International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-2, December 2019

Examination on GGBS based Geopolymer Mortar at elevated temperatures

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***Abstract:** In India approximately 120 million tonnes of flyash is produced every year from thermal power stations and enormous quantities of stone dust, a waste product, produced from the aggregate crusher units at the time of rubble crushing. Usage or disposal of this by-product within the framework of its economic structure becomes a challenging problem to every country because of increasing interest in conservation of energy and resources and growing concern with environmental issues. Also Land disposal becomes a serious problem due to scarcity of land. Due to this the M-sand and GGBS is used as ingredients in mortar which enhance the properties of mortar and utilization of M-sand is helpful for consumption. To study the alkaline solution of NaOH and Na_2SiO_3 is mixed with processed fly ash to become geopolymer mortar. This mortar cubes at different molarities and different temperature so as to increase the strength of the cubes.*

***Keywords:** Ground granulated blast furnace slag, Manufacture sand, Geopolymer mortar, alkali silica, caustic soda (lye)*

I. INTRODUCTION

Now a days Science and technology is developed continuing process for improvement of Infrastructure all around the world. Construction industries are innovated every day newly and safely, economically and environmental supportable. Concrete is mixing with water is the most utilize substances all throughout the world. The ground fine powder is used to adhesive clinker in a Portland cement product customarily [1]. The troubles related to the production of OPC are noted correctly. The manufacturing of ordinary Portland cement (OPC), high amount of carbon dioxide is emitted (or) produced for example one kilogram of Ordinary Portland Cement (OPC) is produce to one kilogram of CO2 is emitted. Geopolymer mortar mix does not required any OPC, but the reactions of alumina silicate materials with stronger than alkali solution, binder is produced [2]. In concrete production,

Revised Manuscript Received on December 30, 2019.
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geopolymer mortar mix is recently innovated all throughout the world where ordinary Portland cement (OPC) is completely replaced by alumina silicate materials, in present strong alkaline solutions is the binder of concrete mix [3]. Hardened by head of geopolymer concrete at a climate classifying of 60^0 C to 90^0 C. In concrete is rapidly increased day by day for example shelter and economic growth also increasing; usage of concrete is developed because of industrialization and globalization of infrastructural facilities. In environmental used to the large quantity of carbon dioxide and energy to surroundings are recognized [4]. M sand normally reacting with caustic soda (NaOH) alkali silica (Na_2SiO_3) and geopolymer mortar mix using M sand and GGBS (Ground granulated blast furnace), the maximum compressive strength is around 40 N/mm2 .The different temperature of oven machine is 40^0 C, 60^0 C, 80^0 C,100^0 C and the molarities are used in sodium hydroxide (NaOH) is 8M,10M,12M,14M [5].

Moreover, addition of alkaline activators of sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) ratio is 1:2.5 and different temperatures with same molarity in geopolymer mortar by using GGBS and M sand. Addition of Na_2SiO_3 into the mix at different temperatures double the compressive strength results. The alkali activated geopolymer are used in ambient curing method and this method is impact on the micros rural and strength development [6]. In geopolymer mortar mixture using M sand hardens normally at room temperature exposes the less strength increases at initial ages in opposition to oven curing specimens. Geopolymerisation process is generally dependent on process of curing. Therefore, the geopolymerisation process is normally dependent on mode of curing [7]. In high temperatures of 60C to 90C, faster in geopolymerisation but the oven curing can reacting only precast concrete structures [8].

During rapid hydration of cement, heat curing and treatment of heat, accelerated curing at elevated temperatures is done to gain more compression strength .Randomly they are different types of curing's are available at different varying temperatures. Out of these mainly there are 2 types of warm produce in a curing are available there are oven curing and warm radiant curing. Steam curing related to live steam and environment temperature in these curing compares both universal strength testing and tensile strength testing of the hard substance [10]. However, in steam curing we have low pressure at high elevated temperatures. In rapid curing we have to produce electric heat and generating hot air around the frame works pipelines is used to for hot water.

Mainly using of these heat produced concrete in constructions to reduce creep and shrinkages .In order to gain more strength of concrete in construction heat produced concrete is more beneficial [11] .Only for prestressed constructional work in order to attain relatively more strength we use these type of heat produced concrete [12] .

The use of these heat required precasting technology in construction is very important method effective steps should be taken by using these technology .Care should be taken by using these technology if there is increase or decrease of temperatures .In preconcrete construction technology, the work should be very fast .During normal curing we cast the concrete and it requires more time. But in this heat treatment process we use these concrete after 24 hours the work should be very fast and it requires less machinery and gives more strength [13].

Dealing with geopolymers is a very important comparing to Portland cement It is used to fill the structural gaps and very fast process in construction but precautions must be taken during these preparation of these hard substances and it is related to heat treatment process which is very important method in these construction all the time the heat treatment must be available at the time of construction if there is any electrical issues it is not possible to treat the concrete and it leads to a problem so when using of geopolymers we have to find all these problems [14].

