed Mu'azu Abdullahi[2]

[1] *Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia*
[2] *Civil Engineering Department, Jubail University College, Royal Commission of Jubail and Yanbu, Jubail Industrial City, Kingdom of Saudi Arabia*

*Corresponding Author: *jaharatuldini@gmail.com*

Abstract: The numerous demanding application of concrete is not readily met with Ordinary Portland Cement (OPC) alone. To meet up the demand and as well as ensured the green concrete durability, it has becomes necessary to incorporate mineral additions with the best combination of others by-product as replacement to improve the performance without jeopardizing the strength of the concrete. In the construction industry, OPC cement and river sand are used as important building material making it scarce and limited. Whereas, as for the cement is well known as the biggest culprits for emitting carbon dioxide (CO_2). Hence, partial replacement of cement becomes a necessity as well as natural sand in concrete by waste material or by-product without compromising the quality of the end product. Partial replacement with Ground Granulated Blast furnace Slag (GGBS), Fly Ash (PFA), Silica Fumes (SILICA) incorporates with 100% of Quarry Dust (QD) as sand replacement. The usage of 100% QD with OPC+PFA+SILICA (Mix 2) produced more durable concrete with good temperature control and better furnishing than with 100% river. In addition to the cost effect benefit, the reduction in depletion of river sand, addressing environment and sustainability issues, it is a valuable contribution in creating a green concrete.

Keywords: *green concrete, high strength, ground granulated blast furnace slag cement, fly ash, silica fumes, quarry dust, by-product*

Article history:
Received 17 October 2017
Received in revised form 15 July 2018
Accepted 1 October 2018
Published online 1 Dec 2018

1.0 Introduction

Concrete is the major building material that widely used substance than other man-made material in this world. Cement being a major ingredient of concrete, its production contributes in harming the earth, is a big driver of climate change, responsible for 5% of man-made carbon dioxide (CO_2) reported in Berndt, (2015). OPC, Type I is the most common cement used in general concrete construction when there is no exposure to sulphates in soil and groundwater. From the statistic, nearly 60% of the cement used in the construction nowadays is OPC. Therefore, with the application of by-products as partial replacement cum substitution of constituents' materials in the green concrete mixes. The reduction in the sources of natural sand and the requirement for reduction in the cost of concrete production has resulted in poor quality sand sources supplied and thus increased need to identify substitute material to sand as fine aggregates in the production of concrete especially in green concrete (Ankit and Jayesh, 2013). Therefore, it is desirable to obtain cheap, environmentally friendly substitutes for cement and river sand that are preferably by products. To overcome from this crisis, the replacement of river sand with QD can be an economical alternative (Mohammad *et al*., 2015). To enhance the green concrete production and overcome from this crisis as mentioned above Venkata *et al*., (2013), partial replacements of portions of the cement with Ground Granulated Blast Furnace Slag (GGBS), Fly Ash (PFA) and Silica Fume (SILICA) with 100 % with quarry dust (QD) as fine aggregates was evaluated (Linoshka and Hwang, 2016) and illustrated in Raharjo, (2013) .

In the Peninsular of Malaysia there were also been many attempts to use quarry dust as partial replacement, but only up to 50% on the lower grades concrete with different construction purposes. This may be expected to bring out a reduce the usage of river sand, but also will cut down the cost of construction with economical concrete production. The choice of utilizing the waste product/by-product as a replacement and substitution for cement and natural river sand has been supported in the previous research, Manassa (2010) and Sukesh *et al*., (2013) showing that up to 20% of sand has been effectively replaced by quarry dust in traditional concrete. Ilangovan *et al*., (2008), Sivakumar and Prakash (2011) have reported that strength of quarry dust concrete was comparably 10-12% more than of similar of conventional concrete. Divakar *et al*., (2012) have experimented on the behavior of the concrete with the use of granite fines as partial replacement for sand up to 50% and obtained the positive results in strength. Using quarry waste as a substitute of sand in construction materials would resolve the environmental problems caused by the large-scale depletion of the natural sources of river and mining sands (Ilangovana *et al*., 2008, Poonam *et al*., 2015). In addition, quarry waste can be a profitable alternative to the natural sands when the overall construction cost increases due to the transportation of sands from their sources (Safiuddin *et al*., 2007). Usually quarry waste is used in large scale as a surface finishing material in highways. Rezende and Carvalho (2003) used this waste as the main construction material for the base layer of flexible pavement and observed its satisfactory performance under field conditions. Quarry waste has also good potential for producing normal and lightweight concretes. Safiuddin *et al*., (2007) and Lohani *et al*., (2012) reported that the workability of fresh concrete is increased, whereas the unit weight and air content remain unaffected in the presence of quarry waste.

