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STRENGTH AND SHORT-TERM DURABILITY OF 6M, 8M, 10M GEO-POLYMERS CONCRETE

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ABSTRACT

India is a developing country concentrated to develop the infrastructure and implement new construction techniques. Concrete is a main source of developing structure. It makes a great demand second only after water. So need an alternative to prevent this demand. Concrete is the mixture of cement, river sand and coarse aggregate. Cement manufacture produce carbon-di oxide and make ozone layer depletion cause global warming. Scarcity of river sand makes a demand in construction. So need an alternative for cement and river sand to prevent environmental effect and also increase the compressive and tensile strength of the concrete. Geo-polymer is a good alternative material. It prevents the environmental effects and increases compressive and tensile strength of the concrete. The combination of sodium hydroxide and sodium silicate is called geo-polymer. Using geo-polymer in concretes called geo-polymer concretes. Due to great demand occurred in the construction materials need to take research by replacement, partial replacement and admixture by use waste materials in geo-polymer concrete and find which composition will give strength and durability of the concrete.

INTRODUCTION

Geo-polymer was researched by a French professor Davidovits in 1978. To found out the alternatives of construction material by used waste materials. In Geo-polymer fly ash is used as a binder material with sodium hydroxide and sodium silicate ratio as 2.5. The schematic formation of geo-polymer material can be shown as described by equation (A) and (B).

$$n(Si_2O_5, Al_2O_2) + 2nSiO_2 + 4nH_2O + NaOH \text{ or } KoH \rightarrow Na^+, K^+ + n(OH)_3 - Si - O - Al^- - O - Si-(OH)_3$$

$\downarrow$

OH_2

(Geo-polymer Precursor)

$$n(OH)_3 - \underset{|\atop O}{\overset{O\atop |}{Si}} - O - \underset{|\atop O}{\overset{O\atop |}{Al^-}} - O - \underset{|\atop O}{\overset{O\atop |}{Si}} - (OH_3) + NaOH \text{ or } KoH \rightarrow (Na^+, K^+) - (- Si - O - Al^- - O - Si - O -) + 4n\,H_2O$$

MAJOR NEED IN GEO-POLYMER CONCRETE

- Fly ash
- Sodium hydroxide
- Sodium silicate
- Super plasticizer

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REPLACEMENT AND ADMIXTURES

- GGBFS
- Bottom ash
- Glass fiber
- Some other materials

APPLICATION

- Geo-polymer was used in bridges, structural members, roads and can also use for repair and rehabilitation work.
- It used for pre-cast construction work.
- It used in building material such as brick and block made by fly ash with used Indian standards
- It process is the 100 percent utilization of waste materials.

ADVANTAGES

- Recycling waste materials
- By used this can able to prevented 80 percentage of carbon-dioxide emission.
- It increases strength and durability of the concrete.
- It is cheap in cost and available material.

DISADVANTAGES

- Tough to mix the concrete due to low workability.
- Carefully handled the sodium hydroxide and sodium silicate while prepare the alkali solution.
- Need ambient curing. It reduced the weight of cube and decreased the early strength of concrete.
- Room temperature taken long days to give high stability.

LITRATURE REVIEW

AbhishekBisarya et al., [1] said that geo-polymer reduces 80 percentages of carbon-dioxide emissions. By used this increased the strength and durability of the concrete. It can used in many field like construction materials, transportations, road buildings, aerospace materials, metallurgy mining etc. It used this fields and achieved high strength and durability compared to cement concrete. Beyond 70°C of ambient cured decreased the strength of concrete.

Amit Mittal et al., [2] said that reduction of fly-ash given maximum compressive strength. 50% replacement by used fly ash given low permeability and resist chloride attack compared to other compositions.

Bennet Jose Mathew et al., [3] analysed that Bottom-ash, GGBS based binder material decreased strength due to large particle size. Fly -ash, GGBS based binder material increased the strength of concrete. Fly-ash cost was low compared to ordinary Portland cement.

Bapugoudapatil et al., [4] proved that used GGBS in geo-polymer can increased the compressive strength of concrete. It need ambient cured to increased strength. Increased the molarity of NaOH can increased the compressive strength. In durability test, deterioration occurred minutely in geo-polymer concrete.

