Compatibility of Waste Glass Powder, Silica Fume & Bagasse Ash as Pozzolanic Material in Concrete

T. Harikrishna[1], B. Ganesh[2]
[1]Dept of Civil Engineering
[2]Associate Professor, Dept of Civil Engineering
[1, 2] Lenora College of Engineering, Rampachodavaram

Abstract- *The increasing demand for infrastructure due to the continuous population growth, and the high rate of urbanization, have led to increased consumption of concrete. The rapid production of cement creates big problems to environment. First environment problem is emission of CO2 during the production process of the cement. The CO2 emission is very harmful which creates big changes in environment. According to the estimation, 1 tone of carbon dioxide is released to the atmosphere when 1 tone of ordinary Portland is manufactured. As there is no alternative building material which totally replace the cement. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. To overcome this issues different pozzolanic materials as supplementary cementitious materials are used in the present study.Today many researches are going into the use of Portland cement replacements, using many waste materials like glass powder, silica fume and Bagasse ash etc.In this study, waste glass powders,silica fume and Bagasse ash have been used as a partial replacements to the concrete ingredient i.e. cement and the mechanical properties like compressive strength, split tensile strength and flexural strength are measured.*

Keywords- Glass powder, Silica fume and Bagasse ash, Compressive strength, split tensile strength test, flexural strength test.

I. INTRODUCTION

In the construction field, Cement is the main ingredient for the production of concrete. But the production of cement requires large amount of raw material. During the production of cement burning of lime stone take place which results in emission of carbon dioxide (CO2) gas into the atmosphere. There are two different sources of CO2 emission during cement production. Combustion of fossil fuels to operate the rotary kiln is the largest source and other one is the chemical process of burning limestone.

In the last three decades, supplementary cementitious materials such as fly ash, silica fume and ground granulated blast furnace slag have been judiciously utilized as cement replacement materials as these can significantly enhance the strength and durability characteristics of concrete in comparison with ordinary Portland cement (OPC) alone, provided there is adequate curing. Fly ash addition proves most economical among these choices, even though addition of fly ash may lead to slower concrete hardening. However when high strength is desired use of silica fume is more useful however, this product is rather expensive.

The main objective of replacement of cement is to increase the strength of concrete by partial replacement of cement by Glass powder, silica fume and bagasse ash. Specific objectives are

To experimentally investigate the strength of concrete with partial replacement of cement with Glass powder, silica fume and bagasse ash and to compare convectional concrete by conducting,

- Compressive test
- Split tensile strength.
- Flexural strength

- For the proper usage of waste materials.
- Reduce disposal problem by using industrial waste as a concrete ingredient.
- The various tests to be done for finding the material properties are
- Sieve analysis
- Normal consistency of cement
- Fineness
- Initial setting time of cement
- Workability tests
- Test for Compressive strength
- Split tensile strength.
- Flexural strength

II. REVIEW OF LITERATURE

The beneficial reuse of waste products from industrial and agriculture seems to be the new trend now. Baggage is the by-product of sugar cane milling. About 33% of the baggage produced supplies the fuel for the generation of steam (Bilba et al 2003). According to ahmad and sheikh (1992), the physical and chemical properties of sugar cane baggage ash as found to satisfactory requirements for pozzolana. This makes it good for replacing by cement partially. Researchers has said that the usage of sugar cane baggage ash as a partial replacement of cement.

Mr. U.R. Kawade et al., had studied on “Effect of use of Bagasse ash on Strength of Concrete” they had Chemically and Physically Characterized and partial replaced in the ratio of 0%, 10%, 15%, 20%, 25% and 30% by weight of cement in concrete. The results show that the SCBA concrete had significantly higher compressive strength compared to that of the concrete without SCBA. It is found that the cement could be advantageously replaced with SCBA up to maximum limit of 15%. Although the optimal level of SCBA content was achieved with 15% replacement. Partial replacement of cement by SCBA increases workability of fresh concrete, therefore use of Super Plasticizer is not essential.