They also showed that the use of quarry waste does not affect the compressive strength, ultrasonic pulse velocity and elastic modulus of concrete as reported by Sivakumar and Prakash, (2011); however, the initial surface absorption can be increased marginally. In addition, Ilangovana *et al*., (2008) reported that the permeability is lower, whereas water absorption is higher than those of conventional concrete. Hence, the durability of concrete could be affected if quarry waste is used with a greater amount. Nevertheless, the durability-related properties of concrete can be improved using quarry waste in the presence of silica fume (Safiuddin *et al*., 2000b) and mentioned by Dilip and Amitava (2012). Hameed and Sekar (2009) studied the feasibility of using quarry waste and marble sludge in concrete. They found that the compressive and splitting tensile strengths and durability of concrete, including quarry waste were better as compared with the conventional concrete reported in Vishal and Pranita, (2014). The concrete resistance to sulfate attack was enhanced, the permeability w as decreased, but its water absorption became slightly higher than that of conventional concrete. These results suggest that the quarry waste can be used to produce adequately durable concrete. Quarry waste can also be used in special concretes such as high-performance and self-consolidating concretes. Safiuddin *et al*., (2000a,b) produced high-performance concrete using quarry waste as a partial replacement of sand. Ho *et al*., (2002) included quarry waste in self-consolidating concrete to improve its self- compatibility with enhanced workability properties. In addition, Felekoglu (2007) showed that a reasonable amount of limestone quarry waste can be used in self- consolidating concrete without affecting its compressive strength. Thus, the successful utilization of quarry waste in high-performance and self-consolidating concretes could turn this waste material into a valuable resource mentioned by (Hmaid, 2015).

The development of high volume fly ash concrete mix designs is typically attributed to Malhotra (2011) and Peter (2016), who developed mixes with 60% and more of the Portland cement replaced by fly ash. Possibly the most important advantage of fly ash is the fact that it is a by-product of coal combustion, which otherwise would be a waste product to be disposed of at great cost. The optimum cement replacement level is often quoted to be about 50% and sometimes as high as 55%. The whole range of natural sand replacement (0 to 100 %) improved the beam deflection (Mangiru *et al*., 2013).The fly ash participates in both early (sulpho-pozzolanic) and late (aluminosilicate) hydration reactions referred to Freeda and Tensing (2010). In addition to the usual products of cement hydration, ettringite (AFt) the ash participates in both early (sulpho-pozzolanic) and late (aluminosilicate) hydration reactions (Berry *et al*., 1990). The motivation for the research is that there was never a times when river sand is 100% replaced by QD together with the by-products. Therefore, the research paper is aimed at the determination of the effect of 100% QD replacement of sand and partial replacement of cement with by-products on properties of concrete. The effect of partial replacement with GGBS, PFA, and SILICA incorporating 100% of QD as a sand replacement on concrete strength was evaluated.

2.0 Materials and Methods

This research was conducted in the laboratory to determine the behavior of the concrete in term of mechanical strength as well as the workability properties. The scope of work covers the mechanical and physical properties with 100% QD as fine aggregates and cement partial replaced with by-products such as; GGBS, PFA and SILICA. The mechanical properties of harden concrete were tested through the compressive strength test with cubes 100mm × 100mm × 100mm mould. The cubes were tested at the age of 4 days, 7 days, 14 days, 28 days and up to 56 days (monitoring stage) after the wet curing process at the curing tank in accordance to procedures in BS 1881: 111 (1983). The test is carried out on cube samples which undergone curing for 56 days as illustrated in BS 1881, Part 116 (1983). The Flexural strength test is applicable only to the rectangular sample of concrete, concrete beam measuring 100mm × 100mm × 500mm. The standard procedures are in accordance with BS 1881, Part 118 (1983). Tensile splitting strength test, was done with the cylindrical sample measuring 150mm diameter by 300mm length. The details of this test are described in BS 1881, Part 117 (1983). The fresh properties of the green concrete are determined through the flow slump test for the best workability, it is done in accordance with BS 1881: Part 101:1983, for sampling at site and BS 1881: Part 125 for sampling at the laboratory. Initial and final from the setting time test was performed in accordance with MS 522: Part 1: 2003 and current practice of determining initial setting time of concrete is based on ASTM C 403-99. According to this standard, initial setting time is identified based on the penetration resistance measured on mortar sieved from a concrete mixture and it is defined as the time taken to achieve a penetration resistance of 3.5 MPA. The chemical admixture used in this research are various types of super plasticizer or high range water reducer at the beginning of the research stage 1. It is needed due to the lower usage of water to produce high strength GGBS cement concrete that would affect the workability of fresh concrete. Adjustment was being made to ensure the best workability obtained will best flow slump without jeopardizing the concrete strength. It is used at a dosage rate, 1% of the total binder weight. The type of super plasticizer used is MIRA 225R which was fulfilled the requirements of ASTM C494 Type A and Type F, BS EN 934-2:2009+A1 (2012) and UNI No. 8145 for high range water-reducing admixtures.