The effects of hydration of cement grains slow down and stop soon , under normal moist conditions, a smaller volume of hydrations would developed . It results the structure of pore is made open or closed and loosely packed hydrations, for non-uniformly distributed throughout the cement matrix is distributed throughout the cement matrix [15]. These is generally a closed pore structure .During the greater hydration of cement grains in concrete was moist cured under normal conditions compared to heat cured. The coarse pore structures are large in size and reduced strength lately to it's ultimately reduced its durability characters and increased the permeability characters and other transport facilities are allowed into concrete to reducing its service life [16].

Several countries have been reported abut DEF phenomenon in concrete recently. It is rare and not understood properly it is a form of internal sulfate attack, so far concrete exposes to high curing temperatures is considered in excess up to 70^0 C . It is reported that DEF is not in concrete field the is not heat treated. When we subjected concrete to high temperatures during hydration, the fresh concrete is destroyed and releasing sulphate and aluminate ions, to these ions are absorbed by calcium silicate hydrates .Due to the presence of moisture, the calcium silicate hydrates releases sulphates ions which they absorbed and they react to mono sulphate ions which are found in cement paste and these leads to disruption and hardened the concrete [16]. Depending upon to types of aggregates, the sizes of aggregate varies DEF is only formed in the ordinary Portland cement. DEF is suspectable to rapid hardening Portland cement. The cements in heat cured concretes are to achieve high strength levels of sulphates and they release heat at higher levels of temperatures. These are the factors which is the combination of other chemical reactions which is influence to DEF [17].The heat treatment cycle the potential of curing the adverse effects of temperatures are associated at elevated temperatures .It consist the heat curing of 3 to 5 hours procure period and heating at a rate of 20K/hour to maximum temperature of 60 to 70c temperature Typically the heat curing cycle consists of 3 to 5 hours procure period followed by heating the maximum temperatures is maintained specific time period at a rate of 20 K/hour. In practicing of mixing the setting time of concrete depends upon the mix design and materials used [18] .Using of plasticizers admixtures it can extend the setting time of binder. .The setting time and properly allowed heat treatment and heat curing ,there is a risk of micro cracking so these results of extending setting time. In setting time, the properly allowed for heat treatment. At high performance concrete it can be higher temperatures above 70^o C without releasing of unusual adverse effects. Therefore, the standard heat curing is optional it cannot be applied for executing heat treatment of concretes [19].

II. LITERATURE REVIEW

Comrie et al. (1988) : Studied and conduct testing on Geo Polymer mortar tube to report on 28 days curing will get more compressive strength compared to 1st two days are curing . Geopolymer mortar is similar to OPC in term of both fire resistance and heat, so that the Portland experiences to rapid compressive strength of 30^0c where geopolymers are upto 60^0 c [4].

S. E. Wallah and B. V. Rangan, 2006: In previous studies it is reported that geopolymers have corrosion resistance, sulphate resistance, to increase early durability, weathering resistance no severe alkali-aggregate reaction, reduced breakage [10].

Davidovits (1988): Based on several laboratory tests, it is proved that at room heat temperature are rapidly hard to the geopolymer and increase the universal strength to classify the 20.4 MPa next during four hours to 20^0C & up to 70-100 MPa next 672 hours [21].

Fernandez et al. (2006): Polymerization process has been take place in geopolymer concrete which is widely different from supplementation of Portland cement [16].

Ramchandran el al. (1992): Report on GGBS which is used in high volume of concrete to reduce the alkali aggregate reaction [17].

Van Jaarsveld et al. (2002): In inter-relationship parameter should effect the GGBS based geopolymers and properties should effect the incomplete solution of material which is involves in geopolymer. In curing time and temperatures in water content should affect the property of geopolymers; specifically, the curing conditions and temperature are also influence the compressive strength. When these samples are cured at 24 hours there is more increase in compressive strength is observed [18].

Alloucher et al. (2011): Reported that self-curing property of geopolymer hard substance. To show the weather to depend on the time of hard substance mixing is studied. The strength increases the geopolymer concrete in the curing time. The Poisson's and modulus of elasticity ratio are corresponding to 28 days within the accept range type of concrete use in structural applications [19].

Mustfa et al. (2012): Based on experiment work to concluding a alkali silica and caustic soda (NaOH) ratios and molarities of GGBS based to achieve more compressional strength on geopolymer concrete.

The sodium hydroxide and sodium silicate ratio 2.5 contribute to the high universal strength is fifty-seven MPa . In molar increases to compressive strength should not give increases. The geopolymer with 12M NaOH showed good results included to reaming molar the higher compressive strength up to a 94.95 MPa corresponding to seven days curing [20] .