Lourdes M. S. Souza et al., had studied on “Hydration Study of Sugar Cane Bagasse Ash and Calcium Hydroxide Pastes of Various Initial C/S Ratio” they had investigated on the reactions between calcium hydroxide (CH) and sugar cane bagasse ash (SCBA). For this purpose, pastes of various initial CaO/SiO2 (C/S) molar ratios were produced. The formed products were analyzed by thermal analyses, X-ray diffraction, scanning electron microscopy and energy dispersive spectrometer. The results show that the main product was found to be C-S-H of not specific morphology and that could not be related to the known products C-S-H (I)/C-S-H (II). Calcium alumina silicate hydrates and calcium aluminate hydrate, in the form of fine plates or needles, were also produced. The main product formed in the pozzolanic reactions between SCBA and CH is C-S-H and it appears as a dense net of amorphous agglomerations.

Perumal & Sundararajan Observe the Effect of partial replacement of cement with silica fume on the effectiveness and strength features of high performance concrete. Strength and durability properties for M60, M70 and M 110 grades of HPC trial mixes and to arrive at the maximum levels of replacement of cement with Silica Fume (SF), investigations were taken. The strength and durability characteristics of these mixes are compared with the mixes without SF. Compressive strengths of 60 MPa, 70 MPa and 110 MPa at 28days were obtained by using the 10 percent replacement of cement with SF. The results also indicate that the SF concretes possess superior strength properties.

Ghutke & Bhandari Examine the Influence of silica fume in concrete. Results indicated that the silica fume is a better replacement of cement. The rate of strength gain in silica fume concrete is high. Workability of concrete decreases as increase with % of silica fume. The optimum value of compressive strength can be achieved in 10% replacement of silica fume. As strength of 15% replacement of cement by silica fume is more than normal concrete. The optimum silica fume replacement percentage is varying from 10 % to 15 % replacement level.

Hanumesh, Varun& Harish Observes the Mechanical Properties of Concrete Incorporating Silica Fume as Partial Replacement of Cement. The primary purpose of this study is to examine the mechanical properties of M20 grade control concrete and silica fume concrete with different percentages (5, 10, 15 and 20%) of silica fume as a partial replacement of cement. The outcome showed that the compressive strength of concrete is increased by the use of silica fume up to 10% replacement of cement. From 10% there is a reduction in compressive strength and the split tensile strength of concrete is increased by the use of silica fume up to 10% replacement of cement. From 10% there is a decrease in split tensile strength. The optimal percentage of replacement of cement by silica fume is 10% for M20 grade of concrete.

P. Murthi and V. Siva Kumar 2008 studied the resistance of acid attack of ternary blended concrete by immersing the cubes for 32 weeks in sulphuric acid and hydrochloric acid solutions. Binary blended concrete was developed using 20% class F fly ash and ternary blended concrete was developed using 20% fly ash and 8% silica fume by weight of cement.

They concluded that the ternary blended concrete was performing better that the ordinary plain concrete and binary blended concrete. They observed that the mass loss for 28 and 90 days of M20 PCC specimens were 19.6% and 16.1% respectively. They also observed that the time taken for reduction of 10% mass loss when immersed in 5% H2SO4 and 5% HCl solutions was 32 weeks.

A.K. Al-Tamimi and M. Sonebi studied the properties of Self- Compacting Concrete when immersed in acidic solutions. Workability was obtained using slump cone test, L-box and orimet for SCC mix. Cylindrical specimens of diameter 45mm and length 90mm were casted and cured for

28 days in water after they were immersed in 1% HCl and 1% H2So4 solutions by maintaining a pH of 5 regularly.

They conclude that self-compacting concrete was performing better than control concrete when exposed to 1% sulphuric acid and hydrochloric acid. They observed that the time taken for 10% mass loss for SCC was 18 weeks and for CC was 6 weeks.