3.0 Results and Discussion

Mix design of concrete is very important in order to produce a batch of concrete, which is having the properties desired. Parameters like compressive strength and workability can be altered through the design process and will be monitored from time to time until obtained the best concrete mix. Table 1 shows the concrete mix proportions for the green concrete that incorporates with the by-products such as fly ash, GGBS, silica fumes and quarry dust as the replacement of cement and natural sand sources. Dosage and amount of constituents utilize will be recorded clearly. The table was discussed on all the data and results collected from the laboratory experiments. All data and results will be tabulated in the table and then presented clearly in the graph and analysis to show the relationship between tested parameters and to be discussed. In the discussions, the possible logical reasons that will be discussed on what and how it would affect the properties of the high strength concrete.

Table 1: Mix proportions for different types of concrete

CONCRETE MIX	*OPC*	*GGBS*	*PFA*	*SILICA FUMES*	*WATER*	*QD*	*20MM*	*ADVA 391M*	*MIRA 225R*
MIX 1A	396	288	-	-	150	567	851	1000 ADVA 222	-
MIX 1	326	136	170	48	145	606	908	1000	200
MIX 2	428	-	204	48	135	603	905	1100	300
MIX 3	428	204	-	48	157	628	941	1200	500

3.1 Properties of Fresh Concrete

3.1.1 Workability (Flow Slump Test)

This section discusses test results on the workability base on concrete slump value referring to the Self Compacting Concrete (SCC) value in mm. The flow slump test was conducted for different concrete mixes: Mix 1, Mix 2 and Mix 3 with various of by product replacement. For this research, every batch consist of 2 samplings were tested on its workability before the fresh concrete was filled into the iron cast moulds. The relationship between the slump test results and different concrete mixes are shown in Figure 1. The flow slumps for concrete Mix 3 and Mix 1 are in the higher flow slumps ranging between (710-730) mm. Where as the concrete mix 2 slump obtained were in the medium flow slump ranging between (680-690) mm. There are several factors that contributed to the differential in flow slump test results for the same portion of concrete composition. For example from concrete Mix 3 with the highest flow slump at (720x730) mm, followed by concrete Mix 1 with the obtained slump at (710x720) mm and the medium flow slump at (680x690) mm for the concrete Mix 2. Although it is expected that the properties of quarry dust used for this research, such as higher fineness than natural sources, however the fineness of the GGBS used consist round shaped particles acted as a lubricant for fresh concrete to increase its slump (Teychene *et al*., 1992). This result shows, there are possibility of some other factors that affected the flow slump such as hot climate and temperature, admixtures and superplasticizer that used, water cement ratio and ways of handling the testing. However, by comparing with the quantity, types of by products replacement that used and the flow slump result, it can be assumes that the quantity and various types of combination by products used in the mixing proportions may cause the differential of flow slump readings in the flow slump results.

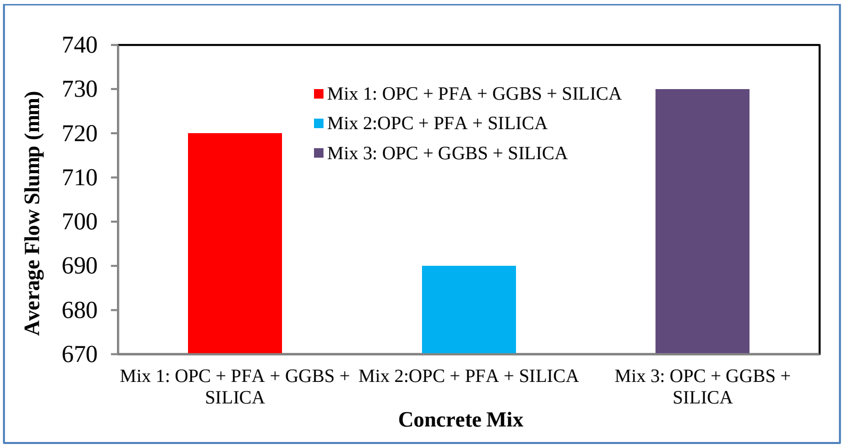

Figure 1: Variation of slump value of fresh concrete with different concrete mixes for 100% QD

3.1.2 Concrete Setting Time Test

From the concrete setting time test, the initial setting time is identified based on the penetration resistance measured on mortar sieved from a concrete mixture and it is defined as the time taken to achieve a penetration resistance of 3.5 MPA. Results were were shown in Figure 2. The result hows that the concrete Mix 1 used longer hours to set at 4 hours whereas concrete Mix 3 is the fastet to set among all the 3 concrete mixes which is 2.5 hours. Concrete Mix 2 used up 3 hours before it fully set. At temperatures less than 85^0F, concrete containing GGBS can have longer times of set, when compared with 100% OPC concrete. The lower the ambient and/or concrete temperatures, the slower the set times will be. Besides, the percentage of various by products used can also affect times of set. However, replacement rates of less than 30 percent generally will not affect times of set significantly. Slower times of set are beneficial in hot weather because the contractor has a longer time to deliver, place, and finish the concrete. If times of set need to be reduced, accelerators, heated materials or reduced percentages of various by product content may be used.

