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A review on Utilization of Fly Ash with Silica Fume and Properties of Portland Cement-Fly Ash-Silica Fume Concrete

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Abstract - *The aim of this study is to evaluate the performance, workability and durability of Silica Fume and Fly ash replaced by the properties of Portland cement. Concrete has a very high compressive strength in compression it can be used for mega projects but for a high rise buildings it can be loaded and make high the dead load for the building and it will be so expensive therefore the admixture of silica fume and fly ash can make low the price of concrete and also the weight of concrete will come done and it will be possible to use in a high rise building till 99 stories. Fly ash is waste product of carbon dioxide overcome these problem ideas developed to investigate the use of industrial by product/waste. The silica fume industrial by produce found to be an striking cementations material, which is by product of smelting process in the silicon and ferrosilicon industry. The partial auxiliary of silica fume and its effects on concrete properties has been studies by adopting M-30 concrete mix in this exposition. The main parameter explored in this study M-30 concrete mix with partial replacement by silica fume with varying 0, 5, 10, 15 and 20% by weight of cement the paper presents a detailed laboratory work-study on compressive strength, flexural strength and split tensile strength for 7 days, 14 day and 28 days respectively. The results of experimental examination indicates that the use of silica fume in concrete has increased the strength and durability at all age when compared to normal concrete. Hence, the use of Silica Fume leads to discount in cement quantity for construction purpose and its use should be promoted for better performance as well as for environmental sustainability.*

Key Words: Silica Fume, Fly Ash, Portland cement, Concrete, Compressive Strength.

1. INTRODUCTION

Concrete In its easiest form, concrete is a mixture of paste and aggregates, or rocks. The paste, mixture of Portland cement with water, coats the surface of the fine and coarse aggregates. Through a chemical effect called hydration, the paste hardens and grows strength to shape the rock-like mass known as concrete. Within this procedure lies the key to a remarkable quality of concrete, it is plastic and malleable when anew mixed, stable and durable when hardened. These abilities clarify why one material, concrete, can make bridges, sidewalks and superhighways, houses and dams.

Portland cement is used to produce all kind of concrete for construction projects. The Portland cement is use to create all kind of masonry and all kind of render and views. Which most commonly used type of Portland cement is Ordinary Portland Cement, but there are other varieties available, such as white Portland cement. Water and cement fixed and harden through a chemical reaction known as 'hydration'. The process of hardening is described as curing, and it wants special conditions of temperature and humidity. After mixing Portland cement with fine aggregate, course aggregate and water it gets shape of concrete. A person which his name was Joseph Aspdin, was the first person which make Portland cement by burning powdered limestone and clay in a kitchen stove in the early-19th century and the 'dry' method is the most communal way of producing Portland cement. The procedure begins with the excavating of the principal raw materials limestone, clay, chalk which may be combined with shale, blast furnace slag, silica sand, iron ore, and so on. The excavated material is then crushed, first to reduce it to a maximum size of approximately 6 inches, and then to about 3 inches or less using secondary crushers or hammer powders. The crushed rock is then ground, mixed and fed into large rotary ovens, which heat it to nearby 2,700ºF (1,500 C). Coolers are used to carry low the temperature of the clinker, before cement plants slog and mix it together with small amounts of gypsum and limestone. Once this is done, so it can be sold for use in construction. An alternate, though less common producing technique is the wet method. It is same to the dry method except that before being fed into the ovens the raw materials are ground with water. As the production of Portland cement comprises quarrying and the use of large amounts of energy to power the kilns, it is not considered to be a 'sustainable' material.

Fly ash is a result from burning pulverized coal in electric power generating plants. As the complex material growths, it cools and solidifies into spherical glassy particles called fly ash. Fly ash is gathered from the exhaust gases by electrostatic precipitators or bag sieves. The fine powder does resemble Portland cement but it is chemically dissimilar. Fly ash is highly economical, use of Fly Ash is environmentally friendly as the waste materials from industries are effectively being used to create quality building materials. Fly Ash has very small particles which makes the concrete highly dense and reduces the permeability of concrete, fly ash can add greater strength to the building. The concrete mixture generates a very low heat of hydration which prevents thermal cracking, Fly Ash concrete is resistant to acid and sulphate attacks, the shrinkage of fly ash concrete is very less and the use of fly ash gives concrete best work ability, good durability and finish. In concrete mix, design for fly ash must be use good quality because the low quality of fly ash can affect the strength of concrete. Low quality of fly ash can increase the workability and durability of the concrete and cause damage to the building.