B.Madhusudhana Reddy et al., studied the effect of HCl on blended cement (fly ash) and silica fume blended cement and their concretes. Concrete cubes were casted using deionised water with a series of dosages (100, 150, 300, 500 and 900 mg/l) implanted into water and using only deionised water for comparison. These cubes were tested for determining chloride ion permeability (RCPT) and compressive strength. They concluded that the compressive strengths reduction of flyash blended concrete and silica fume blended concrete was 2to 19% at 28 and 90 days.

Beulah M. Asst Professor, Prahallada M. C. Professor studied the effect of replacement of cement by metakaolin in high performance concrete subjected to HCl attack. Cubes were casted with different water cement ratios (0.3, 0.35, 0.4 and 0.45), compressive strength was evaluated for 150×150×150 mm cubes and percentage weight loss was evaluated for 100×100×100 mm cubes. These cubes were cured for 30, 60 and 90 days in 5% hydrochloric acid. They concluded that the residual compressive strength after 30, 60 and 90 days of immersion decreases with increasing water binder ratio which is due to porous transition zone leading to the formation of ettringite at higher water levels.

UroojMasood et al., studied the behaviour of mixed fibre reinforced concrete exposed to acids. A mixture 75% glass and 25% steel fibres were used in mixed fibre reinforced concrete and cubes were casted and cured for 30, 60, 90, 120 and 180 days in acids and sodium sulphate. Test specimens were tested for weight loss and deneness of concrete of exposed and unexposed specimens at all the ages and compressive strength at 180 days.

They concluded that the resistance towards the sulphuric acid attack was maximum when 100% steel fibres was used when compared to other fibres and without any fibres. Mixed fibre reinforced specimens and 100% steel fibre reinforced specimens exhibited more resistance towards the attack of sulphuric acid.

III. MATERIALS AND METHODS

The experimental investigation work is started with various tests on the constituent materials. The constituent materials are given below.

1. Cement
2. Aggregates
3. Silica fume
4. Glass powder.
5. Bagasse ash
6. Admixtures
7. Conplast SP 430(G)

I. Cement

Ordinary Portland Cement (OPC) was used in the experimental work which is conforming to I.S 4031-1988.The O.P.C is classified into three grades, those are 33grade, 43grade and 53 grade, depending upon the strength of the cement in this experiment 43grade cement is used.

II. Fine Aggregate

Fractions from 4.75 mm to 150 microns are termed as fine aggregate. Locally available river sand passed through 4.75mm IS sieve is applied as fine aggregate conforming to the requirements of IS 383:1970.

III. Coarse Aggregate

The crushed aggregates used were of 20mm nominal maximum size.Aggregate most of which is retained on 4.75-mmIS Sieve and containing only so much finer material as is permitted for the various types described in this standard.

IV. Glass Powder

Glass is one of the most versatile substances on earth used in many applications and in a wide variety of forms. Glass occurs naturally when rock high in silicates melt at high temperature and cool before they can form a crystalline structure. Obsidian or volcanic glass is a well-known example of naturally occurring glass. Heat can return the glass to a liquid and workable form, making it easy to reuse and recycle.

V. Silica fume

Silica fume is a byproduct in the reduce of high-purity quartz with coke in electric arc furnaces in the manufacture of silicon and ferrosilicon alloys. Micro silica consist of fine element with a surface area on the order of

20,000 m²/kg when particular by nitrogen adsorption techniques, with particle just about one hundredth the size of the average cement Because of its excessive fineness and high silica content, micro silica is a very efficient pozzolanic material particle. Addition of silica fume also decrease the permeability of concrete to chloride ions, which protect the reinforcing steel of concrete from corrosion, especially in chloride-rich environment such as coastal region. It has been reported that the pozzolanic reaction of silica fume is very important and the no evaporable water content decreases between 90 and 550 days at low water /binder ratios with the addition of silica fume

VI. Bagasse ash

Bagasse is a by-product from sugar industries which is burnt to generate power required for different activities in the factory. The burning of bagasse leaves bagasse ash as a waste, which has a pozzolanic property that would potentially be used as a cement replacement material. It has been known that the worldwide total production of sugarcane is over 1500 million tons. Sugarcane consists about 30% bagasse whereas the sugar recovered is about 10%, and the bagasse leaves about 8% bagasse ash (this figure depend on the quality and type of the boiler, modern boiler release lower amount of bagasse ash) as a waste, this disposal of bagasse ash will be of serious concern.