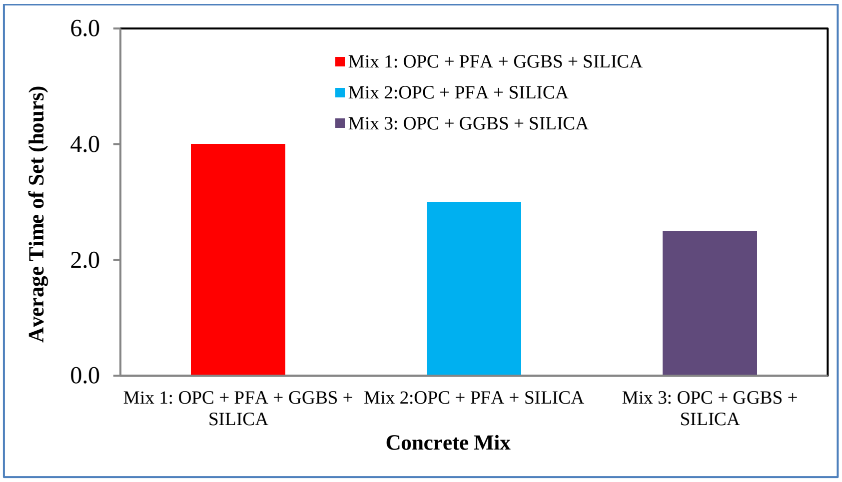

Figure 2: Effect of different constituents concrete mixes in initial time of set for 100% QD

3.2 Mechanical Properties of Harden Concrete

This section discusses test results on the mechanical properties of the quarry dust sand concrete and natural sand concrete. The test results for this research including the compressive strength, flexural strength test and tensile split test.

3.2.1 Compressive Strength Test

As mentioned early, cube test was done in this research to obtain the compressive strength of the concrete specimens. Every two samplings of cubes were cast for every individual different concrete mixes. The specimens were being tested with 5 different curing periods, namely 4 days, 7 days, 14 days, 28 days and 56 days. The details of test results on different concrete mixes were shown in Figure 3. The test results on the compressive strength for concrete Mix 2 shows as early strength of 73.1 MPA gain at 4 days age curing, following by the concrete Mix 3 at 72.60 MPA and concrete Mix 1 at 62.30 MPA. By comparing the strength of 3 different concrete mixes, the lesser combination of by products, materials gains faster and higher in compressive strength compare to the other concrete mixes. However, the strength gain will be greater after the 56 days up to the long time period based on the research done by (Hussin *et al*., 2012). In addition to the usual products of cement hydration, ettringite (AFt) identified as a product of the early hydration of the fly ash. A two-step mechanism for pozzolanic reaction between fly ash and OPC involving depolymerization/silanolation of the glassy constituents of the ash by the highly alkaline pore fluids, followed by reaction between solubilized silicate and calcium ions in solution to form C--S—H. This phenomenon highly constributes more durable concrete with good temperature control and better furnishing than with 100% river sand with normal cement water+aggregates+admixture.

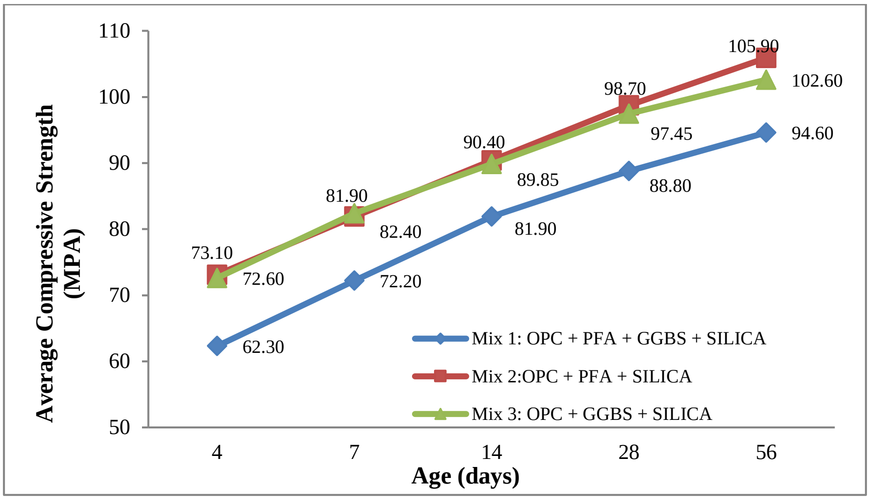

Figure 3: Average of compressive strength of different concrete mix and age for 100% QD