L.Krishnan et al., [5] proved that 24 hours ambient cured without water cured given high strength in geo-polymer concrete. The strength of geo-polymer increased with increased the percentage of GGBS increased in fly ash. F_{60} G_{40} given maximum compressive strength compared to $F_{90}G_{10}$, $F_{80}G_{20}$, $F_{70}G_{30}$.

G.S.V.Brahammaji et al., [6] analysed that after immersion of Hcl, H_2SO_4, $MgSO_4$ loss of weight is less in GPC compared to OPC. GPC is sensitive to $MgSO_4$ acid because $MgSO_4$ immersed GPC concrete weight loss is more compared to OPC.

GanesanLavanya and JosephrajJegan [7] recommended that GPC corrosion resistance is less compared to OPC. Water absorption and sorptivity is less compared to OPC.

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L.Krishnan et al., [8] proved that 24 hours ambient cured without water cured given high strength in geo-polymer concrete. The strength of geo-polymer increased with increased the percentage of GGBS increased in fly ash. F_{60} G_{40} given maximum compressive strength compared to $F_{90}G_{10}$, $F_{80}G_{20}$, $F_{70}G_{30}$.

More PratapKishanrao [8] analyzed that the partial replacement GGBFS in fly ash combination in geo-polymer concrete losses weight due to ambient cured. So used the sunlight cured at least in tropical countries for geo-polymer concrete mixes.

Neethu Susan Mathew and S. Usha [9] analysed that Partial replacement of fly-ash 50% by used GGBFS in GPC given maximum compressive, tensile, flexural strength, pull-out strength compared to OPC. Durability test GPC water absorption and sorptivity is less compared to OPC.

S.S.Bachhav and S.K Dubey [10] proved that geo-polymer resisted both acid and salt environment compared to Portland cement concrete specimen. Increased the percentage of fine and coarse aggregate the compression strength were increased. Cured temperature in the range of 60-90ºC given better strength.

SonalP.Thakkar et al., [11] said that geo-polymer concrete with GGBS given more compressive strength. The percentage of slag increased in geo-polymer concrete the compressive strength was increased but it need ambient cured to gained strength.

Vishnu P Anirudhan and AravindUnnithan [12] said that increased the molarity of NaOH given more compressive strength. It need ambient cured but the room temperature was convenient in practical condition. It acted as eco-friendly material.

MATERIAL PROPERTIES

FLY-ASH
Specific gravity of fly-ash is 1.56
GGBFS
Specific gravity of GGBFS is 2.85
RIVER-SAND
Specific gravity of river sand is 2.36
BOTTOM-ASH
Specific gravity of bottom-ash is 2.08
COARSE-AGGREGATE
Specific gravity of coarse aggregate is 3.10

METHODOLOGY

MIX DESIGN

Mix Proportion

	Fly ash	Fine aggregate	Coarse aggregate
For $1m^3$	408	591.36	1256.64
For 50%	1	1.44	3.08

BATCHING FOR COMPRESSION TEST AND ACID CURING

For 1 Cube

$0.15 \times 0.15 \times 0.15 = 0.003375m^3$
Fly-ash = 0.003375 × 408 = 1.37 Kg/cube
River-Sand = 0.003375 × 591.36 = 1.99 Kg/cube
Coarse-Aggregate = 0.003375 × 1256.64 = 4.24 Kg/cube

Extra 20%
Fly-ash = 1.377 x 1.2 = 1.652 Kg/cube
River-Sand = 1.995 x 1.2 = 2.394 Kg/cube
Coarse aggregate = 4.241 x 1.2 = 5.089 Kg/cube

For 18 cubes combination (fly-ash, River sand, coarse-aggregate with 6M, 8M, 10M). Each molar put 3 cubes
Fly-ash = 1.652 x 18 = 29.736 Kg/cube

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River-sand = 2.394 x 18 = 43.092 Kg/cube
Coarse-aggregate = 5.089 x 18 = 91.602 Kg/cube

