Study on Effects of Metalized Plastic Fibers and Alkaline Activator Compounds on Fresh State Properties of Geopolymer Concrete

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Abstract*—Properties of freshly mixed fly ash based geopolymer concrete containing metalized plastic fibers were investigated. The objective was to study the effects of different Na_2O_3/NaOH ratios, NaOH molarities, SiO_2/Na_2O ratios, along with metalized plastic waste fiber dosage on freshly prepared concrete behavior. Two mixes with 2.25 and 3.35 SiO_2/Na_2O ratios were prepared at 0.5 liquid to solid ratio. NaOH molarities varied between 8M, 12M and 16M and Na_2O_3/NaOH ratios were 1,2and 3. Metalized plastic waste fibers were added in all mixes with 0.5%, 1% and 1.5% by volume. Slump test, compaction factor test and determination of density were performed. The test results revealed reduction of slump and compaction factor for increased NaOH molarities at a constant Na_2O_3/NaOH ratio. For all three variations of Na_2O_3/NaOH ratios the concrete showed greater reduction of property values for 3.35 SiO_2/Na_2O ratios compared to 2.25 SiO_2/Na_2O the ratio. With increased percentage of metalized plastic fibers for both mixes the slump and compaction factor values were also reduced at all other variables as constant. Concrete density was increased with the increased values of NaOH molarities, Na_2O_3/NaOH ratios but was reduced with the increased dosage of metalized plastic fibers. It was however noticed that mixes prepared with 2.25 SiO_2/Na_2O showed less reduction of property values and provided better performance at full dosage of metalized plastic waste fibers.

***Keywords*— Metalized plastic waste, Geopolymer concrete, fly ash, Slump, Compaction factor, Density, Alkaline liquid Introduction**

I. INTRODUCTION

Inorganic polymer concrete or geopolymer concrete has shown a promising behavior to be utilized as a potentially environmental friendly construction material in past few decades. It requires less energy for its production as compared to the conventional cement concrete. Cement production releases approximately one tone of the CO2 for to produce one tone of cement from the raw materials during the manufacturing process. In 1978 J. Davidovits introduced the inorganic polymer concrete by mixing the pozzolanic material with the alkaline solution at an elevated temperature. The process of polymerization resulted in a solid state product. The material demonstrated the properties at its fresh and hardened state like the conventional concrete. Till then many researchers and engineers have extensively studied all aspects and behavior of geopolymer concrete. Being a heterogeneous material geopolymer and its properties are affected by more than a couple of parameters and variables namely liquid to solid ratio, proportions of alkaline liquid chemical contents, molarities of sodium contents, temperature for curing, casting and curing and type of fly ash etc. For each new variation in any of the above parameter provided a different property to the material.

Geopolymer concrete has been examined for its fresh and hardened properties by many researchers. However the fresh properties are generally examined via compaction factor test, slump test and density determination as geopolymer exhibits similar behavior to the conventional concrete. For such reasons geopolymer has been tested for various properties in both fresh and hardened state just as the cement concretes.

Different researchers have suggested their own ranges of values of the hardened properties of geopolymer according to their experimental results and observations. However a few research works have highlighted the behavior of geopolymer concrete in fresh state and role and effects of its chemical contents and other constituents like aggregates, water content, plasticizers etc. It has been observed that the workability of geopolymer concrete was good for low liquid to solid ratio [5]. Changes are observed due to varying SiO_2/Al_2O_3 ratios, and the setting time was governed by the Al_2O_3 contents in the mix. It has been noticed that the initial slump of the concrete reduced with the increased content of Na_2O contents [7]. Lower solid to liquid ratio provided homogeneity and better workability of geopolymer concrete. This established that the increased content of Na_2O in the alkaline liquid reduced the workability of concrete [3]. Constituents like aggregates and the effect of angularity of aggregate on workability via slump test and has observed that the lower value of angular aggregate increased the slump values [4]. The effects of water content on fresh properties of geopolymer via slum tests have also been examined. They observed that due to fast chemical reactions of sodium silicate and water absorbed by the aggregates affected the slump and reduced the same [7].

In this research the fresh state behavior of geopolymer is studied carefully. Researchers have found generally a quick set of geopolymer concrete at early stage or immediately after wet mixing. Though it could be studied carefully that what are the factors affecting such phenomenon. This research discusses a novel addition of metalized plastic waste fibers as a constituent. Therefore all the fresh and hardened properties were required to be explored and studied for all future experimental works to be carried out.