Silica fume is a derivative product of producing silicon metal or ferrosilicon alloys. One of the most advantageous uses for silica fume is in concrete because of its chemical and physical properties, it is a very sensitive pozzolan. Concrete containing silica fume has a very good workability and a very good durability. Silica fume can be find from suppliers of concrete admixtures and, when specified, is simply added during concrete production. For mixing of silica fume with concrete like placing, finishing and curing need special and good attention. The silica fume make high the compressive strength of concrete before a few year the concrete made with the compressive strength of 6000 psi and now it can be made with the compressive strength of 15000 psi by using the admixture of silica fume in concrete. The silica fume has a high range of it use in construction project and construction industries because silica fume strengths and weaknesses are accepted. Silica fume mixtures have an average diameter of less than 1 micron and it is grey powder with a density of 2.2g/cm^3. Generally divided into densified silica fume and unidentified silica fume, the bulk density of unidentified silica fume is 200-350kg /m^3, the bulk density of densified silica fume is 480-720kg /m^3. Silica fume increased compressive strength, it is very low chloride ion diffusion, reduced water permeability, improved sulfate resistance, improved abrasion resistance, improved resistance to chemical attack, improved stability in geothermal environments and Reduced efflorescence. Exactly to the filling effect of silica fume, the moisture in concrete decreases and local dry shrinkage cracks are caused. Therefore, strengthening concrete maintenance after construction can effectively improve the problem. When the outward temperature is too high, it will cause the dry shrinkage of concrete surface. Before concrete condensation, if the surface water vaporization rate is higher than the exploiting rate, the dry shrinkage crack will appear on the surface. The undue amount of silica powder will reduce the constructability, make the concrete become compacted, and make the surface of construction difficult.

1.1 Scope of Paper

The durability pores and cost of the concrete work is a major concern now a day so the use of Portland cement with fly ash and silica fume in construction work and construction industries is increasing the durability of it and decreasing the cost and pores in concrete. This study is focused on the addition of silica fume and fly ash mix to reduce the percentage of Portland cement in the mix and its properties are evaluated and investigated.Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

2. Literature Review

(Thanongsak Nochaiya, Watcharapong Wongkeo and Arnon Chaipanich. 2009) These researchers were working to determine the normal consistency, setting time, workability and compressive strength results of Portland cement, fly ash and silica fume systems. In this research, they use the admixture 2.5%, 5% and 10% silica fume and 5%, 10%, 20% and 30% fly ash on the properties of Portland cement with water cement ratio of 0.5 and with curing time of 7, 14, 28, 60 days. For the concrete mix design they used ASTN C187 standard for water cement ratio and for time they used the ASTM C191 standard. The results show that the highest compressive strength is 48.2 MPa for by added the admixtures of 5% fly ash and 5% silica fume. They said that the water demand was so high for mixing of fly ash and silica fume and the workability go higher with increasing of water and curing time. Silica fume is better to increase the workability of concrete. The utilization of silica fume with fly ash in concrete was found to increase the compressive strength of concrete mixes, an increase of up to 145% was observed when compared to the Portland-fly ash mixes without silica fume. [1]

(F.A. Mustapha, A. Sulaiman, B.R.N.Mohamd and S.A. Umara. 2020) This research is done to determine feasibility substituting of Portland cement with fly ash and silica fume. For the concrete mix design the admixture 0%, 25%, 40%, 50%, 65% and 75% fly ash and 10% silica fume were replaced by the properties of Portland cement with water cement ratio of 0.3 and with the curing time of 7 and 28 days. The blend of 40% Portland cement, 50% fly ash and 10% silica fume achieved the highest compressive strength of 87.06 MPa at 28 days curing time. The highest compressive strength is related to the percentage of the admixture of silica fume and fly ash by the properties of Portland cement and compressive strength is from 42.82 MPa to 87.06 MPa. [2]