Duxson et al. 2007, Sofi et al. 2006: Study on previous literature review the present experiment investigations is aimed to study the effect of curing conditions, i.e. temperature curing & ambient, to study the universal strength of GGBS base on GPC [22] .

III. MIX DESIGN OF GEOPOLYMER CONCRETE

During the mix design of geopolymer the aggregates plays a very important role in mix designing .The mix design for geopolymer is same as ordinary Portland cement . The mass of aggregates is between 75% and 80 % to the mass of geopolymer mortar .The mass of both coarse aggregate and fine aggregate will be together is considered 77.3% the mass of the entire mixture. The fine aggregate should be taken 30% by the weight of total aggregate. The M-sand and alkaline liquids were taken 23% to the density of the concrete. From previous literatures, the average density of m-sand based geopolymer is similar to OPC concrete (2400 kg/m3).The density of concrete and mass of alkaline liquids together to the total density of concrete . while taking these ratios of alkaline liquids to m-sand is 0.4 to the mass of alkali liquid .To obtain the ratios to mass of caustic soda and alkali silica is to be taken 2.5 and 3.5 . Water (water is used for the preparation of alkaline mixture other than used to the add mixtures) [23].

In earlier stages, it was observed that Geopolymer mortar has two main delays it requires more setting time and sufficient amount of heat during the heat treatment process . In order to achieve these delays GPC mix is replaced 10% to the (GGBS) ground granulated blast furnace slag and mix designs were modified. Geopolymer mix designs were related to the geopolymer concrete [24].

For preparing of solution 12M sodium hydroxide concentration was mix with alkali silica the one day before mixing of concrete to get the desired amount of alkalinity in the alkali liquid. Gravel aggregate, fine aggregate m-sand GGBS was mixed for three or four minutes with the hand mix. After mixing, the alkali liquid is adding to the hard mixture solution to mixes up to four minutes then get the wet mixture. Finally, extra water is added to these mixtures. The mixing was done until the binding paste combined to become homogeneous and it mixed properly. After these the casted cubes and cylinders and prisms for each specimen we casted in three layers by compacted by using tampering rod. For each layer the compaction should be done by 25 strokes by using compacting rod and for further compaction we use compacting variation table. Standard compaction of each layer is 25 strokes. After these the specimens should be remoulded 24 hours since they got a similar type of the specimen. All these specimens were left at a room temperature and left ambient curing till the date of testing [23 - 58].

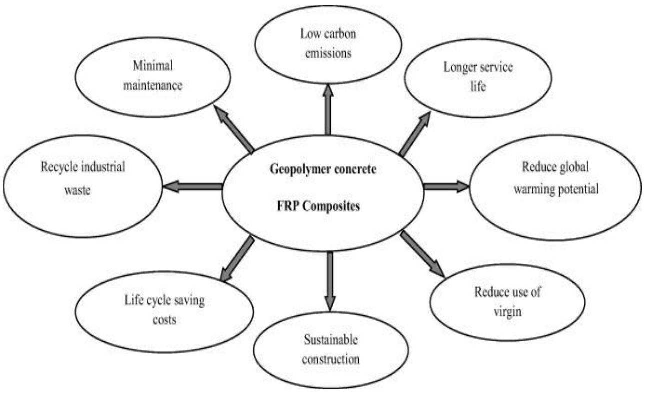

Chart-1: Geopolymer concrete FRP composites.

IV. MATERIAL PROPERTIES

A. GGBS:

Full form of GGBS is Ground granulated blast-furnace slag to it provides better workability, in large pores it reduces the hazard of thermal cracking**.** The content of GGBS typically ranges from 30 to 70 % and its production is ready mixed or batching curable concrete. It is a non-materialistic material and non-hazardous waste material from Iron Industry, is suitable for mortar mix and enhanced properties of mortar like compressive strength, reduces the drying shrinkage, heat of hydration and retards the setting time of cement etc**.**

Fig. 1: ground granulated blast furnace slag.

B. M-SAND:

M -Sand is a type of river sand which is used in concrete mixtures and it is produced during the crushing of hard granite stone. These crushed m-sand with different shapes should be washed and graded and use as a constructional material. In size of M-sand is lower than 4.75mm. During the preparation of conventional cement mortar, natural sand is used to fine aggregate. It is having very high potential to replace the river sand in preparation of cement mortar. It is having very high strength to replace this m-sand in cement mortar. In construction industry it is used mainly for concrete production to its mortar mix.

Fig.2: Manufacture sand.

C. SODIUM HYDROXIDE:

Sodium hydroxide (NaOH) is an inorganic compound with the formula NaOH. 8 M to 16 M concentrations of NaOH is used. Based on preparation of concentration of NaOH solution required a caustic soda pellets is added in 1000ml of distilled water. Then molarity of NaOH is found from the laboratory measurements. For example, 8M NaOH solution consist of 8 × 40 = 320grams of NaOH solids per liter of solution. And the normal consistency of 8M is 44 .NaOH solution was prepare to before the day in casting of 750cm cube and make the solution in cool environment.

