ISSN XXXX XXXX © 2018 IJESC

Research Article **Volume 8 Issue No.2**

Effects of Aluminium Addition on the Mechanical Properties of Al-Glass Composites

O.W. Abodunrin[1], F. H. Abejide[2]
Lecturer[1], Assistant lecturer[2]
Department of Physics
Natural Sciences, Joseph Ayo Babalola University, Osun State, Nigeria

Abstract:
Effects of Aluminium addtion on compressive strengths of Al-Glass based samples are reported in the study. The particle size of 25µm was used for both Aluminium and Glass. The samples were formed together by applying compacting pressures of 200 and 500 bars. Proton Induced X-ray Emission (PIXE) and Rutherford Back Scattering (RBS) analyses for elemental quantifications were evaluated on the composites at 200 bars while compressive test measurement was conducted on the samples at 500 bars. The result in the research showed that as the percentage weight of Aluminium in composites increases the point of breakage increases to maximum and subsequently reduces. Compressive strength analyses are in support of these observed data. With specific amount of Aluminium added in the composition of Glass, strength increased considerably high. There was an improvement in the composites considered from ordinary Glass to Al-Glass composite and different element tops the lead in each sample elemental investigation.

Keywords: pressure, compressive stress and strain, fracture or rupture point, fracture toughness ,breakage point and strength

I. INTRODUCTION

Aluminium addition in the composition of Glass and subsequent effects in relation to fracture toughness has been subject of interest in metallic-Glass composites in the field of condensed matter and related disciplines.

Aluminium reinforcement level with its exceptional properties such as ductility, wear resistance, stress, structural and mechanical stabilities have influenced the mechanical properties of Glass [1, 2].

For instance, fracture point of samples varies depending on the proportion of Aluminium added if too high its results in low compressive strength and if the proportion is low the maximum compressive strength is higher at specific proportions [3].

The physical properties of these Glass-Al based composites can be tailored by careful selection of matrix and binder, and the quantity of each. For instance, in Al-Glass system, the thermal expansion coefficients can also be tailored by modifying the respective weight composition of the different components [4]. The expansion can also be tailored even further by altering the binder phase composition [5].

In addition, sodium silicate binder phase has good oxidation and fire resistance property. The composites are normally non-magnetic [6]. The present research centers on the strength, effect of pressure and gradual Aluminium addition on the point of breakage in Al-Glass composites.

The evaluation of the specific properties such as compressive stress and strain at maximum compressive force could reveal the level of strength of the material for domestic and industrial use.

II. EXPERIMENTAL PROCEDURE

The materials used for the study include Aluminium powder of purity of 95.5% purity, sodium silicate powder of purity 99.5% both of particle size of 25µm obtained from British drug House (BDH), England.

Glass powder of particle size of 25µm which had earlier been crushed and pulverized before sieving with a mechanical mesh from the mechanical section at Centre for Energy Research and Development (CERD), Obafemi Awolowo University, Ile-Ife, Nigeria was used.

A manually operated press capable of producing one composite at a time with an average thickness of 21.5 mm and cross sectional area of 1156 mm^2 was used for molding the samples at Engineering Geology Laboratory at Federal University of Technology, Akure. The Aluminium and Glass powders in grams were mixed together in 10 different ratios. The weighing of Aluminium and Glass were carried out with digital weighing balance of Model BT 200 with sensitivity of 0.001g. The mixing was carried out manually in a closed container. Different pressures of 200 and 500 bars were exerted to produce two sets of samples. The samples were subjected to same moisture condition for four weeks. Samples were analyzed with instruments i.e. compressive test machine and Accelerator, Proton Induced X-ray Emission (PIXE) and Rutherford back Scattering (RBS). In percentage the mixing formula is Al_xGlass_{100-x}. x= 0, 10, 20, 30, 40, 50, 60, 70, 80 and 90 for Samples presented for Compression test at 500 bars. X= 20, 40, 50 and 80 for composites presented for PIXE and RBS analyses at 200 bars. Sodium silicate liquid was prepared by adding sodium silicate powder with warm water at 80 ^oC, which thereafter was added to composites between 3.3-3.8 g.