(Heba A. Mohamed. 2011) This research show that the objective is to determine the suitable percentage of fly ash and silica fume in self-compacting concrete that gives the highest compressive strength. For concrete mix design, the researcher used 10%, 15%, 20%, 25%, and 30% fly ash and 10% 15% and 20% silica fume on the properties of Portland cement. The higher percentage for fly ash was found 30% and for silica fume was found 15% by properties of Portland cement. The highest compressive strength for these percentages is 27 MPa in 7 days curing age for 30% fly ash used replace of Portland cement and 35 MPa for 15% silica fume used replace of Portland cement in 7 days curing age. [3]

(J.J. Chen, P.L. Ng, L.G. Li and A.K.H. Kwan. 2017) Conflict between demand for high strength and demand for high flow ability, the development of high performance concrete has encountered a bottleneck. In this regard, increasing the padding density of the cementitious materials should provide room for further advancement of high performance concrete. The researchers used 0%, 20%, and 40% of fly ash and 0%, 10% and 20% silica fume in place of Portland cement properties with deferent water cement ratios of 0.1, 0.15, 0.2, 0.25, 0.3 and 0.35. Double blending of Portland cement with both fly ash or silica fume, and triple blending of Portland cement with both fly ash and silica fume can expressively increase the packing density. Moderately, the finer silica fume is more active in increasing the packing density. The optimum water cement ratio for maximum strength is generally lower at higher fly ash and silica fume contents. Hence, the addition of fly ash or silica fume would allow the water cement ratio to be lowered in order to increase the strength. [4]

(Durga Chaitanya Kumar Jagarapu. 2019) The addition of fly ash and silica fume has improve the workability and durability of concrete. In this experimental research work, the researcher replaced 10% and 22% fly ash and 5%, 8% and 10% silica fume by the weight of grade 53 Portland cement. Compressive strength, split tensile and bending strength tests for 7, 28 and 56 days were applied under Indian standard code. The experimental results increase since M1 to M2 and gradually decrease from M2 to M3. The bending strength is gradually increase from 20% to 25% of silica fume and fly ash replaced by the properties of Portland cement. Split tensile strength spreads its maximum value when Portland cement is replaced with 10% of silica fume and 15% fly ash. For the highest range of compressive strength is 58 N/m2 by replacing of 15% fly ash and 10% silica fume by weight of Portland cement. [5]

(Xinhua Cai, Shengwen Tang and Xiaorun Chen. 2016) Sandblasting test is an operative testing method for evaluation of the abrasion erosion characteristics of concrete and other abrasion resistant materials. Moderate heat Portland cement (Grade 42.5, named P.MH42.5) and Class F fly ash were used. Moderate heat Portland cement was cleared by standard (GB200-2003, Moderate heat Portland cement, Low heat Portland cement, Low heat Portland slag cement) in which maximum contents of C2S, C3A and free CaO are 55%, 6% and 1.0%. Total content of supplementary cementations materials content was varied at 0%, 20% and 40%. For this experimental work the temperature for mixing concrete and placing samples for curing was 20+5 or 20-5 centigrade and the humidity was 95% for the curing age of 7, 28 and 90 days. The compressive strength test was gone under SL 352-2006 standard. The results show that the compressive strength decrease with the content of fly ash. The results for the compressive strength come 29.1 - 44.2 MPa in 7 days, 50.6 – 68.3 MPa in 28 days and 65.5 – 78.6 MPa in 90 days. [6]

(Arnon Chaipanich and Thanongsak Nochaiya. 2009) The concrete mixing design was to replace 10%, 20% and 30% fly ash and 5% and 10% silica fume on the properties of type I Portland cement with the water cement ratio of 0.5 under 7, 28, and 90 days curing age. The microstructure of the samples was examined using scanning electron microscopy (SEM; JEOL- JSM- 840A). For 10%, 20% and 30% of fly ash contents without silica fume contents the values of compressive strength of fly ash mixes 37 – 45 MPa are all les then those Portland cement paste 47 MPa. Mixes with the use of silica fume there is a decrease in Ca(OH)2 with increasing silica fume content at 5% and 10% same to that of the reference of Portland cement paste and a obeying increase in calcium silicate hydrate (C-S-H) can be detected. [7]