Fig. 3: Sodium Hydroxide.

D. SODIUM SILICATE:

Alkali silica is known as a liquid glass. It is possible in both solution and gel form in markets. In ratio of Na_2SiO_3 is 24 hours before casting and mixes its pellets. It includes water with 36 hours is used.

Fig. 4: Sodium Silicate.

V. LABORATORY TESTS

A. SIEVE ANALYSIS:

1. Take 1 kg of dry M sand from lab.
2. Arrange the sieves in descending order of Is sieves no's 4.75mm, 2.36mm, 1.18,600 mic ,300mic and150mic and keeping sieve no 4.75 at the top and 150 at the bottom and cover the top 4.75 sieve.
3. Keep a pan below the 150 mic sieve to take fine aggregate passing through 150 mic sieve.
4. Place the M sand in top of the sieve and keep the sieves set in a
5. Sieve shaker in 15 minutes.
6. To know the weight of M sand retained in each sieve and shown in the table.
7. And calculate the weight retained, percentage of weight retained and cumulative percentage of weight retained on each sieve.
8. Calculate the fineness modulus of fine aggregate.

Fig.5 : Sieve Pans ,Sieve Shakers.

Table 1: sieve analysis:

S.no	IS sieve designation	Weight retained	% of weight retained	Cumulative % of weight retained	% of passing
1.	4.75mm	12	1.2	1.2	98.80
2.	2.36mm	21.5	2.15	3.35	96.65
3.	1.18mm	140.5	14.05	17.4	82.60
4.	600 mic	318.5	31.85	48.9	51.10
5.	300 mic	409.0	40.9	89.9	10.2
6.	150 mic	86.5	8.65	98.45	1.55
7.	pan	11	1.1	-	-

Fineness modulus = ∑ cumulative % of weight retained /100

= 2.59

B. STANDARD CONSISTENCY:

1. Normal consistency of GGBS with 8M solution of NaOH and Na_2SiO_3

Normal consistency = (176/400)*100
= 44%

2. Normal consistency of GGBS with 10M alkali liquids of NaOH (caustic soda) and alkali silica (Na_2SiO_3) is

Normal consistency = (184/400)*100
= 46%

3. Normal consistency of GGBS with 12M alkali liquids of NaOH(caustic soda) and alkali silica (Na_2SiO_3) is

Normal consistency = (190/400)*100
= 47%

4. Normal consistency of GGBS with 14M alkali liquids of NaOH (caustic soda) and alkali silica (Na_2SiO_3) is

Normal consistency = (208/400)*100
=50%

5. Normal consistency of GGBS with 16M alkali liquids of NaOH (caustic soda) and alkali silica (Na_2SiO_3) is

Normal consistency = (208/400)*100
= 52%

Fig. 6: Vicat apparatus.

C. COMPRESSIVE TESTING:

It is only one of the alternate to find the strength of the concrete. The cube size of molds 70.6x70.6x70.6mm mortar cubes are casting with different molarities (i.e., 8M, 10M, 12M, 14M, 16M). This test is carried out by placing the specimen in testing machine firmly in position. Load is applied on the specimen at the rate of 140 kg/cm^2.maximum capacity of loading for compressive testing machine is 2000 KN

Fig .7: compression testing mechine.

Compressive strength of cube is required for assuring the design strength. Non-destructive tests are employed to assess the strength and uniformity of quality of a built up structure, the development of strength with time of the same specimen, to assess the probable damage caused by corrosive environment on concrete, fine, loading etc.

Table 2: Mix Proportions of NaOH: Na_2SiO_3

S no	NaOH Molarity(M)	Masses of pellets dissolved in 1 lit of distilled water (g)	Masses of NaOH; Na_2SiO_3 ratio of 1:2.5 (g)
1.	8M	320 grams	112 grams
2.	10M	400 grams	116 grams
3.	12M	480 grams	120 grams
4.	14M	560 grams	124 grams

D. PROCEDURE OF NAOH SOLUTION:

1. To prepare the sodium hydroxide solution we have to dissolve the caustic soda (NaOH) flakes in distilled water.
2. The caustic soda (NaOH) solution was prepared is used after 24 hours.
3. To get desired solution NAOH solution mixed with sodium silicate.