IV. MIX DESIGN

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance. Percentage dosage of super plasticizer was fixed as per the mix design method described in IS 10262- 2009. Mix proportion was arrived through various trial mixes. The grade of concrete prepared for the experimental study was M30 grade concrete.

V. TESTS ON FRESH CONCRETE

The results of the experimental investigation on Silica fume, Glass powder and Bagasse ash in concrete wherever Silica fume, Glass powder and Bagasse ash has been used as partial replacement of cement in concrete mixes. On commutation cement with completely different percentages of Silica fume Glass powder and Bagasse ash the workability, compressive strength is studied the compressive strength, split tensile strength and flexural strength for various mixes then studied.

5.1 WORKABILITY OF CONCRETE

It is the important property of fresh concrete which gives the behavior of concrete from mixing to compaction. The workability of concrete is the most complex property, which is difficult to define and measure. A concrete which has high consistency and which has high consistency and which is more workable, need not be of right workability for a particular job. Every job requires a particular workability.

The vertical settlement of unsupported fresh concrete, flowing to the sides and sinking in height is known as slump. Slump is a measure indicating the consistency or workability of cement concrete.

5.1.1 VARIATION OF SLUMP VALUES FOR DIFFERENT POZZOLONIC MATERIALS

Slump test was carried out to measure the workability of various mixes. The workability of various mixes was assessed as per the IS 1199:1959 specification. Fig shows the variation of slump values with different percentages of Glass powder, Silica fume and Bagasse ash.

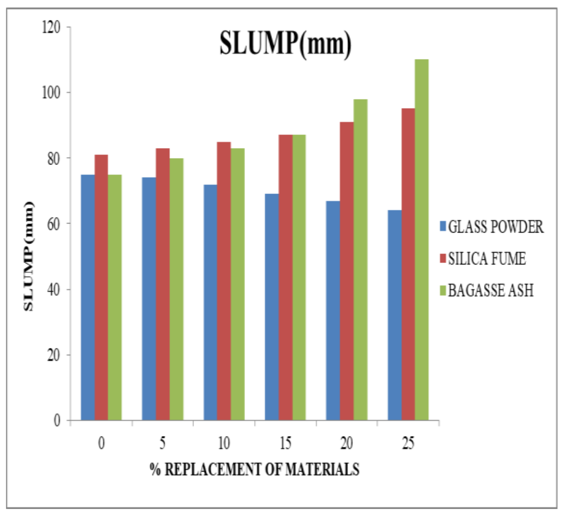

Fig 5.1: Plot shows the Summarized Slump Values for % replacement of materials

5.2 COMPRESSIVE STRENGTH

Concrete specimen cubes are used to determine compressive strength of concrete and were tested as per IS 516:1959. The compressive strength is usually obtained experimentally by means of a compressive test. 150x150x150 mm size mould is used for the casting of compressive test specimen, after the 24 hours of casting of specimens remove the cubes from moulds and the cubes are placed in curing tank up to one day before the testing. During testing on a UTM with a capacity of 300T, the load is delivered to the cubes at a continuous rate of 140kg/sq.cm/minute. The specimen is placed in the UTM with the cast faces facing the opposite to the observer. The specimen's ultimate load is defined as the load at which it fails. At the ages of seven and twenty-eight days, this test was conducted. The average load of three specimens is used to calculate strength for each mix.

5.2.1 Variation of compressive strength for different mixes

Compression test is most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. Compression test was conducted on 150mm×150mm×150mm cubes. Compressive strength of concrete with different percentages of Silica fume, Glass powder and Bagasse ash for curing periods of 7-days and 28-days respectively and Tables and figures shows the results for compressive strength of concrete for different percentages of Silica fume, Glass powder and Bagasse ash at different curing periods.