3.2.2 Flexural Strength Test

Flexural test was done in this research to obtain the flexural strength of concrete specimens with different type of mixes such as Mix 1, Mix 2 and Mix 3. The specimens were also being test with 5 different curing periods such as 4 days, 7 days, 14 days, 28 days and up to 56 days. The average test results were shown in Figure 4.All flexural strength test results of concrete samples were shown in Figure 4 from 4 days until 56 days curing periods. The results are the plotted on the graph of flexural strength versus curing period of different type of concrete mixes. The graph is shown in Figure 5. It can be seen from the graph that the flexural strength of concrete mixes are increase from 4 days curing until 56 days curing. The concrete strength of Mix 1 and Mix 3 increased from 3.10 Mpa to 15.10 MPA and 3.60 MPA to 16.10 MPA at 4 days curing to 56 days respectively. However, the increment of the concrete Mix 2 is more obvious and rapid after 4 days curing where increased from 3.7 Mpa to 18.00 MPA at 56 days curing. The increment of flexural strength strikes above 10% of the compressive strength obtained from the test. The flexural strength of the concrete also increased from time to time which are 3.10 MPA, 5.00 MPA, 7.00 MPA, 8.90 MPA and 15.10 MPA for concrete Mix 1, 3.70 MPA, 6.60 MPA, 7.70 MPA, 9.90 MPA and 18.00 MPA for concrete Mix 2 and the final concrete Mix 3 at 3.60 MPA, 5.80 MPA, 7.60 MPA, 9.70 MPA and 16.10 MPA respectively. The increment of the concrete strength shown is in a gradual manner.

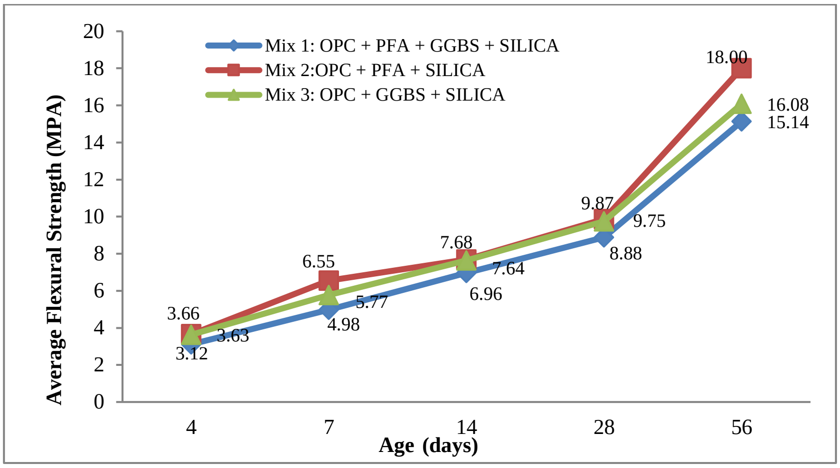

Figure 4: Average of flexural strength of different concrete mix and age for 100% QD

3.2.3 Tensile Splitting Strength Test

Tensile Splitting test was done in this research with the objective to obtain the tensile strength on a concrete specimen with different type of concrete mixes such as Mix 1, Mix 2 and Mix 3. Every 2 cylinder sampling of specimens were cast and was being test with 5 different curing periods such as 4 days, 7 days, 14 days, 28 days and up to 56 days. The average tensile strength test results were tabulated in the Figure 5. The results show the average tensile strength results of concrete specimens were plotted using a chart to present the trending of strength gain for all the different concrete mixe with specific age curing. The tensile strength shows the early strength gain in concrete Mix 2 and concrete Mix 1 is slightly slower than the concrete Mix 3. However, both mixes; Mix 1 and Mix 2 strength gain become faster. This phenomenal show the pozzolanic activity from the by products may contribute to the concrete tensile strength. Initially, hydration process from Portland cement and water will produces calcium silicate hydrate, CSH which is the principle source of concrete strength and calcium hydroxide, Ca $(OH)^2$, by product of hydration process that does not contribute to any strength of concrete. However, presents of high silica content of slag in concrete and water, calcium silicate will be converted into CSH molecules and increase the strength of the concrete. The percentage of tensile strength gain at the age 4 days to 56 days reached above 8% for both concrete Mix 1 at 1.20 MPA and 7.80 MPA and Mix 3 at 1.30 MPA to 8.80 MPA whereas the highest percentage tensile strength gain spike above 9 % for concrete Mix 2 at 1.50 MPA to 9.70 MPA.