VI. RESULTS

Table 3: Compressive Strength of 8 Molar GPM

Days	Trails	100%M-Sand
For 3 days	Trail-1	32.59
	Trail -2	44.82
	Trail-3	36.67
	Average:	**38.02667**
For 7 days	Trail-1	57.04
	Trail-2	48.89
	Trail-3	44.82
	Average:	**50.25**
For 28 days	Trail-1	48.893
	Trail-2	30.55
	Trail-3	48.89
	Average:	**42.77767**

Table 4: Compressive Strength of 10 Molar GPM

Days	Trails	100%M-Sand
For 3 days	Trail-1	36.67
	Trail -2	46.85
	Trail-3	36.67
	Average:	**40.06333**
For 7 days	Trail-1	34.63
	Trail-2	52.97
	Trail-3	34.63
	Average:	**40.74333**
For 28 days	Trail-1	48.893
	Trail-2	30.55
	Trail-3	48.89
	Average:	**42.77767**

Table 5: Compressive Strength of 12 Molar GPM

Days	Trail	100% M-Sand
For 3 days	Trail-1	26.4
	Trail-2	32.59
	Trail-3	34.63
	Average:	**31.20**
For 7 days	Trail-1	38.7
	Trail-2	36.67
	Trail-3	38.7
	Average:	**38.02**
For 28 days	Trail-1	50.93
	Trail-2	48.89
	Trail-3	55
	Average:	**51.60**

Table 6: Compressive Strength of 14 Molar GPM

Days	Trail	100% M-Sand
For 3 days	Trail-1	46.85
	Trail-2	50.93
	Trail-3	40.74
	Average:	46.17333
For 7 days	Trail-1	42.78
	Trail-2	34.63
	Trail-3	48.89
	Average:	42.1
For 28 days	Trail-1	50.93
	Trail-2	40.73
	Trail-3	32.59
	Average:	41.41667

Table 7: Compressive Strength of 16 Molar GPM

Days	Trail	100% M-Sand
For 3 days	Trail-1	38.7
	Trail-2	57.04
	Trail-3	59.08
	Average:	51.60667
For 7 days	Trail-1	38.7
	Trail-2	48.89
	Trail-3	52.97
	Average:	46.85333
For 28 days	Trail-1	34.63
	Trail-2	46.85
	Trail-3	52.97
	Average:	44.81667

Table 8: Compressive Strength of 8M with Different Temperature

S.NO	Molarity	Temp (degree)	Compressive Testing		
			3 Days	7 Days	28 Days
1	8 M	40^0C	36.67	47.87	56.53
2	8 M	60^0C	42.27	41.76	39.72
3	8 M	80^0C	53.47	52.96	45.32

Table 9: Compressive Strength of 10M with Different Temperature

S.NO	Molarity	Temp (degree)	Compressive Testing		
			3 Days	7 Days	28 Days
1	10 M	40^0C	45.83	45.83	46.85
2	10 M	60^0C	47.87	44.3	42.78
3	10 M	80^0C	52.45	51.93	55

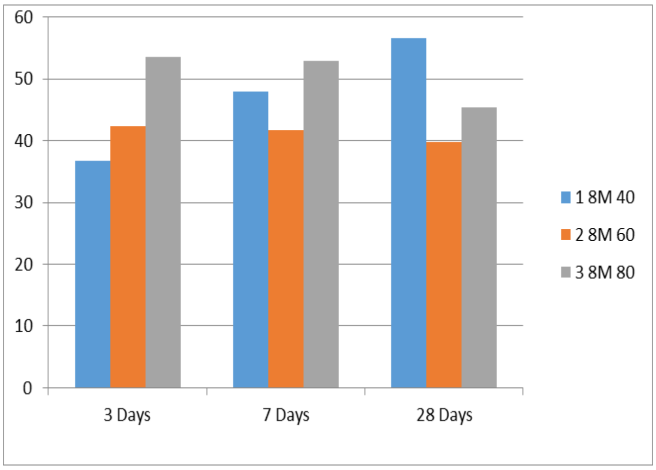

Chart-2: Compressive Strength of 8M with Different Temperatures

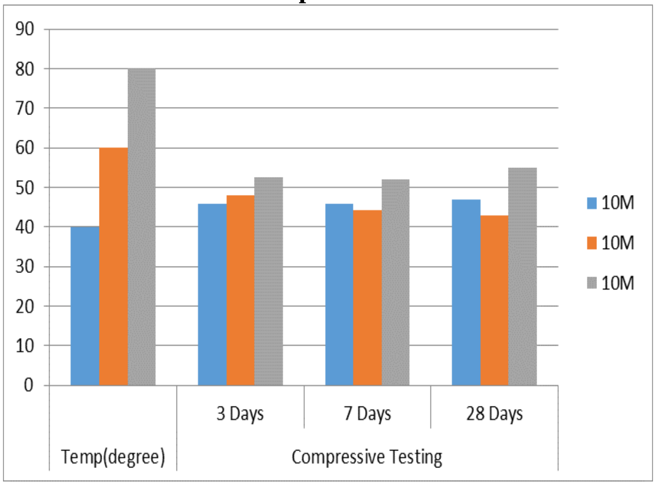

Chart-3: Compressive Strength of 10M with Different Temperatures

VII. CONCLUSION

1. The present work has reviewed the methods of curing of geopolymer mortar.
2. Different methods of curing have been attempt by various research papers with taken information of researchers the mortar cubes to heat in oven.
3. Oven curing method to the most efficient method of curing of geopolymer concrete.
4. The compressive strength of geopolymer mortar cubes by using M sand has gained more strength compared to geopolymer mortar cubes by using normal sand.
5. From overall comparison and studies that geopolymer mortar cubes has more compressive strength Compared to normal cubes.