II. EXPEIMENTAL PROGRAM

A. Materials

Fly ash from the thermal power plant of Vanankbori – Gandhinagar, Gujarat, India was used to produce the geopolymer concrete containing the chemical composition as shown in table no.1.

Table: 1 Chemical composition of fly ash used

Oxides	% by mass
Silica (SiO_2	52.8
Alumina (Al_2O_3)	22.3
Ferric Oxide (Fe_2O_3)	9.2
Calcium Oxide (CaO)	2.4
Magnesium Oxide (MgO)	0.2
Sodium Oxide (Na_2O)	0.37
Potassium Oxide (K_2O)	0.82
Sulfur Trioxide (SO_3)	0.7
Loss On Ignition (LOI)	1.39

The alkaline activator liquid solution was prepared from sodium silicate and sodium hydroxide with varying molarities in water. Mix proportions are sown in table no.2.The Natural aggregates of 10mm and 20mm sizes were received from local sources. The super plasticizer from the FOSROC Company was received and added to the freshly prepared geopolymer mix. The novel addition of metalized plastic waste fiber was done by adding fibers rendered into the shredded form from metalized plastic film received from Umiya Plastics – Rajkot, Gujarat, India as shown in fig.1 used for food packaging. The typical properties of metalized plastic used in consumer products are shown in table no.3. Distilled water was used during the mixing of the ingredients as per the needs.

Table 2 Oxide proportions and composition of alkaline liquid

Constituents	Combination in %	
	SiO_2/ Na_2O =2.25	SiO_2/ Na_2O =3.35
Sodium Oxide (Na_2O)	14.46	8.5
Silicate Oxide (SiO_2)	32.53	28.49
Water	53	63

Table 3 Mechanical and physical properties of metalized plastic film

Property	Values	Unit
Resin category	Polythene	--
Plastic type	LDPE	--
Recycling code	4	--
Density range	0.94-1.4	Gm/cm^3
Thickness	0.05	mm
Water vapor resistance	Good	--
Oxygen permeability	High	--
Tensile strength	1800-1900	Kg/cm^3
Elongation	90 -110	%
Co efficient of friction	0.45 – 0.55	--

Fig.1 Shredded metalized plastic waste fibers

B. Material mixing and prepartion of batches

Two mixes were prepared with different SiO_2/Na_2O ratios like 2.25 and 3.35 for Na_2SiO_3 liquid solution. Each mix was prepared with further three variations in Na_2SiO_3/ NaOH ratios like 1, 2, and 3. Each batch in a mix was further prepared with different molar of NaOH content. To achieve this NaOH flakes were mixed with water in three different molar weights like 8M, 12M and 16M. The liquid solution of Na_2SiO_3/ NaOH was prepared 24 hours in advance to the day of experiment by mixing Na_2SiO_3 and NaOH solutions. Sometimes a flash setting concrete was observed due to higher molar content of NaOH and for this reason one of the batch could not be casted for Na2SiO3/NaOH ratio-1 and 16M NaOH solution. Another problem of accelerated polymerization of liquid solutions was observed at lower temperature due to the winter. At the time experiment, the constituents like fly ash and aggregates were added to the drum mixture machine in dry state as per the mix design proportions. Then the alkaline solution was added in rotating drum gradually. The metalized plastic fibers were added at the same time and the super plasticizer and extra water was also added at this stage as shown in fig 2. After thorough mixing the concrete was taken out and used for casting for further experimental work. Mean while the tests of slump and compaction factor were performed and readings were recorded. The testing of each new batch and mix was repeated in the same manner.

As shown in figure no.3 two mixes were prepared bearing different SiO_2/Na_2O ratios. The mixes were divided in batches further as per the Na2SiO3/NaOH ratios, NaOH Molarities and the percentage variations of metalized plastic waste fibers. The concrete prepared here was a part of the different tests procedures for hardened state also; therefore batches were prepared as per the number of test specimens for future use.