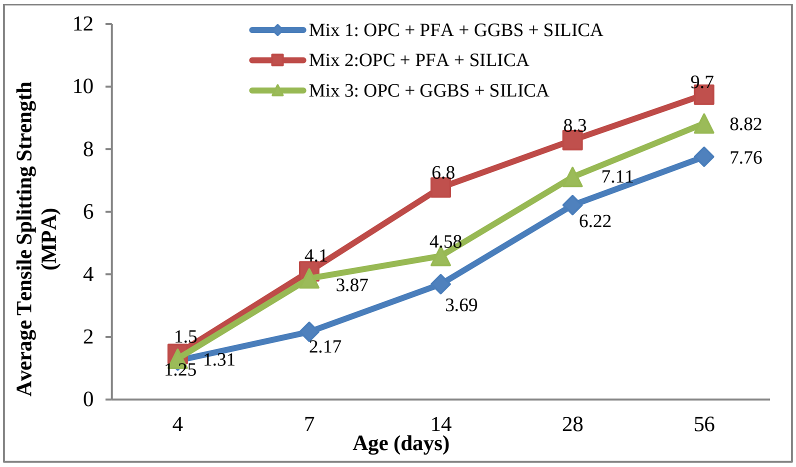

Figure 5: Average of tensile splitting strength of different concrete mix and age for 100% QD

3.3 Superplasticizer Dosage

From the Figure 6, a high strength in concrete (100MPA) was easily obtained from trial mix, but workability wise very poor with recorded flow of 660 x 660 mm at 0.23 w/c. Hence, have to example, ADVA 1200, AGG 960 and QD 528. The flow be revised and adjusted to achieve both targets of bench mark 85 MPA high strength and good workability (flow sump) without concrete segregation and bleeding. At the beginning of the trial mix, the admixture used was basically a single dosage of ADVA222. Due one problem of the segregation and workability difference mixes are combined and recombined using an admixture as single or double doses of ADVA 222, ADVA 391M, MIRA 225R, varying the H2O, AGG and QD. Resulting in selection of 3trial mixes namely; OPC+PFA +GGBS +SILICA, OPC+PFA+SILICA and OPC+GGBS+SILICA with an admixture of ADVA 391M, MIRA 225R for further analysis.

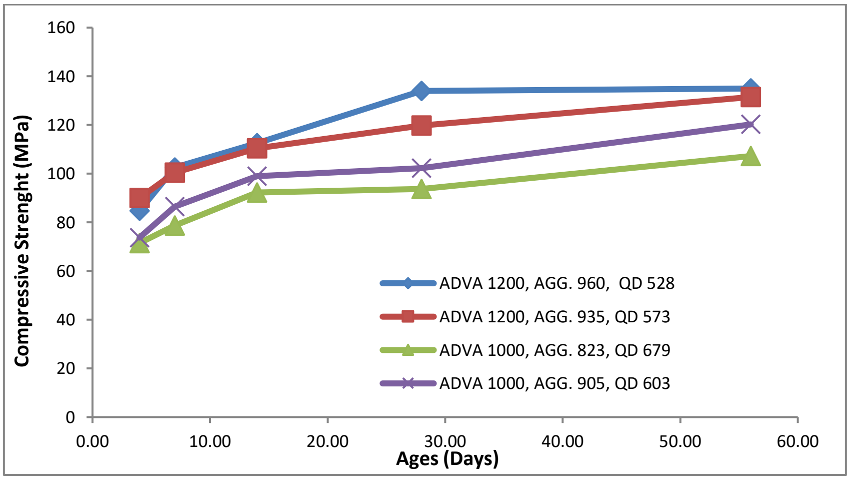

Figure 6: Variation of compressive strength with curing times for different ADVA, AGG. & QD contents at 155 H2O & 436 OPC m3/kg at PFA (30 %) +SILICA (6 %)

4.0 Conclusions

All the laboratory testing results that obtained shown the additional of the industrial wastes such as quarry dust and by-products namely fly ash, granulated blast furnace slag and silica fumes improve the physical and mechanical properties of the concrete mix. The results are of great importance because concrete is the major building material that widely used substance than other man-made material in this world. Concrete requires large amounts of cement and fine aggregates (sand) which are major ingredients of concrete production. Concrete production contributes in harming the earth, is a big driver of climate change, responsible for 5% of man-made carbon dioxide (CO_2) and depletion of the natural sand source. Therefore, to overcome from this crisis, the replacement of river sand with quarry dust can be an economical alternative. To enhance the green concrete production and overcome from this crisis as mentioned above, partial replacements of portions of the cement with Ground Granulated Blast Furnace Slag (GGBS), Fly Ash (PFA) and Silica Fume (SILICA) with 100 % of quarry dust (QD) as fine aggregates was evaluated.

On the basis of results obtained from the research, the following conclusions can be drawn:

1. It is found that quarry dust can be used as an alternative material to the natural sand without jeopardizing the concrete strength, proven by obtaining above 100 MPA for concrete mix 2 and mix 3 during the compressive strength testing.
2. Usage of quarry dust also reduces the cost of concrete (economical) because it is a waste from the final harvest from quarries that incurred zero costing value.
3. Used of quarry dust as natural sand replacement in concrete will eradicate the disposal problem and maintain the environmental friendly thus paving way for

greener concrete.