(Santhi A.S and Mohan Ganesh. 2011) The researcher's presents the results of an experimental investigation carried out to evaluate the compressive strength of High Strength Concrete under ASTM C 192M-07 Standard. For the concrete mixed design they replace 30%, 40% and 50% class C fly ash and 6% and 10% silica fume by the properties of Portland cement with the water cement ratio of 0.4. The total binder content was 450 kg/m3. The compressive strength was checked in 1, 3, 7, 28, and 90 days and fly ash + silica fume + Portland cement increase the compressive strength of concrete. The slump of all concrete mixtures were greater than 165 mm. The results show that the compressive strength decrease with the increase in fly ash contents at all initial times. The mix of 40% fly ash showed a maximum strength of 60.2 MPa and the silica fume with 6% replacement show a maximum compressive strength of 61.2 MPa. [8]

(Kanish Kapoor and S. P. Singh and Bhupinder Singh. 2020) The researchers' presents the Permeability of self-compacting concrete made with recycled concrete aggregates and Portland cement-fly ash-silica fume binder. The researchers used 0%, 50% silica fume and 0%, 25%, 50%, 75%, 100% fly ash in the properties of Portland cement. The substitution of 25% fly ash with FRCA was observed to marginally increase the compressive strength of self-compacting concrete mixes made with Portland cement – fly ash binder. The range for the compressive strength in deferent times are 20 – 49 MPa in 7, 28, 56, and 120 days. It was found in general that with the increase in the percentage content of FRCA in the self-compacting concrete mixes led to a rise in the initial surface absorption ISA values and ISA values are 3%, 2.5% and 3.8%. It was observed that the UPV values decrease with an increase in the content of silica fume and fly ash in self-compacting concrete mixes. For self-compacting concrete mix silica fume and fly ash 25%, the UPV values decreased by 4.3%, 4.4% and 4.7% at the curing period of 28, 56 and 120 days. [9]

(Mehran Khan and Majid Ali. 2019) This research paper presents the workability keeping the ASTM C143 standard and ACI committee 544.2R was followed to determine the workability of fresh fly ash – silica fume concrete. They did three tests (compressive strength test with ASTM C39, Flexure test with ASTM C1609 and split tension strength test with ASTM C496 standards) The slump test values are decreased by 67%, 70%, 78% and 100% respectively than that of Portland cement. There is an increase in elastic modulus compressive strength, compression total energy absorbed and compression toughness index of best fly ash – SCFRC.i.e Fly ash 10% SCRC by 40%, 35%, 68% and 22% respectively than that if CFRC with 2% coconut fiber content 10% fly ash and 15% silica fume content can be used for improved mechanical properties. [10]

(Sandor Popovics. 1993) The researcher mixed the materials 25%, 28%, 29%, 30% fly ash and 1%, 2%, 5% silica fume on the properties of Portland cement and the curing time for the compressive strength test was 1, 3, 7 and 28 days. The substitution of silica fume in the quantity of 5% by weight of Portland cement did improve the strength of mortars made with type I Portland cement. The substitution of any of the two fly ashes for 30% of any of the four Portland cements increases the standard flow by about 10% points. [11]

(H. Süleyman Gökçe, Daniel Hatungimana and Kambiz Ramyar. 2018) In this research paper, the researchers did to find the effects of foam content as well as fly ash and silica fume enclosure on some physical and mechanical properties of foam concrete, subjected to several curing regimes, were researched. They replaced 10%, 20% fly ash and 10%, 20% silica fume on the properties of CEMI42.5R type cement. The compressive strength curing time for the tests are 7 days and 28 days. The flow values of the mixtures were determined according to EN 1015-3 standard mixed with ordinary or blended cement. The compressive strength values were found to be between 45 and 88.1 MPa depending on the mix proportions and the applied curing age. Except for mixtures without foam, the compressive strength results reached up to 23.3 MPa. Silica fume increase the density of the foam concrete up to 55%. For the maximum compressive strength and minimum acuter absorption, the optimum density of foam concrete was found to be around 1320 kg/m3. [12]