Fig. 2 Dry mix of geopolymer contents with metalized plastic waste fibers

No	Fly ash	Aggregates			Na_2SiO_3	NaOH Solution		NaOH	Na_2SiO_3	Plastic fibres
		Coarse		Fine	Solution	NaOH solids	Water	Molarities	NaOH	
		20mm	10mm						ratio	
	Kg	Kg	Kg	Kg	Kg	Kg	Kg	M		percentage
1	368	433.52	850	554	92	22.3	69.69	8	1	0.5
2	368	433.52	850	554	92	22.3	69.69	8	1	1
3	368	433.52	850	554	92	22.3	69.69	8	1	1.5
4	368	433.52	850	554	92	33.45	58.55	12	1	0.5
5	368	433.52	850	554	92	33.45	58.55	12	1	1
6	368	433.52	850	554	92	33.45	58.55	12	1	1.5
7	368	433.52	850	554	92	14.87	46.46	8	2	0.5
8	368	433.52	850	554	92	14.87	46.46	8	2	1
9	368	433.52	850	554	92	14.87	46.46	8	2	1.5
10	368	433.52	850	554	92	22.3	39	12	2	0.5
11	368	433.52	850	554	92	22.3	39	12	2	1
12	368	433.52	850	554	92	22.3	39	12	2	1.5
13	368	433.52	850	554	92	29.74	31.6	16	2	0.5
14	368	433.52	850	554	92	29.74	31.6	16	2	1
15	368	433.52	850	554	92	29.74	31.6	16	2	1.5
16	368	433.52	850	554	92	11.15	34.85	8	3	0.5
17	368	433.52	850	554	92	11.15	34.85	8	3	1
18	368	433.52	850	554	92	11.15	34.85	8	3	1.5
19	368	433.52	850	554	92	16.73	29.27	12	3	0.5
20	368	433.52	850	554	92	16.73	29.27	12	3	1
21	368	433.52	850	554	92	16.73	29.27	12	3	1.5
22	368	433.52	850	554	92	22.3	23.7	16	3	0.5
23	368	433.52	850	554	92	22.3	23.7	16	3	1
24	368	433.52	850	554	92	22.3	23.7	16	3	1.5

Figure no. 3 Mix proportions of geopolymer

C. Testing Methods

Utmost care and good observations were carried out throughout the tests performed at laboratory. All relevant ASTM standards like ASTM C 172, ASTM C 143, IS 1199-1959, IS 456, IS 10262 were referred and followed pertaining to the freshly prepared concrete. A slump test was carried out to observe the possible segregating nature of freshly mixed geopolymer concrete for all the variations in chemical contents and with each dosage of metalized plastic waste fibers. The same concrete was used then for the compaction factor test. Determination of density was carried out as per guidelines of ASTM C 138.

III. RESULTS AND DISCUSSION

A. Slump

Test results of slump tests are shown in fig.4 (a), 4(b) and 5(a) and 5(b).

1) Effect of NaOH molarities

For a constant Na2SiO3/NaOH ratio and plastic fiber dosage, the slump value was reduced with the increased molarities of NaOH. The reduction was noticed for both mixes. For 2.25 SiO_2/Na_2O ratios the slump was reduced up to 37.5% till the plastic fiber dosage of 1%. At 1.5% plastic content the slump reduction was reduced to 20%. For 3.35 SiO_2/Na_2O ratios the slump was reduced up to 37.77% up to the metalized plastic fiber dosage of 1% and it was reduced for the plastic fiber dosage at 1.5% up to 26.67%. This could be due to the decreased value of Na_2O content in liquid as well as partial contribution from smooth plastic fibers.

2) Effects of Na_2SiO_3 /NaOH ratios

For 2.25 SiO_2/Na_2O ratio the slump reduced up to 28.57% with the increased Na2SiO3/NaOH value from 1 to 2. The slump reduced up to 20% for the increased ratio from 2 to 3. The slump reduction was less for the metalized plastic fibre dosage of 1.5%. For 3.35 SiO_2/Na_2O ratio the slump reduced up to 25% for the variation of Na_2SiO_3/NaOH value from 1 to 2. The slump reduced up to 25% for variation of Na_2SiO_3/NaOH from 2 to 3. Again the slump reduction was less at 1.5% metalized plastic dosage of 1.5% equal to 28.57%. The increased value of sodium silicate played important role in improvement of the slump values.

3) Effects of percentage of metalized plastic waste fiber

For constant Na_2SiO_3/NaOH values and NaOH molarities, the slump was reduced for both mixes with increased percentage of plastic dosage from 0.5% to 1% and from 1% to 1.5% up to 28.57% and 60% respectively for 2.25 SiO_2/Na_2O ratios respectively. The reduction at 3.35 SiO_2/Na_2O ratios was similar to the previous variations.