For 54 cube combination (fly-ash, GGBFS, Bottom-ash, Coarse aggregate with 6M, 8M, 10M). Each molar put 3 cubes

- 10% GGBFS + 90% Fly-ash
  Fly-ash = 1.48716 x 18 = 26.768 Kg/cube
  GGBFS = 0.16524 X 18 = 2.974 Kg/cube
  Bottom-ash = 2.394 x 18 = 21.546 Kg/cube
  Coarse-aggregate = 5.089 x 18 = 91.602 Kg/cube
- 20% GGBFS + 80% Fly-ash
  Fly-ash = 1.3219 x 18 = 23.794 Kg/cube
  GGBFS = 0.330 X 18 = 5.940 Kg/cube
  Bottom-ash = 2.394 x 18 = 43.092 Kg/cube
  Coarse-aggregate = 5.089 x 18 = 91.602 Kg/cube
- 30% GGBFS + 80% Fly-ash
  Fly-ash = 1.156 x 18 = 20.808 Kg/cube
  GGBFS = 0.495 x 18 = 8.91 Kg/cube
  Bottom-ash = 2.394 x 18 = 43.092 Kg/cube
  Coarse-aggregate = 5.089 x 18 = 91.602 Kg/cube

BATCHING FOR TENSILE STRENGTH

For 1 cylinder

$\pi/4 \times (0.15)^2 \times 0.3 = 0.00529875$

Fly-ash = 408 x 0.00529875 = 2.161 Kg/cylinder
River-Sand = 591.36 × 0.00529875 = 3.133 Kg/cylinder
Coarse-Aggregate = 1256.64 × 0.00529875 = 6.658 Kg/cylinder

Extra 20%

Fly-ash = 2.161 x 1.2 = 2.593 Kg/cylinder
River-Sand = 3.133 x 1.2 = 3.759 Kg/cylinder
Coarse aggregate = 6.658 x 1.2 = 7.989 Kg/cylinder

For 9 cylinders combination (fly-ash, River sand, coarse-aggregate with 6M, 8M, 10M). Each molar put 3 cylinders

Fly-ash = 2.593 x 9 = 23.337 Kg/cylinder
River-sand = 3.759 x 9 = 33.831 Kg/cylinder
Coarse-aggregate = 7.989 x 9 = 71.901 Kg/cylinder

For 27 cylinders combination (fly-ash, GGBFS, Bottom-ash, Coarse aggregate with 6M, 8M, 10M).). Each molar put 3 cylinders

- 10% GGBFS + 90% Fly-ash
  Fly-ash = 2.33388 x 9 = 21.00492 Kg/cylinder
  GGBFS = 0.25932 X 9 = 2.33388 Kg/cylinder
  Bottom-ash = 3.759 x 9 = 33.831 Kg/cylinder
  Coarse-aggregate = 7.989 x 9 = 71.901 Kg/cylinder
- 20% GGBFS + 80% Fly-ash
  Fly-ash = 2.07456 x 9 = 18.669 Kg/cylinder
  GGBFS = 0.51864 X 9 = 4.66776 Kg/cylinder
  Bottom-ash = 3.759 x 9 = 33.831 Kg/cylinder
  Coarse-aggregate = 7.989 x 9 = 71.901 Kg/cylinder
- 30% GGBFS + 80% Fly-ash
  Fly-ash = 1.81524 x 9 = 16.33716 Kg/cube
  GGBFS = 0.7779 x 9 = 7.0011 Kg/cube
  Bottom-ash = 3.759 x 9 = 33.831 Kg/cube
  Coarse-aggregate = 7.989 x 9 = 71.901 Kg/cube

Molarity of NaOH

6M = 239g

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8M = 262g
10M = 314g

Add respective molarity grams with water to make NaOH solution. For example take 6M of NaoH add 239g of NaOH pallet with 76ml of water to make 1 litter of NaOH solution. These solution prepared before 24hrs on concrete mix For 1 litter of NaOH solution add 2.5 litter of sodium silicate to make geo-polymer solution instead for water. These solutions added in NaOH solution during mixing the concrete. Use 1% of super-plasticizer by weight of fly-ash in concrete.