4. The replacement of the natural sand with quarry dust incorporates with the by - product materials in concrete not only shows an improved compressive strength, but also in flexural and tensile splitting strength by achieving the 8-9 percentage of strength gain.
5. The replacement of the natural sand with quarry dust decreases the workability at 0.23 (water cement ratio) of the concrete due to water absorption by quarry dust. However, the workability problem was solved by blending the combined doses of admixture namely ADVA 222, ADVA 391M and MIRA 225R obtaining good flows slump.
6. With usage of quarry dust content with the mixture of by-products materials in concrete, percentage water absorption increases. It is well-known that the water cement ratio increases as the strength decreases. The adjustment was made and monitored during the laboratory work to obtained best and ideal concrete mix.
7. The 100 percentage of quarry dust as a natural sand replacement proven to have contributes in strength increased by results obtained from concrete mix 1, mix 2 and mix 3 respectively (age of 4days, 7 days, 14 days, 28 days up to 56 days).
8. Used of partial replacements of portions of the cement with Ground Granulated Blast Furnace Slag (GGBS), Fly Ash (PFA) and Silica Fume (SILICA) with 100 percentage of quarry dust (QD) as fine in concrete will preserve natural resources particular river sand, decreases the emission of CO_2 thus produces concrete construction industry more sustainable.

The above conclusion gives a clear picture that quarry dust can be utilized in concrete mixtures as a good substitute for natural river sand with the good effects of strength increased incorporates with cement by-products partial replacement in concrete mixes.

5.0 Acknowledgements

The authors gratefully acknowledge the support for this research from Tasek Concrete Sdn. Bhd Laboratory, YTL Cement, Tasek Cement, WR Grace and Faculty of Civil Engineering, University Teknologi Malaysia.

References

Ankit Nilesh Chandra Patel, Jayesh Kumar Pitroda, (2013). *Stone Waste: Effective Replacement of Cement for Establishing Green Concrete*, Inter. J. Innovative Tech. And Exploring Engineering, 2(5): 24-27.

ASTM C403 / C403M - 99 (1999). *Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance.*

ASTM C494 / C494M - 17 (2014). *Standard Specification for Chemical Admixtures for Concrete*.

Berndt, M.L. (2015). *Inflluence of concrete mix design on CO_2 emissions for large wind turbine foundations*. Renewable Energy, 83: 608-614.

Berry, E. E, Hemmings R. T., and Cornelius B. J. (1990). *Mechanisms of Hydration Reactions in High Volume Fly Ash Pastes and Mortars.* Concrete Composites, 12: 253-261.

British Standard Institution, BS 1881: Part 101 (1983). Methods of Sampling Fresh Concrete on Site.

British Standard Institution, BS 1881: Part 102 (1983). *Methods for Determination of Slump*.

British Standard Institution, BS 1881: Part 111 (1983). *Methods of Normal Curing and at Test Specimens.*

British Standard Institution, BS 1881: Part 116 (1983). *Methods for Determination of Compressive Strength of Concrete Cube*.

British Standard Institution, BS 1881: part 117 (1983). *Method for Determination of Tensile Splitting Strength*.

British Standard Institution, BS 1881: part 118 (1983). *Method for Determination of Flexural Strength*.

British Standard Institution, BS 1881: part 125 (1983). *Method for Mixing and Sampling of Fresh Concrete in the Laboratory*.

British Standard Institution, BS EN 934-2:2009+A1 (2012*). Admixtures for Concrete, Mortar and Grout Admixtures for Masonry Mortar. Definitions, Requirements, Conformity and Marking and Labelling.*

Dilip Kumar Singha Royl, Amitava Sil (2012). *Effect of Partial Replacement of Cement by Silica Fume on Hardened Concrete*. Inter. J. Emerging Tech. and Advanced Engineering, 2(8): 472-475.

Divakar, Y., Manjunath, S., and Aswath, M. U. (2012). *Experimental Investigation on Behaviour of Concrete with the use of Granite Fines*. International Journal of Advanced Engineering Research and Studies, 1(4): 84- 87.

Felekoglu, B. (2007). *Utilization of High Volumes of Limestone Quarry Wastes in Concrete Industry* (Self-Compacting Concrete Case). Resources, Conserv. Recycling, 51: 770-791.

Freeda Christy, C., and Tensing D. (2010). *Effect of Class-F Fly Ash as Partial Replacement with Cement and Fine Aggregates In Mortar*. Indian Journal of Engineering and Materials. 17:140-144.

Hameed, and Sekar. (2009). *Properties of Green Concrete Containing Quarry Rock Dust and Marble Sludge Powder as Fine Aggregate.*

Hmaid Mir, A. (2015). *Improved Concrete Properties Using Quarry Dust as Replacement for Natural Sand*. International Journal of Engineering Research and Development, 11(3): 46-56.