B. Compaction factor

Test results are shown in fig. 6(a), 6(b) and 7(a), 7(b).

1) Effect of NaOH molarities

For a constant Na2SiO3/NaOH ratio and plastic fibre dosage, the compaction factor reduced with the increased NaOH molarities form 8M to 10M up to 5.31% and 7.59% respectively. The reduction was found to be 3.57% and 9.87% for the changed molarities from 12M to 16M respectively for mix prepared by 2.25 SiO_2/Na_2O ratios. For the mix prepared with 3.35 SiO_2/Na_2O the reduction was noticed as 4.91% and 11.62% from 8M to 12M of NaOH respectively. The reduction was noticed as 3.57% and 3.89% from 12M to 16M NaOH respectively.

2) Effect of Na_2SiO_3 / NaOH ratio

With the increased in the ratio value, the compaction factor was reduced for both mixes. For the increase of 1 to 2 ratio the reduction was 2.25% and 8.13% respectively for 2.25 SiO_2/Na_2O ratios. At further increased value of 2 to 3 ratio, the reduction was up to 11.33% and 9.87% respectively. The mix prepared with 3.35 SiO_2/Na_2O ratios the compaction factor reduced up to 6.74%, 5.61% and 10.46% for Na_2SiO_3 / NaOH ratios as 1, 2 and 3.

3) Effect of percentage of metalized plastic waste fibers

For a constant Na_2SiO_3 / NaOH ratio and NaOH molarities the compaction factor was reduced with the increase of the percentage of metalized plastic waste fibres in both mixes. From 0.5% to 1% and from 1% to 1.5% the reduction of compaction factor was up to 7.95% and 17.04% respectively for the mix prepared with 2.25 SiO_2/Na_2O ratios. For the mix made with 3.35 SiO_2/Na_2O ratios, the reduction was up to 8.98% and 15.73% for the increased plastic fiber percentage from 0.5% to 1% and from 1% to 1.5% respectively.

C. Geopolymer concrete density

Results of determination of geopolymer density are shown in fig.8 (a), 8(b) and 9(a), 9(b).

1) Effect of NaOH

Increase in molarities of NaOH in the solution prepared with water, the density was increased. For the mix made with 2.25 SiO_2 / Na_2O ratio, the density was increased up to 1.01% and 1.36% from 8M to 12M and 1.1% and 0.83% for the molar increase of 12M to 16M respectively. For the concrete prepared with 3.35 of SiO_2 / Na_2O ratio, the density was increased up to 1.57% and 2.02% from the molar value changed from 8M to 12M. On the change of molar value from 12M to 16M, the density was increased up to 0.58% and 1.48% respectively.

2) Effect of Na_2SiO_3 / NaOH ratio

The density of geopolymer concrete was increased with the increase in Na_2SiO_3 / NaOH ratios. For the mix prepared with 2.25 SiO_2 / Na_2O ratio the density was increased up to 1.22% and 1.48% respectively for the increase of 1 to 2 ratio values. From the increase of 2 to 3 ratio values of Na_2SiO_3 / NaOH the density was increased up to 0.57% and 1.16% respectively. The geopolymer prepared with 3.35 of SiO_2 / Na_2O ratio demonstrated the increase of density for the ratio value 1 to 2 up to 1.87% and 1.42% respectively and from ratio value 2 to 3 the density was increased up to 0.7% and 0.77% respectively.

3) Effects of percentage of metalized plastic waste fibres

Density of the geopolymer concrete was reduced for the increased dosage of metalized waste plastic fibres. At a constant value of NaOH molarities and Na_2SiO_3 / NaOH ratios, the density was reduced up to 2.71% and 3.04% for the increase percentage of fibres from 0.5% to 1% and from 1% to 1.5% for the mix prepared with 2.25 ratios. The mix prepared with 3.35 SiO_2 / Na_2O ratio showed the density reduction up to 1.76% and 3.76% for the increase in the plastic percentage from 0.5% to 1% and from 1% to 1.5% respectively.