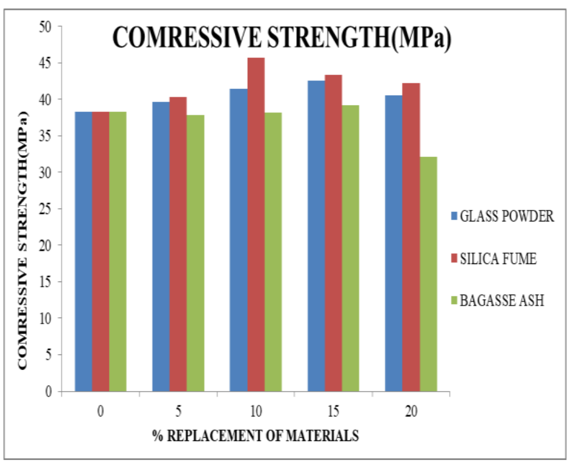

Fig 5.2: Plot shows the Summarised results of Compressive strength for % replacement of different materials

5.3 SPLIT TENSILE STRENGTH

The cylinder specimen is of the size 150 mm diameters and 300mm height was cast to determine the split tensile strength of concrete. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of compression testing machine and the load is applied until failure of cylinder, along its longitudinal direction. The cylinder specimens are tested at 7 days and 28 days. The average of three specimens was reported as the split tensile strength provided the individual variation is not more than 15% of average value.

5.3.1 Effect of different pozzolanic materials on Splitting Tensile Strength of concrete

The Split Tensile strength of the concrete mix for M-30 with partial replacement of cement by Silica fume, Glass powder and Bagasse ash for curing periods of 7-days and 28-days. The below tables and figures shows the summarized Split tensile strength Results for different curing periods– M30 grade. The cylinders were cured for 7 days and 28 days after removed from moulds. These were tested for split tensile strength in the respective days. The following are the results obtained after testing.

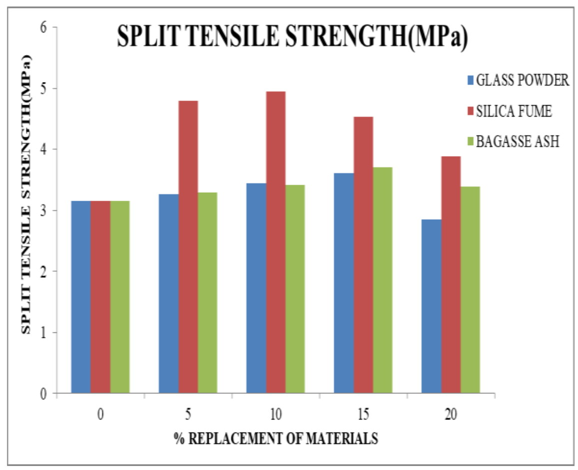

Fig 5.3: Plot shows the Summarized results of Split Tensile strength for % replacement of different materials

5.4 FLEXURAL STRENGTH

The size of specimens 100 mm x 100 mm x 500 mm was used and the specimens were cured in water. Concrete specimen beams are used to determine flexural strength of concrete and were tested as per as per IS 516 (1959).

5.4.1 Effect of different pozzolanic materials on flexural Strength of concrete

The beams were cured for 7 days, 14 days and 28 days after removed from moulds. These were tested for split tensile strength in the respective days. The following are the results obtained after testing.

After 7 and 28 days curing, prismatic specimens are placed on flexural testing machine having a maximum of 100 KN and a constant rate of loading of 40 kg/m2 per minute is applied on the test specimen by placing the specimen in such a way that the two point loading should be placed at a distance of 13.3 cm from both the ends. Ultimate load at which the prismatic specimen fails is noted down from dial gauge reading. The Flexural strength of the concrete mix for M-30 with partial replacement of cement by Silica fume, Glass powder and Bagasse ash.