(Lateef N. Assi, Edward (Eddie) Deaver and Paul Ziehl. 2018) This study examines the initial and final setting times of fly ash-based geopolymer concrete using an activating solution that was a mixture of silica fume, sodium hydroxide, and water. The results of the research show that sucrose (granulated sugar) delays the initial and final setting times of fly ash-based geopolymer concrete. The average compressive strength was not affected when the sucrose weight percentage was increased from 0%, to 9% in the mix design. However, a significant improvement was achieved when the curing procedure was changed from ambient cured conditions to heat cured conditions. ASTM C642 showed that when sucrose (sugar) weight percentage was increased, the captivation and penetrable void ratio percentage was decreased. However, the bulk and apparent density was decreased when the sucrose weight percentage was increased. By since the concrete samples made with 3% sucrose as a reference, the volume of permeable pore space ratio was decreased by 32% and 48% when 6% and 9% of sucrose were mixed with fly ash individually. [13]

(Ping Duan, Chunjie Yan and Wei Zhou. 2017) This experimental work purposes is to reveal the effects of silica fume on properties of fly ash based geopolymer under thermal cycles. Fly ash was used as source material of alkali activation. The span for fly ash and silica fume was 3.39 and 1.44, correspondingly. They replaced 10%, 30% fly ash and 10%, 20%, 30% silica fume on the properties of Portland cement. The compressive strength test were done after 7, 28 and 56 days. In this research for concrete mix design procedure they used the temperature 200, 400, and 800 C for two hours after that in normal temperature room. The compressive strength of geopolymer incorporating different content of silica fume is 62 MPa at 0% silica fume, 68 MPa at 10% silica fume, 78 MPa at 20% silica fume and 90 MPa at 30% silica fume. Compressive strength of geopolymer concrete increases with the increase of silica fume. [14]

(LI Chengdong and YU Hongfa. 2010) This research paper says that combination of fly ash or silica fume into magnesium oxychloride (MOC) cement, a high water resistance material can be formed for successful industrial applications. They replaced 5%, 15%, 30% fly ash and 5%, 15%, 30% silica fume on the properties of Portland cement. The compressive strength of the magnesium oxychloride mortars decreased with the increase amount of silica fume addition. The compressive strength of the magnesium oxychloride mortars with 15% fly ash is the highest compressive strength. The compressive strength 27.58 – 37.32 MPa after 3 days curing time, 36.84 – 48.09 MPa after 7 days curing time and 44.75 – 69.37 MPa after 28 days curing time was resulted. [15]

(Vili Lilkov, Ekaterina Dimitrova and Ognyan E. Petrov. 1997) Results from studies on the early hydration (until the 24th hour) of cements mixed with silica fume, fly ash or a mixture of both, called Pozzolit, are presented. The particles of Pozzolit mineral preservative have a heterogeneous character-separately existing silica fume and fly ash particles and developments of fine fly ash particles surrounded by silica fume grains. The conditions of early hydration in the Pozzolit - covering paste are more favorable in comparison with these of the silica fume-containing paste where a part of the silica fume particles remains closed between the forming hydrates on the cement grain surface and do not actively participate in the cement hydration during the first 24 hours. The effect of Pozzolit mineral improver is expressed in increased total amount of hydration products and in a decreased amount of calcium hydroxide. [16]

(Ergul Yasar. 2014) This research study presents some results of ongoing experimental lab work to design a lightweight concrete using colemanite waste and pumice materials. Hisarcik and Espey colemanite wastes, acidic pumice aggregate as well as normal Portland cement were used to create not heavy concrete with financial and environmental remunerations. In this research paper the effect of colemanite waste on workability and strength of lightweight concrete were analysed by fresh and hardened concrete tests in lab work. He used ASTM standard for all experimental concrete mix design procedure. The compressive test was done after 7, 14, 28 and 90 days. The density and compressive strength test results of concrete made with Espey colemanite and pumice aggregate were discovered to be between 850 and 935 g/cm3, and 4.5 and 5.5 MPa. The density test results of concrete made with Hisarcik colemanite and pumice aggregate were discovered to be between 848.3 and 917.4 g/cm3, and 6.3 and 10.92 MPa. [17]