IV CONCLUSIONS

Careful observations revealed that the fresh state of geopolymer concrete was largely affected by the changed chemical contents and proportions of the alkaline liquid solution and due to the presence of the metalized plastic waste fibers in the mix. The NaOH molarities in the alkaline activator affected the slump and compaction factor as well as the density of the concrete. With the increase in the NaOH molarities the slump values and the compaction factor were reduced, while the density of concrete was increased. The Na_2SiO_3 / NaOH ratio values also affected the fresh state behavior of geopolymer concrete. With the increase in the ratio of Na_2SiO_3 / NaOH, the slump and compaction factor were reduced and the density was increased. Presence of the metalized plastic waste fibers greatly affected the freshly mixed geopolymer concrete. With the increase in the percentage of metalized plastic fibers in the mix, the slump and compaction factors were reduced, while the density was also reduced. It was observed that the mix prepared with the 2.25 SiO_2 / Na_2O ratio showed less reduction in the values of fresh properties compared to the mix prepared with 3.35 SiO_2 / Na_2O ratio. The results discussed here were the part of the extended experimental program and hence the findings were useful to understand the response of the material wisely. More importantly the research provided good understanding about the role of metalized plastic waste fibers and their effects on workability properties when added as a novel concept of the utilization of the hazardous plastic wastes as construction material making it preferable sustainable material.

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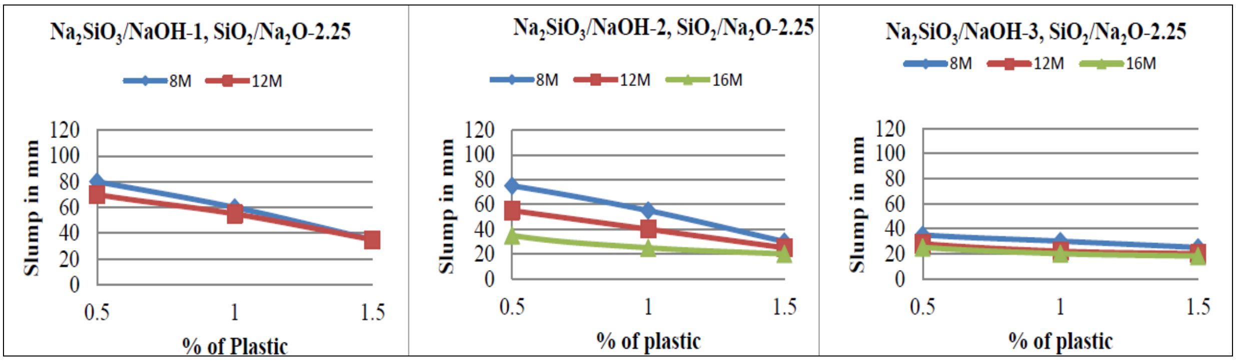

Figure 4(a) Slump values with variation of $Na_2SiO_3/NaOH$ ratios (2.25 SiO_2/Na_2O)

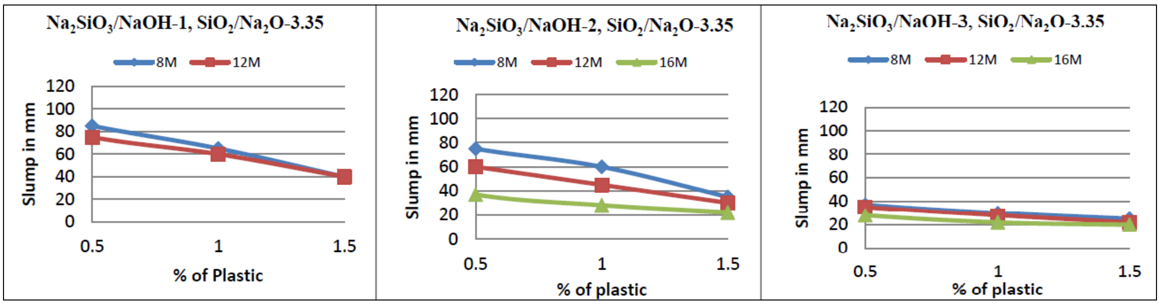

Fig.4 (b) Slump values with variation of $Na_2SiO_3/NaOH$ ratios (3.35 SiO_2/Na_2O)