TEST FOR CONCRETE

COMPRESSION TEST

Compression strength for M20 mix (28 days)

MOLARITY: 6M

S.No	Fly ash and GGBFS added %	Load in (KN)	Area in (mm)	Strength (N/mm^2)	Average strength in (N/mm^2)
1	100% Fly ash and 0% GGBFS	492	22500	21.86	22.02
2		495	22500	22	
3		500	22500	22.22	
4	90% Fly ash and 10% GGBFS	630	22500	28	28.07
5		640	22500	28.44	
6		625	22500	27.77	
7	80% Fly ash and 20% GGBFS	560	22500	24.88	24.98
8		562	22500	24.97	
9		565	22500	25.11	
10	70% Fly ash and 30% GGBFS	530	22500	23.55	23.44
11		525	22500	23.33	
12		528	22500	23.46	

MOLARITY: 8M

S.No	Fly ash and GGBFS added %	Load in (KN)	Area in (mm)	Strength (N/mm^2)	Average strength in (N/mm^2)
1	100% Fly ash and 0% GGBFS	528	22500	23.46	23.44
2		530	22500	23.55	
3		525	22500	23.33	
4	90% Fly ash and 10% GGBFS	658	22500	29.24	29.22
5		655	22500	29.11	
6		660	22500	29.33	
7	80% Fly ash and 20% GGBFS	610	22500	27.11	27.21
8		615	22500	27.33	
9		612	22500	27.20	
10	70% Fly ash and 30% GGBFS	610	22500	27.11	27.06
11		612	22500	27.20	
12		605	22500	26.88	

MOLARITY: 10M

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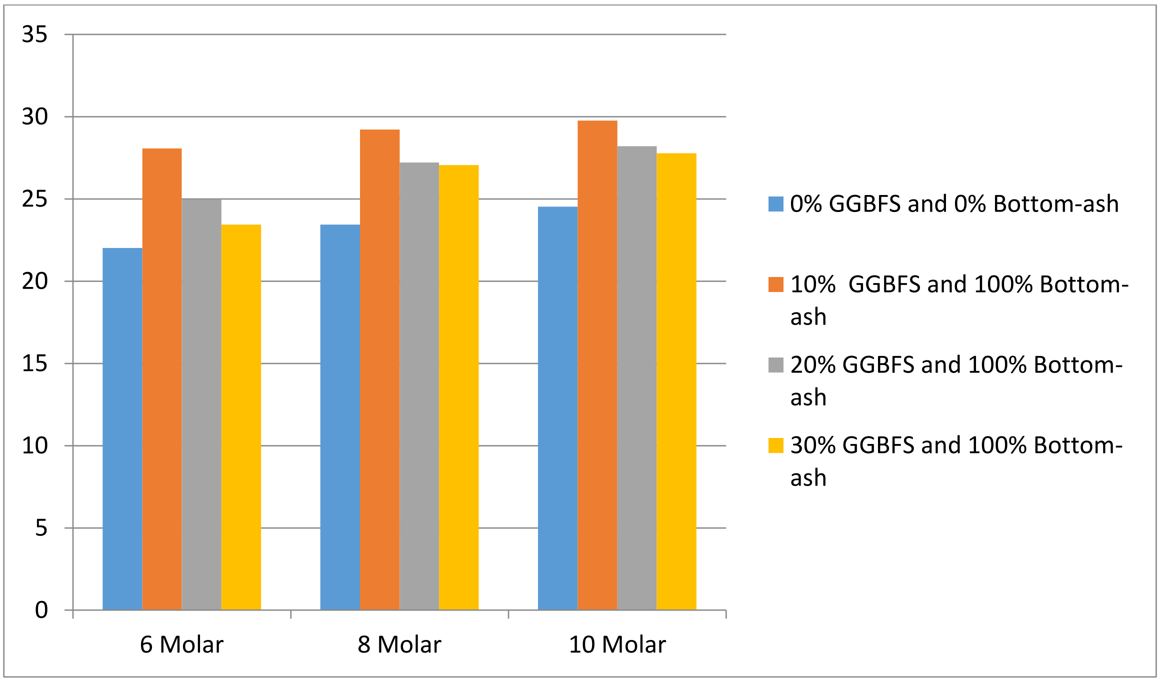
S.No	Fly ash and GGBFS added %	Load in (KN)	Area in (mm)	Strength (N/mm^2)	Average strength in (N/mm^2)
1	100% Fly ash and 0% GGBFS	550	22500	24.44	24.52
2		555	22500	24.66	
3		551	22500	24.48	
4	90% Fly ash and 10% GGBFS	670	22500	29.77	29.77
5		665	22500	29.55	
6		675	22500	30	
7	80% Fly ash and 20% GGBFS	630	22500	28	28.20
8		636	22500	28.26	
9		638	22500	28.35	
10	70% Fly ash and 30% GGBFS	625	22500	27.77	27.77
11		620	22500	27.55	
12		630	22500	28	