Ho, D. W. S., Sheinn A. M. M., Ng, C. C. and Tam C. T. , (2002). *The use of Quarry Dust for SCC. Applications*. Cement and Concrete Research. 32(4): 505–511.

Hussin, M. W. (2002). *Strength Properties of Self-Compacting Mortar Mixed with GGBFS*. ICE-Construction Materials; 165(2):87-98.

Ilangovan, R., Mahendran, N. and Nagamani, K. (2008). *Strength and Durability Properties of Concrete containing Quarry Rock Dust as Fine Aggregates*. ARPN Journal of Engineering and Applied Science. .3(5): 20-26.

Linoshka, S.P., and Hwang. (2016). *Mix design and Pollution Control Potential of Pervious Concrete with Non-compliant Waste Fly ash, Journal of Environmental Management*. 176:112-118.

Lohani, T. K., Padhil M., Dash K. P., and Jena S. (2012). *Optimum Utilization of Quarry Dust as Partial Replacement of Sand in Concrete*. Inter. Journal of Applied Sciences. 1(2): 391- 404.

Malhotra, V. M. (2011) *Fly Ash in Concrete*. Canada. Dept. of Energy, Mines and Resourcesthe University of California. Digitized (pp 178).

Manassa, J. (2010). *Use of Crushed Granite Fine as Replacement to River Sand in Concrete*. Leonardo Electronic Journal of Practices and Technologies. 17:85-96.

Mangiru, G. N., Karugu, C.K., Oyawa, W.O., Abuodha, S.O., and Mulu P.U. (2013). *Partial Replacement of Natural River Sand with Crushed Rock Sand in Concrete Production*. Global Engineers & Technologist Review. 3(4):7-14.

Mohammad Iqbal Malik, Syed Rumysa Jan, Junaid A. Peer, S., Azhar Nazir, Khubbab Fa Mohammad. (2015). *Study of Concrete Involving Use of Quarry Dust as Partial Replacement of Fine Aggregates*. 5(2): 2278-8719.

Peter, A. C. (2016). Chapter 21-*Concrete mix Design*. Civil Engineering Materials, 201-217.

Poonam, Anoop Bishnoi, and Manju Bala. (2015). *Effect of Quarry Dust as Partial Replacement of Sand in Concrete*. International Journal of All Research Education and Scientific Methods 3(6):1-5.

Raharjo, D., Subakti, A., and Tabvio. (2013). *Mixed Concrete Optimization using Fly Ash,Silica Fume and Iron Slag on the SCC's Compressive Strength*. Procedia Engineering, 54: 827-839.

Rezende, L.R., and Carvalho, J.C. (2003). *The Use of Quarry Waste in Pavement Construction.* Resources, Conservation and Recycling. 39(1): 91-105.

Safiuddin, M., Raman, S. N., Zain, M. F. M. (2007). *Flowing Concretes with Quarry Waste Fine Aggregate*. J. Civil Eng. Res. Pract., 4(1): 17-25.

Safiuddin, M., Zain, M. F. M., and Yusof, K. M. (2000a). *Utilization of quarry dust in developing high performance concrete*. In D. McTavish, G. Knights, F. M. Bartlett, R. K. Rowe, and S. Easa (Eds.), *2000 Annual Conference Abstracts - Canadian Society for Civil Engineering* (pp. 233).

Safiuddin, M, Zain, M. F. M, Yusof, K. M. (2000b). *Development of High Performance Concrete Using Quarry Dust as a Partial Replacement of Sand*. In: Proceedings of the PCI/FHWA/FIB International Symposium on High Performance Concrete, Orlando, Florida, USA. pp. 173-182.

Sivakumar, A., and Prakash, M. (2011). *Characteristic studies on the mechanical properties of quarry dust addition in conventional concrete*. Journal of Civil Engineering and Construction Technology. 2(10): 218-235.

Sukesh, C., Krishna, K. B., Sai Teja, P. S. L., and Rao, J. K. (2013). *Partial Replacement of Sand with Quarry in Concrete*. Int. Journal of Innovative Technology and Exploring Engineering. 2(6): 254- 258.

Teychene, D. C., Franklin, R. E. and Erntroy, H. C. (1992). *Design of Normal Concrete Mixes.* Second edition,. Bre press, Watford, Herts, WD2 7QG, pp.1-46.

Vishal, S. G., Pranita, S.. B. (2014). *Influence of Silica Fume in Concrete*. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 44-47.

Venkata Sairam Kumar, N. , Panduranga Rao, B., and Krishna Sai M. L. N. (2013). *Experimental Study on Partial Replacement of Cement with Quarry Dust*. International Journal of Civil Engineering and Technology (IJCIET), 2(3): 136-137.