(Mateusz Radlinski and Jan Olek. 2011) Paper is about to primarily conducted to verify the incidence of synergistic effects in ternary cementitious systems containing Portland cement, class C fly ash and silica fume. The researchers used 20% fly ash and 5% silica fume in place of the properties Portland cement in the curing time of 7 days. The physical effect related with packing density was somewhat contrary to general beliefs and performed to have not been caused by optimized particle size distribution of binder components of the ternary cementitious system. Instead, it was a result of smaller initial inter-particle spacing resulting from lower specific gravity of both fly ash and silica fume, which led to lower volumetric w/cm. If the mixture design was adjusted to account for these differences, it is expected that the physical effect would be shrank. The synergy observed for the ternary OPC/FA/SF system was accredited to both chemical and physical effects. [18]

(Jinbang Wang, Mingle Liu, Yuguang Wang, Zonghui Zhou, Dongyu Xu, Peng Du and Xin Cheng. 2020) This research is about to determine the combined utilization of mineral admixtures and nano-materials in cement-based composites is an inevitable trend based on the purpose of improving the durability. The compressive strength was improved by adding nano-silica, and high content of fly ash with moderate fineness is profit to the compressive strength progress in later stage. Nano-silica promotes hydration process of cement and provides conditions and high alkalinity environment for fly ash in later stage, synergetic effect accelerates cement hydration. Synergistic effect increases non-evaporable water content and optimizes pozzolanic reactivity of nano materials and active mineral admixtures. Besides, Synergistic effect significantly decreases porosity and improves the pore structure. [19]

(Chalermphan Narattha, Pailyn Thongsanitgarn and Arnon Chaipanich. 2015) The researchers examined thermogravimetry analysis, compressive strength and thermal conductivity tests of non-autoclaved aerated Portland cement fly ash, silica fume concrete. In this research for concrete mix design they used 20%, 25%,30% fly ash and 5%, 10% silica fume in place of Portland cement properties on a curing age of 3,7 and 28 days according to the ASTM D5930-01 standard. Aluminum-added aerated concrete was cast and tested (density &1765–1869 kg/m3) having compressive strength at 28 days in the range of 13–23 MPa. These results can be used for moderate-strength concrete and structural concrete. [20]

3. CONCLUSIONS

1. The higher the percentage of FA the higher the values of concrete compressive strength until 30% of FA. However, the highest value of concrete compressive strength is obtained from mix holding 15% SF.
2. SCC mixes with 15% SF as a replacement of cement content give higher values of concrete compressive strength than those with 30% FA by about 12% and 10% for 550 kg/m3 and 450 kg/m3 cement content respectively.
3. The pore structure of the foam concrete was significantly affected by the introduction of foam, fly ash and silica fume. Due to the durable relations between the properties of foam concrete and its mix proportions, optimization of the mixtures seems to be of higher significance in mineral admixture bearing foam concrete.
4. The utilization of ternary cementitious systems (silica fume + fly ash + cement) to balance the desired properties of foam concrete having high foam contents is recommended.
5. ASTM C642 showed that when sucrose (sugar) weight percentage was increased, the absorption and permeable void ratio percentage was decreased. However, the bulk and apparent density was decreased when the sucrose weight percentage was increased. By considering the concrete samples made with 3% sucrose as a reference, the volume of permeable pore space ratio was decreased by 32% and 48% when 6% and 9% of sucrose were mixed with fly ash respectively.
6. A significant delay in the initial and final setting times occurred when the sucrose (granulated sugar) was implemented. For instance, the initial and final setting times for 0% sucrose plus 10% Portland cement replacement geopolymer paste were 10 min, and 25 min, while they were 530 min and 730 min when 9% sucrose was included.
7. Silica fume compensations for low early strength of concrete with high CaO fly ash.
8. Fly ash increases long period of time strength growth of silica fume concrete.
9. Fly ash equipoises increased water demand of silica fume.
10. Very high resistance to chloride ion penetration can be found with ternary blends.
11. The mixture of 6% silica fume to different fly ash replacements has a high compressive strength than 10%

silica fume.CFS546 ternary system had high compressive strength than all other mixes. The optimum and high strength concrete can be obtained with 6% silica fume and 40% fly ash.

12. The relatively poor cost of fly ash offsets the improved cost of silica fume.

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