REFERENCES

1. Prakash R. Vora, Urmil V. Dave, 2012. "Parametric Studies on Compressive Strength of Geopolymer Concrete", Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirmal University International conference on Engineering (NUICONE-2012)
2. Harisha.M, Chaitanya kumar.J.D, 2017. " Analysis of Multi Storey Building with Pre-cast Load Bearing Walls without Openings" International Journal of Civil Engineering and Technology (IJCIET), Volume 8, Issue 1, pp.764-780
3. Sravan kumar Reddy.Ch, Sarath Chandra Kumar.B, Asadi.SS (2019), "Utilization of Low Density Polyethylene Waste in the Manufacturing of Paver Bricks", International Journal of Recent Technology and Engineering (IJRTE), Volume 07, Issue 6C2, pp. 62-67

4. Comrie, D. C., Paterson, J. H., & Ritchey, D. J. (1988). Geopolymer Technologies in Toxic Waste Management. Paper presented at the Geopolymer", First European Conference on Soft Mineralurgy, Compiegne, France.
5. Sujit Kumar, Puru Deep Gautam, Sarath Chandra Kumar.B (2019), "Effect of Alkali Activator Ratio on Mechanical Properties of GGBS based Geopolymer Concrete", International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume 08, Issue 12, pp. 947-952
6. Nagendra Reddy.K, Surya Narayana.K, Damodhar Reddy.J, Sarath Chandra Kumar.B, Himath Kumar.Y (2017), " Effect of Sodium Hydroxide and Sodium Silicate Solution on Compressive Strength of Metakaolin and GGBS Geopolymer", International Journal of Civil Engineering and Technology, Volume 08, Issue 07, pp.1905-1917
7. Adisekhar.G, Sarath Chandra Kumar.B (2017), "Effect on Flexural strength of Reinforced Geopolymer Concrete Beams by using GGBS, Metakaolin and Alkaline Solution", International Journal of Civil Engineering and Technology, Volume 08, Issue 05, pp.175-188
8. Arunakanthi.E, Chaitanya Kumar.J.D, (2019), " Experimental Analysis of Light Weight Fiber Reinforced Concrete by Incorporating Palm Oil Sheels", Materials Today: Proceedings 19P2, pp.850-858
9. Srinivasa Rao.G and Sarath Chandra Kumar.B (2019), "Experimental Investigation of GGBS based Geopolymer Concrete with Steel Fibers", International Journal of Recent Technology and Engineering (IJRTE), (ISSN 2277-3878), Volume 07, Issue 6C2, pp. 49–55
10. Wallah and Rangan "low-calcium fly ash-based geopolymer concrete: long-term properties", Faculty of Engineering Curtin University of Technology Perth, Research Report GC 2, 2006 Australia.
11. Ratna.M, Srinivas, Himath Kumar.Y, Sarath Chandra Kumar.B, 2019. "Study on Flexural Behaviour of Geopolymer Concrete Beams with GGBS", International Journal of Recent Technology and Engineering (IJRTE), ISSN: 2277-3878, Volume-7, Issue-6C2, April 2019, pp. 199-205.
12. Jaffery.I, Himath Kumar.Y and Sarath Chandra Kumar. B (2017),**"**Study on Strength And Durability Parameters of Geopolymer Concrete with GGBS For 12M and 14M Alkali Activators**",** ARPN Journal of Engineering and Applied Sciences, (ISSN 2321-1814), Volume 12, Issue 04, February 2017, pp. 1202-1212
13. Prakash R. Vora, Urmil V. Dave, 2012. "Parametric Studies on Compressive Strength of Geopolymer Concrete", Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirma University International conference on Engineering (NUICONE-2012).
14. Wasan Ismail Khalil, Waleed A. Abbas et al., 2018. "Mechanical Properties and Thermal Conductivity of Lightweight Geopolymer Concrete", 1st International Scientific Conference of Engineering Sciences-3rd Scientific Conference of Engineering Science (ISCES).
15. Malhotra V.M., 2000. "Introduction: Sustainable Development and Concrete te1chnology", ACI Concrete Journal, pp.1147-1165.
16. Fernández, J.A., Palomo, A. and López, H.C. (2006), "Engineering properties of alkali activated fly ash concrete", ACI Mater. J., **103**(2), pp.106-112.
17. Ramchandran, S., Ramakrishnan, V. and Johnston, D. (1992), "Roll of high volume fly ash in controlling alkali-aggregate activity", Am. Concrete Inst. SP, 132, pp.591-614.
18. Jaarsveld, J.G.S., Deventer, J.S.J. and Luckey, G.C. (2002), "The effect of composition and temperature on the properties of fly ash and Kaolinite based geopolymers", Chem. Eng. J., 89(1), pp.63-73.
19. Allouche, E.N., Vaidya, S. and Diaz, E.I. (2011), "Experimental evaluation of self cure geoplymer concrete for mass pour application", World of Coal Ash (WOCA) Conference (May 9-12), Denver, USA.
20. Mustafa Al Bakri, A.M., Kamarudin, H., Bnhussain, M., Rafiza, A.R. and Zarina, Y. (2012), "Effect of Na2SiO3/ NaOH ratios and NaOH molarities on compressive strength on fly ash based geopolymer", ACI Marerials J., 109(5), pp.503-508.
21. Davidovits J., 1998. "Chemistry of Geopolymeric Systems, Terminology, Geopolymer" 99 International Conference, France, pp. 3077-3085.
22. Duxson, P., Fernández, J.A., Provis, J.L., Lukey, G.C., Palomo, A. and van Deventer (2007), "Geopolymer technology- The current state of the art", J. Mater. Sci., 42 (9), pp.2917-2933.