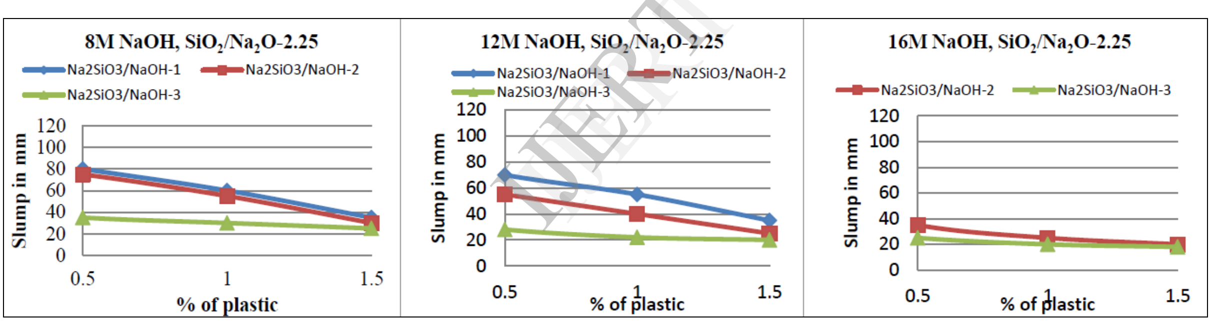

Fig. 5(a) Slump values with variation of NaOH ratios (2.25 SiO_2/Na_2O)

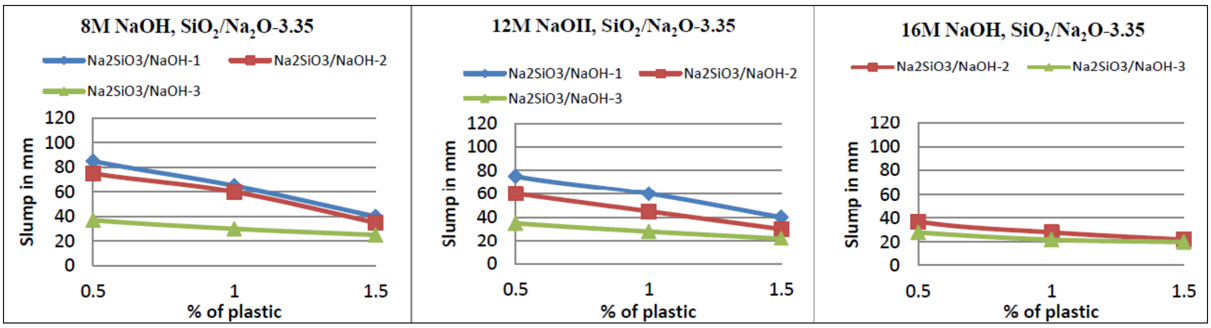

Fig.5 (b) Slump values with variation of NaOH ratios (3.35 SiO_2/Na_2O)

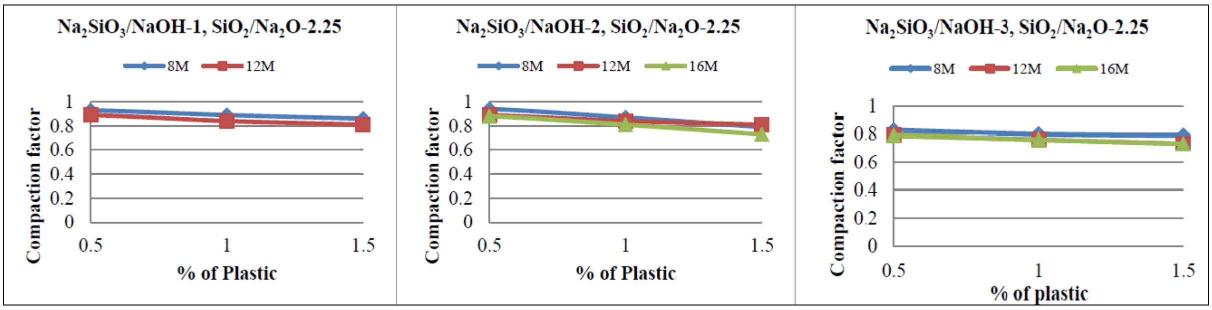

Fig. 6 (a) Compaction factor values with variation of Na_2SiO_3/NaOH ratios (2.25 SiO_2/Na_2O)