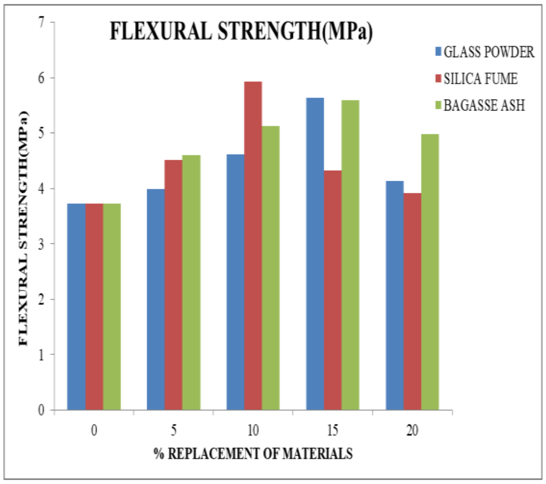

Fig 6.16: Plot shows the Summarized results of Flexural strength for % replacement of different materials

The significance of test results of obtained from the average of 3 samples. It is observed from the results that the specimens containing Nano particles show an increase in compressive, Split tensile and flexural strength of concrete when compared with the conventional concrete. The results exhibits that the concrete modified by 10% Silica fume shows an improvement results in strength aspects compare to normal concrete and concrete made with glass powder and silica fume for 28 days for M30 grade. The enhancement in the strength of concrete can be mainly due to that Nano particles act as nuclei in promoting the cement hydration and filling up of pores to increment in the flexural strength of concrete.

VI. CONCLUSIONS

This experiment shows that, partial replacement of cement with Glass powder, Silica fume and Bagasse ash gives good results. It will improve durability and reduce pollution, we studied the require properties of concrete like workability, compressive strength, flexural strength and compared with the normal standard concrete. This experiment gives satisfactory results, so these results are enhancing usage of Glass powder, Silica fume and Bagasse ash in concrete, the following conclusions were made:

- It has been observed that by the incorporation of pozzolanic materials like Silica fume and Bagasse ash as partial replacement to cement in fresh and plain concrete increases workability and for the replacement off bagasse ash workability decreases.
- It is noted that replacement of cement with Glass powder, Silica fume and Bagasse ash gives satisfactory results.
- It is clearly observed that the concrete modified by 10% Silica fume enhanced the compressive strength about 19% when compare with that of Normal concrete for 28 days for like M30 grade concrete. The compressive strength for the mix is 45.66 N/mm2.
- The compressive strength for the mixes glass powder and bagasse ash for 28 days of M30 grade concrete is 42.59 N/mm2 and 39.21 N/mm2.respectively.
- The chosen mineral admixtures are behaving like cement in all aspects. Comparing with the nominal mix, the supplementary cementitious mixes attain good results.
- The split tensile strength results exhibits that the concrete modified by 10% Silica fume shows more than results like split tensile strength of Normal concrete for 28 days of M30 grade concrete.
- Silica fume enhanced the split tensile strength of concrete about 57% when compare with that of Normal concrete for 28 days. The split tensile strength for the mixes glass powder and bagasse ash for 28 days of M30 grade concrete is 3.61N/mm2 and 3.70 N/mm2.respectively.
- From the results it is noted that the concrete modified by 10% Silica fume shows prominent results when compared to Glass powder and Bagasse assh and the improvement is about 59% with that of Normal concrete for 28 days M30 grade concrete. The flexural strength for the mix is 5.3 N/mm2.
- It is evident from the present investigation, influence of Silica fume will improves the micro structure as well as decrease the free calcium hydroxide concentration by consuming it through a pozzolanic reaction.
- The use of Silica fume, Glass powder and Bagasse ash is economic when compared to cement in concrete. Likewise saves a great deal of waste disposal problems and reduces the cement price rise and intensities of CO2 release by the cement production.