ACID ATTACK (CUBE IMMERSED IN Hcl ACID)
Compression strength for M_{20} mix (28 days)
MOLARITY: 6M

S.No	Fly ash and GGBFS added %	Load in (KN)	Area in (mm)	Strength (N/mm^2)	Average strength in (N/mm^2)
1	100% Fly ash and 0% GGBFS	395	22500	17.55	17.50
2		390	22500	17.33	
3		397	22500	17.64	
4	90% Fly ash and 10% GGBFS	563	22500	25.02	25.05
5		570	22500	25.33	
6		558	22500	24.80	
7		460	22500	20.44	20.25

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8	80% Fly ash and 20% GGBFS	450	22500	20	
9		457	22500	20.31	
10	70% Fly ash and 30% GGBFS	429	22500	19.06	19.12
11		435	22500	19.33	
12		427	22500	18.97	

MOLARITY: 8M

S.No	Fly ash and GGBFS added %	Load in (KN)	Area in (mm)	Strength (N/mm^2)	Average strength in (N/mm^2)
1	100% Fly ash and 0% GGBFS	440	22500	19.55	19.3
2		433	22500	19.24	
3		430	22500	19.11	
4	90% Fly ash and 10% GGBFS	588	22500	26.13	26.11
5		593	22500	26.35	
6		582	22500	25.86	
7	80% Fly ash and 20% GGBFS	510	22500	22.66	22.76
8		515	22500	22.88	
9		512	22500	22.75	
10	70% Fly ash and 30% GGBFS	495	22500	22	21.98
11		498	22500	22.13	
12		491	22500	21.82	

MOLARITY: 10M

S.No	Fly ash and GGBFS added %	Load in (KN)	Area in (mm)	Strength (N/mm^2)	Average strength in (N/mm^2)
1	100% Fly ash and 0% GGBFS	489	22500	21.73	21.86
2		495	22500	22	
3		492	22500	21.86	
4	90% Fly ash and 10% GGBFS	600	22500	26.66	26.87
5		610	22500	27.11	
6		604	22500	26.84	
7	80% Fly ash and 20% GGBFS	530	22500	23.55	23.44
8		528	22500	23.46	
9		525	22500	23.33	
10	70% Fly ash and 30% GGBFS	511	22500	22.71	22.76
11		516	22500	22.93	
12		510	22500	22.66	