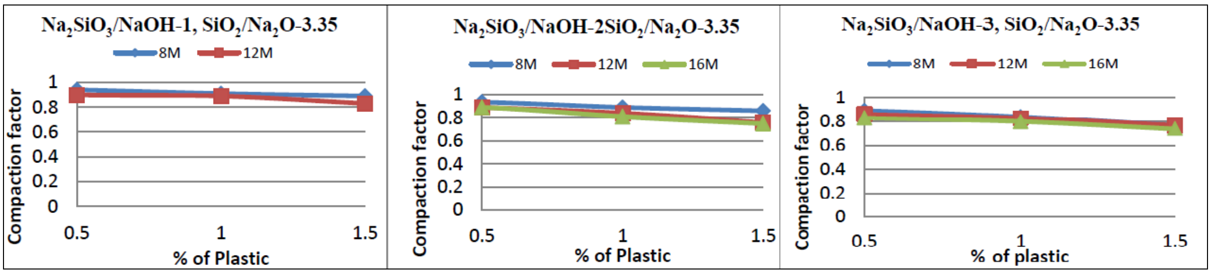

Fig. 6(b) Compaction factor values with variation of Na_2SiO_3/NaOH ratios (3.35 SiO_2/Na_2O)

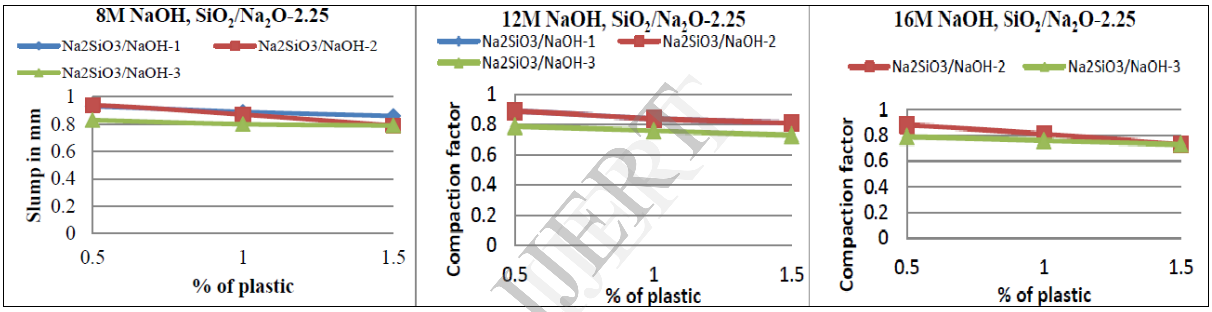

Fig. 7 (a) Compaction factor values with variation of NaOH ratios (2.25 SiO_2/Na_2O)

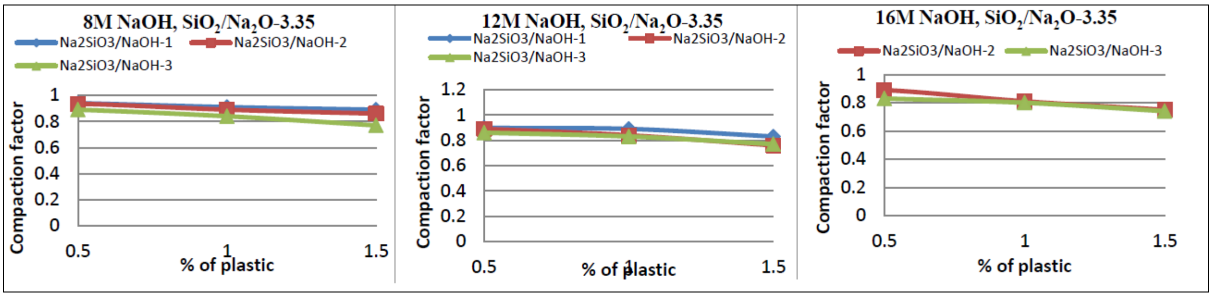

Fig. 7 (b) Compaction factor values with variation of NaOH ratios (3.35 SiO_2/Na_2O)

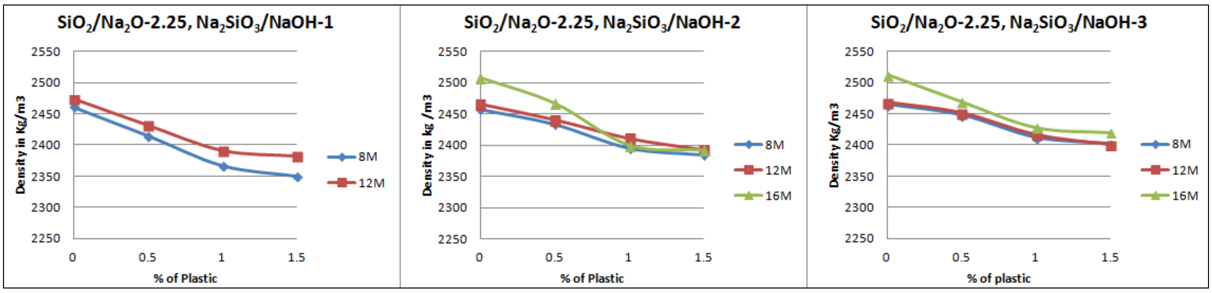

Fig. 8 (a) Density values with variation of Na_2SiO_3/NaOH ratios (2.25 SiO_2/Na_2O)