23. S. Sai Sandeep, Sk. Kalesha, Y. Himath Kumar and B. Sarath Chandra Kumar (2017), "Effect of Molarity on Compressive Strength of Geopolymer Mortar with GGBS and Metakaoline". International Journal of Civil Engineering and Technology, (ISSN 0976-6308), Volume 08, Issue 04, pp. 935-944
24. Pradeep U., Purushotham Rao S, Markandeya Raju P., "The Effect of Age on Alkali-Activated Geo Polymer Mortar at Ambient Temperature". SSRG International Journal of Civil Engineering (SSRG – IJCE) – Volume 3 Issue 12 – December 2016.
25. B. Sarath Chandra Kumar, K. Ramesh and P. Poluraju (2017), "An Experimental Investigation on Flexural Behavior of GGBS and Metakaolin based Geopolymer Concrete**"**, ARPN Journal of Engineering and Applied Sciences, (ISSN 2321-1814), Volume 12, Issue 07, pp. 2052-2062.
26. Anusha H S, Bhargavi S P, Syed Zabiulla, Prakash M, "Replacement of Fine Aggregate by M-Sand". IJSTE - International Journal of Science Technology & Engineering, Volume 3, Issue 12, June 2017 ISSN (online): 2349-784.
27. Shyam S, Drishya P, "Reuse of Plastic Waste as Replacement of M Sand in Concrete". IOSR Journal of Engineering (IOSRJEN), ISSN (e): 2250-3021, ISSN (p): 2278-8719, Vol. 08, Issue 6 (June. 2018), Volume 5, Issue 3, pp. 41-47.
28. Suseela. K and Dr. Baskaran T., "Strength analysis on concrete with M-sand as partial replacement of fine aggregate", International Journal of Civil Engineering and Technology (IJCIET) Volume 8, Issue 12, December 2017, ISSN Print: 0976-6308.
29. Chaitanya Kumar. J.D and Arunakanthi. E "optimum mix design for light weight fiber reinforced concrete by incorporating agriculture solid waste" International Journal of Management, Technology And Engineering (IJMTE), Volume-9, Issue-VI, June -2019.
30. D, Sravanthi, B. Sarath Chandra Kumar, Y. Himath Kumar (2019), " Experimental Study on GGBS based on Geopolymer Concrete", Proceedings
31. Amol A. Patil, Chore. H. S, Dode. P. A, (2014) " Effect of Curing Condition on Strength of Geopolymer Concrete" Advances in Concrete Construction, volume 02,Issue No 01(2014) 20-37
32. Chandra Padmakar K., Sarath Chandra Kumar B., 2017, "An experimental study on metakaolin and GGBS based geopolymer concrete", International Journal of Civil Engineering and Technology, Volume 9, Issue 2, pp. 341 - 349.
33. Sarath Chandra Kumar B., Ramesh K., 2017, "Durability studies of ggbs and metakaolin based geopolymer concrete", International Journal of Civil Engineering and Technology, Volume 8, Issue 1, pp. 17 - 28.
34. Chamundeswari P., Ranga Rao V., 2017, "Effect of activator ratio on strength properties of geopolymer concrete", International Journal of Civil Engineering and Technology, Volume 8, Issue 1, pp. 559 - 564.
35. Keerthy V., Kumar Y.H., 2017, "Experimental studies on properties of geopolymer concrete with GGBS and fly ash", International Journal of Civil Engineering and Technology, Volume 8, Issue 1, pp. 206 - 209.
36. Shahbuddin S.M., Ranga Rao V., 2017, "Experimental study on behaviour of flyash based geopolymer concrete", International Journal of Civil Engineering and Technology, Volume 8, Issue 1, pp. 575 - 582.
37. Keerthi M., Prasanthi K., 2017, "Experimental study on coir fibre reinforced fly ash based geopolymer concrete for 10M", International Journal of Civil Engineering and Technology, Volume 8, Issue 1, pp. 464 - 472.
38. NarasimhaSwamy P.A.N.V.L., VenuGopal U., Prasanthi K., 2017, "Experimental study on coir fibre reinforced flyash based geopolymer concrete with 12m & 10m molar activator", International Journal of Civil Engineering and Technology, Volume 8, Issue 4, pp. 2210 - 2216.
39. Kumar H.T.K., Prasanthi K., 2017, "Experimental study on coir fibre reinforced flyash based geopolymer concrete with 12M molar activator", International Journal of Civil Engineering and Technology, Volume 8, Issue 1, pp. 438-443.
40. Gowtham Kumar A., Prasanthi K., 2017, "Experimental study on plastic fiber reinforced flyash based geopolymer concrete", International Journal of Civil Engineering and Technology, Volume 8, Issue 4, pp. 1522 - 1530.
41. Bhargav M.V., Sarath Chandra Kumar B., 2017, "Strength and durability study of geopolymer concrete incorporating metakaolin and GGBS with 10M alkali activator solution", International Journal of Civil Engineering and Technology, Volume 8, Issue 1, pp. 473-487.
42. Hymavathi G., Ranga Rao V., 2017, "Strength characteristics of fly ash based geopolymer concrete with 14 molar naoh activator", International Journal of Civil Engineering and Technology, Volume 8, Issue 1, pp. 431-437.
43. Sowjanya V., Srujana N., 2017, "Strength properties of flyash based geopolymer concrete", International Journal of Civil Engineering and Technology, Volume 8, Issue 1, pp. 834 - 840.