III. RESULTS

Table .1. Concentration of Elements in $\mathrm{Al}_{20}\mathrm{Glass}_{80}$ for 200 bars and 25µm particle size

Element / Symbol	% Conc.	Conc. Error	% LOD	Present
Oxygen (O_2)	25.08791	±0.198594	0.20269	Y
Sodium (Na)	18.79087	±0.191667	0.20381	Y
Aluminium (Al)	6.03031	±0.025327	0.01248	Y
Silicon (Si)	26.44890	±0.060832	0.01633	Y
Potassium (K)	0.27622	±0.009005	0.01504	Y
Calcium (Ca)	4.03258	±0.015324	0.00756	Y
Titanium (Ti)	0.03816	±0.003347	0.00569	Y
Iron (Fe)	0.25718	±0.004038	0.00102	Y
Total	80.95791			

Y=Yes and LOD = Level of Determination. Oxygen is obtained from RBS analysis and other elements are from PIXE. Air trap and moisture constitute the remaining percentage.

Table .2. Concentration of Elements in $\mathrm{Al}_{40}\mathrm{Glass}_{60}$ for 200 bars and 25µm particle size

Element / Symbol	% Conc.	Conc. Error	% LOD	Present
Oxygen (O_2)	25.04632	±0.188574	0.20269	Y
Sodium (Na)	25.37627	±0.197935	0.18404	Y
Magnesium (Mg)	0.77385	±0.110970	0.11081	Y
Aluminium (Al)	13.81357	±0.034534	0.01199	Y
Silicon (Si)	13.10013	±0.053711	0.01798	Y
Potassium (K)	0.12881	±0.006415	0.01082	Y
Calcium (Ca)	2.64598	±0.012172	0.00520	Y
Titanium (Ti)	0.02713	±0.002632	0.00464	Y
Manganese (Mn)	0.00490	±0.001151	0.00184	-
Iron (Fe)	0.11787	±0.002817	0.00194	Y
Nickel (Ni)	0.00019	±0.000141	0.00025	-
Copper (Cu)	0.00043	±0.000111	0.00016	-
Zinc (Zn)	0.00235	±0.000915	0.00124	-
Total	81.05632			

Y=Yes, LOD = Level of Determination and dash = not certain. Oxygen is obtained from Rutherford Back Scattering (RBS) analysis and other elements are from Proton Induced X Ray Emission (PIXE). Air trap and moisture constitute the remaining percentage.

Table.3. Concentration of Elements in $\mathrm{Al}_{50}\mathrm{Glass}_{50}$ for 200 bars and 25µm particle size

Element / Symbol	% Conc.	% Conc. Error	% LOD	Present
Oxygen (O_2)	20.04991	±0.198594	0.20269	Y
Sodium (Na)	19.11595	±0.198806	0.23187	Y
Magnesium (Mg)	1.21148	±0.124904	0.12058	Y
Aluminium (Al)	24.14778	±0.037609	0.01597	Y
Silicon (Si)	16.35173	±0.070029	0.01787	Y
Potassium (K)	0.15512	±0.008020	0.01400	Y
Calcium (Ca)	3.07208	±0.013210	0.00596	Y
Titanium (Ti)	0.02624	±0.002949	0.00510	Y
Iron (Fe)	0.09363	±0.002584	0.00145	Y
Zinc (Zn)	0.00286	±0.000707	0.00096	-
Total	84.226			

Y=Yes, LOD = Level of Determination and dash = not certain. Oxygen is obtained from RBS analysis and other elements are from PIXE. Air trap and moisture constitute the remaining percentage. The total concentration of the elements in the composites ranges between approximately 80 to 88 %. In addition, the certainty of the presence of some elements such as Nickel, manganese, phosphorus, copper and zinc was not affirmed by the Proton induced X ray Emission (PIXE) device.