REFERENCES

[1] IS 456 (2000): Plain and Reinforced Concrete - Code of Practice.
[2] IS 516 (1959): Method of Tests for Strength of Concrete.
[3] IS 5816 (1999): Method of Test Splitting Tensile Strength of Concrete.
[4] IS 10262 (2009): Guidelines for concrete mix design proportioning.
[5] L Mohammed , M N M Ansari, G Pua, J Mohammad, IM Saiful. A Review on Natural Fiber Reinforced Polymer Composite and Its Applications. Internation¬al Journal of Polymer Science, 2015.

[6] KY Lee, A Yvonne , AB Lars, O Kristiina, B Alexan¬der. On the use of nanocellulose as reinforcement in polymer matrix composites. Composites Science and Technology, 2014, 105: 15-27.

[7] S Firat, G S Yılmaz, T Comert, M Sumer. Utilization of marble dust, fly ash and waste sand (Silt-Quartz) in road subbase filling materials. KSCE Journal of Civil Engineering, 2012: 16(7).

[8] BI Oza, A S Amin. Effect of untreated Cenosphere on Mechanical properties of Nylon-6. International Journal on Recent and Innovation Trends in Comput¬ing and Communication, 2015, 3(2321-8169).

[9] MallikarjunaRao, G., &GunneswaraRao, T. D. (2018). A quantitative method of approach in designing the mix proportions of fly ash and Silica fume-based geopolymer concrete. Australian Journal of Civil Engineering, 16(1), 53-63.

[10] Rangan, B. V., Hardjito, D., Wallah, S. E., &Sumajouw, D. M. (2005, June). Studies on fly ash- based geopolymer concrete. In Proceedings of the World Congress Geopolymer, Saint Quentin, France (Vol. 28, pp. 133-137).

[11] BIS (Bureau of Indian Standards) 2019. IS 10262-2019 Indian standard concrete mix proportioning-guidelines (second revision). New Delhi: Bureau of Indian Standards.

[12] Rangnekar D.V., integration of sugarcane and milk productionin western India http://www.fao.org/docrep/003/s8850e/S8850E17.html

[13] ASTM, concrete and mineral aggregates (including manual of concrete testing), part 10, Easton, Md., USA, 1972

[14] M Narmatha, T Felixkala, "Meta kaolin –The Best Material for Replacement of Cement in Concrete" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) Volume13, Issue 4 ,2016

[15] E Siva Subramanian, V R Vaishnave, V T S Vignesh "Experimental Investigation of Concrete Composite Using Nylon Fiber" (IJESRT) ISSN: 4.116 DEC- 2016.

[16] Nano-Materials in High Strength Concrete. Journal of Chemical and Pharmaceutical Sciences. (Special Issue 3): 15-22.

[17] S. Dhanasekar, S. Vinothraj, P.T. Ravichandran, A. Aravindan, Experimental Study on High Strength Concrete by Partial Replacement of Fine Aggregate by Ceramic Tile waste, International Journal of Engineering & Technology, 7 (2.12) (2018) 443-445.

[18] HasanShMajdi, Ali AbdulhusseinShubbar, Mohammed Salah Nasr, Zainab S. Al-Khafaji, HassnenJafer, Muhammad Abdulredha, Zainab Al Masoodi, MonowerSadique, Khalid Hashim, Experimental data on compressive strength and ultrasonic pulse velocity properties of sustainable mortar made with a high content of GGBFS and CKD combinations, Data in Brief 31 (2020) 105961, https://doi.org/10.1016/j.dib.2020.105961.

[19] G. Vamsi Krishna Reddy, V. RangaRao, M. Achyutha Kumar Reddy, Experimental investigation of strength parameters of cement and concrete by partial replacement of cement with Indian calcium bentonite, International Journal of Civil Engineering and Technology, Volume 8, Issue 1, January 2017, pp. 512–518.

[20] V. Suresh, M. Suresh Babu, and M. Achyutha Kumar Reddy, Experimental Study On Strength And Durability Parameters Of Concrete By Partial Replacement Of Cement With Sodium Polyacrylate, International Journal of Civil Engineering and Technology, Volume 8, Issue 1, January 2017, pp. 498–503.