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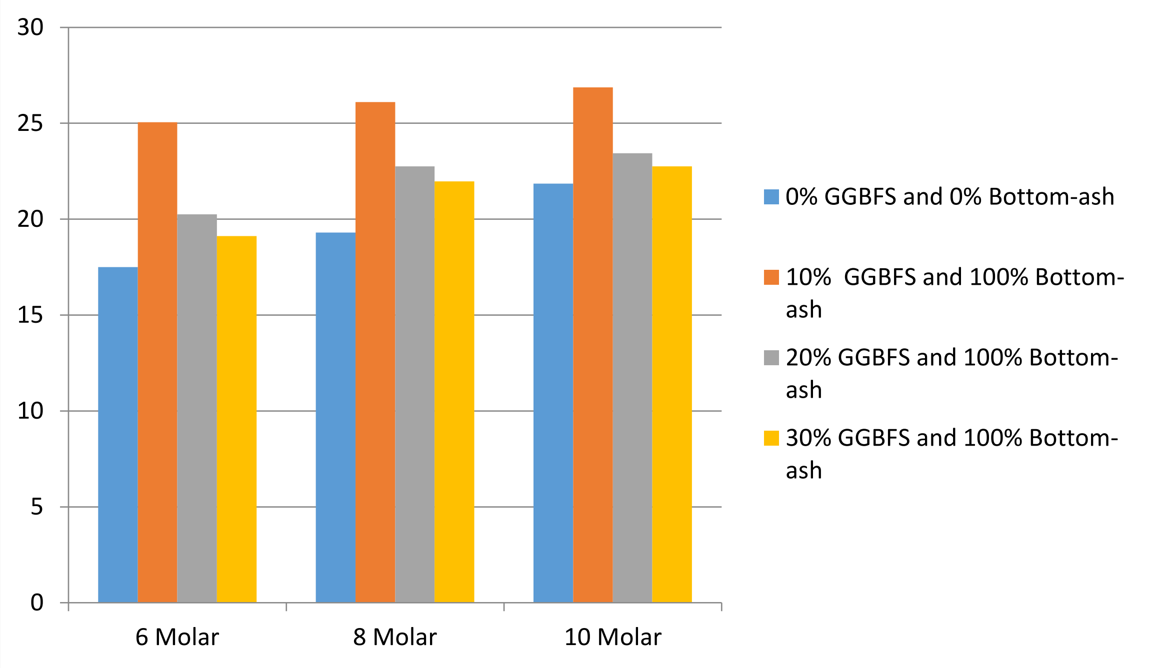

TENSILE STRENGTH

MOLARITY: 6M

Tensile strength for M_{20} mix(28 days)

S.No	% of GGBFS replaced in fly-ash and % of bottom ash replaced in river-sand	Load in KN	2P/πd	Tensile Strength	Average tensile strength
1	0% GGBFS and 0% Bottom-ash	130	260/471	0.55	0.54
2		120	240/471	0.50	
3		135	270/471	0.57	
4	10% GGBFS and 100% Bottom-ash	165	330/471	0.70	0.69
5		160	320/471	0.67	
6		170	340/471	0.72	
7	20% GGBFS and 100% Bottom-ash	150	300/471	0.63	0.66
8		160	320/471	0.67	
9		165	330/471	0.70	
10	30% GGBFS and 100% Bottom-ash	150	300/471	0.63	0.63
11		160	320/471	0.67	
12		140	280/471	0.59	

MOLARITY: 8M

S.No	% of GGBFS replaced in fly-ash and % of bottom ash replaced in river-sand	Load in KN	2P/πd	Tensile Strength	Average tensile strength

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1	0% GGBFS and 0% Bottom-ash	139	278/471	0.59	0.58
2		140	280/471	0.59	
3		135	270/471	0.57	
4	10% GGBFS and 100% Bottom-ash	175	350/471	0.74	0.75
5		177	354/471	0.75	
6		180	360/471	0.76	
7	20% GGBFS and 100% Bottom-ash	176	352/471	0.74	0.73
8		173	346/471	0.73	
9		175	350/471	0.74	
10	30% GGBFS and 100% Bottom-ash	170	340/471	0.72	0.71
11		168	336/471	0.71	
12		165	330/471	0.70	

MOLARITY: 10M

S.No	% of GGBFS replaced in fly-ash and % of bottom ash replaced in river-sand	Load in KN	2P/πd	Tensile Strength	Average tensile strength
1	0% GGBFS and 0% Bottom-ash	145	290/471	0.61	0.62
2		147	294/471	0.62	
3		150	300/471	0.63	
4	10% GGBFS and 100% Bottom-ash	190	380/471	0.80	0.80
5		187	374/471	0.79	
6		192	384/471	0.81	
7	20% GGBFS and 100% Bottom-ash	187	374/471	0.79	0.78
8		185	370/471	0.78	
9		184	368/471	0.78	
10	30% GGBFS and 100% Bottom-ash	180	360/471	0.76	0.75
11		178	356/471	0.75	
12		176	352/471	0.74	