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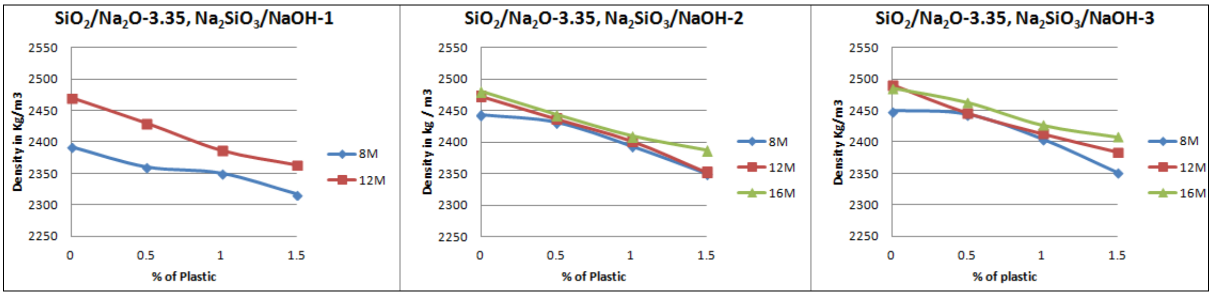

Fig.8 (b) Density values with variation of $Na_2SiO_3/NaOH$ ratios (3.35 SiO_2/Na_2O)

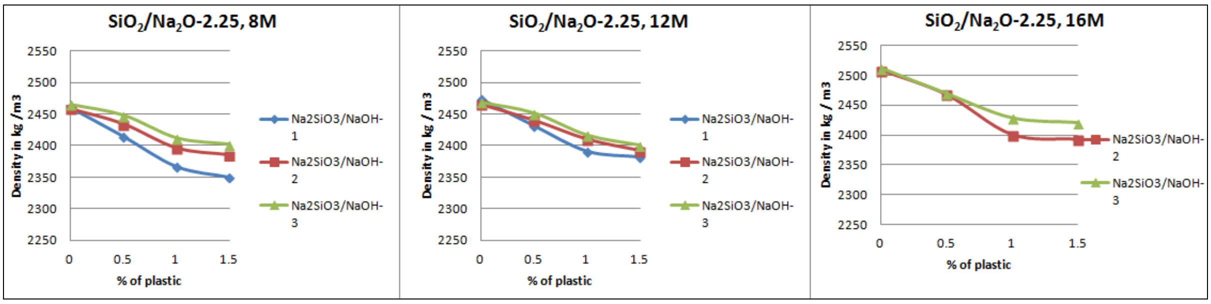

Fig. 9(a) Density values with variation of NaOH ratios (2.25 SiO_2/Na_2O)

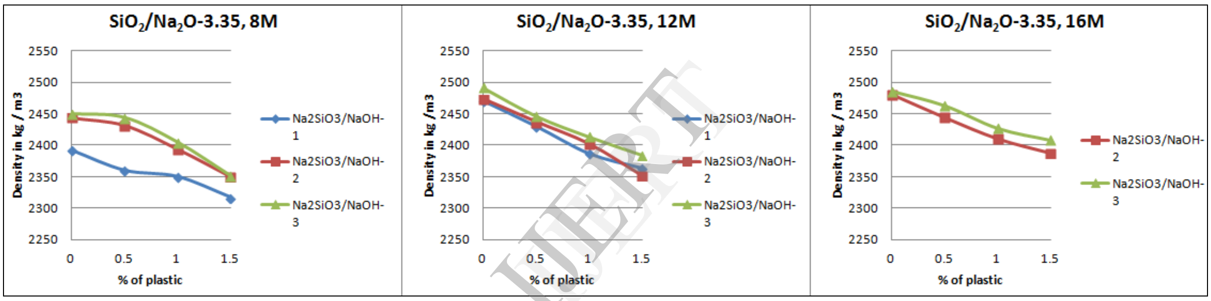

Fig.9 (b) Density values with variation of NaOH ratios (3.35 SiO_2/Na_2O)

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