44. Malleswara Rao P., Hamantha Raja K., 2017, "Study of the properties of metakiolin and GGBS based geopolymer concrete", International Journal of Civil Engineering and Technology, Volume 8, Issue 1, pp. 565 - 574.
45. Sindhusha C.H., Ranga Rao V., 2017, "Study on behavior of alkali activated flyash based geopolymer concrete", International Journal of Civil Engineering and Technology, Volume 8, Issue 1, pp. 728-733.
46. Jaffery I., Himath Kumar Y., Sarath Chandra Kumar B., 2017, "Study on strength and durability parameters of geo polymer concrete with ggbs for 12m and 14m alkali activators", ARPN Journal of Engineering and Applied Sciences, Volume 12, Issue 4, pp. 1202-1212.
47. Sindhusha C.H., Ranga Rao V., 2017, "Study on behavior of alkali activated flyash based geopolymer concrete", International Journal of Civil Engineering and Technology, Volume 8, Issue 1, pp. 728 - 733.
48. Naga Vinay B., Venkateswara Rao A., 2019, "Performance of geopolymer concrete under ambient curing", International Journal of Recent Technology and Engineering, Volume 7, Issue 6C2, pp. 546 - 550.
49. Sarath Chandra Kumar B., Ramesh K., 2018, "Analytical Study on Flexural Behaviour of Reinforced Geopolymer Concrete Beams by ANSYS", IOP Conference Series: Materials Science and Engineering, Volume 455, Issue 01, pp. 01-09.
50. N. Sai kiran, Y. Himath Kumar, B. Sarath Chandra Kumar, 2019, "Experimental Investigation on Reinforced Geopolymer Concrete Slabs", International Journal of Recent Technology and Engineering (IJRTE), Volume 7, Issue 6C2, pp. 248-254.
51. A. Siva Krishna and V. Ranga Rao, 2019, "Strength Prediction of Geopolymer Concrete using ANN", International Journal of Recent Technology and Engineering (IJRTE), Volume 7, Issue 6C2, pp. 661-667.
52. A. Siva Krishna and V. Ranga Rao, 2019, "Strength Prediction of Geopolymer Concrete using FUZZY", International Journal of Recent Technology and Engineering (IJRTE), Volume 7, Issue 6C2, pp. 668-671.
53. V. L. S. Srinvas, U. Anees Ahamed, V. Y. S. V. Somaraju, Y. Himath Kumar, 2019, "Study on Properties of Geopolymer Self Compacting Concrete", International Journal of Recent Technology and Engineering (IJRTE), Volume 14, Issue 2, pp. 52-66.

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