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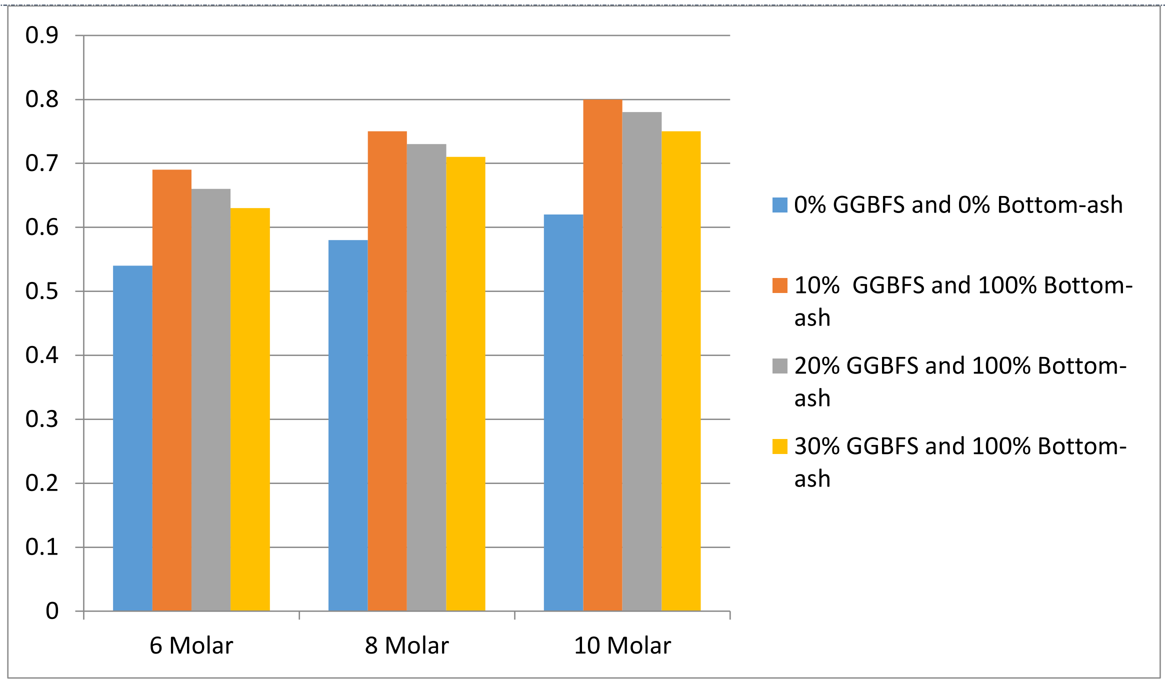

RESULT AND DISCUSSION

RESULTS ON CONCRETE SPECIMEN

The molarity of the geo-polymer concrete increased the strength of the concrete also increased. In m_{20} grade concrete the bottom ash mixed concrete replacement of river sand given better compression strength. The replacement of 10 percentage GGBFS in fly-ash gives better compression and tensile strength compared to 0, 20, and 30. In short-term durability results Hcl acid immersion of 28 days cured cubes acid attack less in fly-ash, GGBFS, Bottom-ash, Coarse aggregate combination compared to fly-ash, River-sand, coarse-aggregate combination. 10% replacement of GGBFS in fly-ash and fully replacement of bottom-ash in river-sand result gives less acid attack compared to other compositions.

CONCLUSION

Geo-polymer was widely used in structural work, road construction, aero-space materials, transportation, metallurgy mining etc. it was given better compressive strength concrete. By used these can recycle the waste material. Government taken steps to collected the sodium hydroxide and sodium silicate in chemical industries waste materials. So it reduced the cost of construction materials. Ambient cured in the range up to 1200°C given better compressive strength. Beyond 1200°C reduced the strength of concrete. The major disadvantage of ambient cured reduced the weight of concrete and it losses the early strength of the concrete. So used sunlight cured at

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least in tropical countries. The water content presented in the concrete was very low due to low water fly ash ratio. So the super-plasticizers were used mainly to make the workability in concrete.

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