Table .4. Concentration of Elements in $Al_{80}Glass_{20}$ for 200 bars and 25µm particle size

Element / Symbol	**% Conc.**	**% Conc. Error**	**% LOD**	**Present**
Oxygen (O_2)	15.34062	±0.027508	0.01497	Y
Sodium (Na)	14.36917	±.0214101	0.29254	Y
Magnesium (Mg)	1.92386	±0.164.50	0.14014	Y
Aluminium (Al)	28.00618	±0.043875	0.01638	Y
Silicon (Si)	25.80859	±0.084019	0.02860	Y
Phosphorus (P)	0.03202	±0.033525	0.04675	-
Potassium (K)	0.21240	±0.008369	0.01430	Y
Calcium (Ca)	2.66130	±0.012508	0.00753	Y
Titanium (Ti)	0.03694	±0.002881	0.00480	Y
Manganese (Mn)	0.00591	±0.001442	0.00251	-
Iron (Fe)	0.34269	±0.004524	0.00117	Y
Copper (Cu)	0.00055	±0.000158	0.00025	-
Zinc (Zn)	0.00333	±0.000829	0.00116	-
Total	88.75862			

Y=Yes, LOD = Level of Determination and dash = not certain. Oxygen is obtained from Rutherford Back Scattering (RBS) analysis and other elements are from Proton Induced X Ray Emission (PIXE). Air trap and moisture constitute the remaining percentage.

Table.5. Compressive Test Values of Samples at 27 ^{0}C, 25 µm and 500 bars

% weight of Al/Glass	**Maximum Compressive strain (mm/mm)**	**Maximum Compressive Stress (MPa)**
0.00/100.0	0.12	32. 33
10.0/90.0	0.39	43. 94
20.0/80.0	0.20	48. 04
30.0/70.0	0.18	50.32
40.0/60.0	0.17	40. 76
50.0/50.0	0.12	35. 28
60.0/40.0	0.08	18.30
70.0/30.0	0.07	14.63
80.0/20.0	0.04	5. 28
90.0/10.0	0.04	1.43
100.0/0.00	0.03	1.22

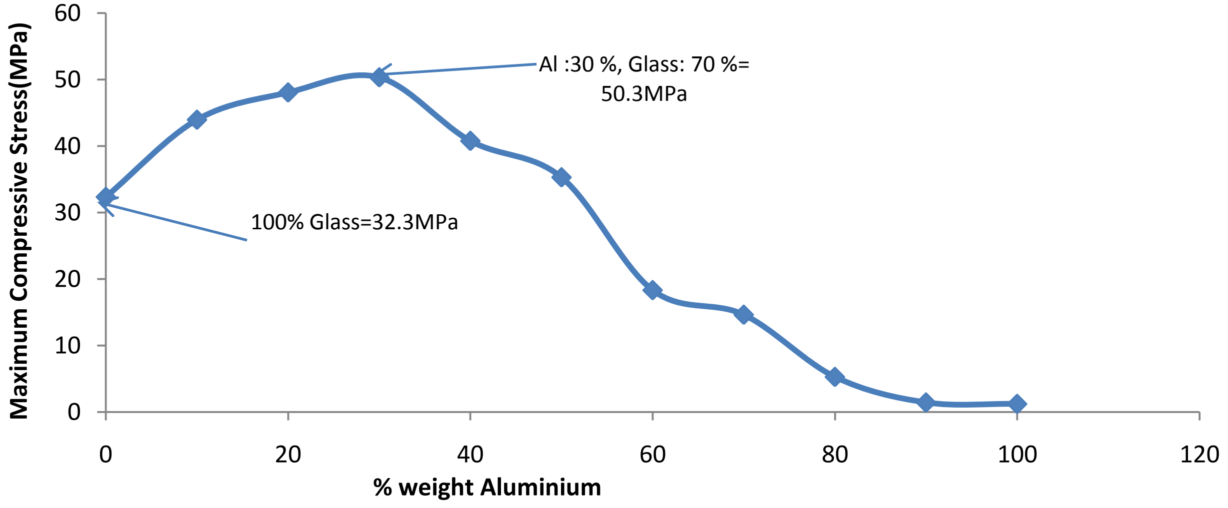

Figure.1. Maximum **Compressive strength Vs % weight of Aluminium at 25µm and 500 bars**

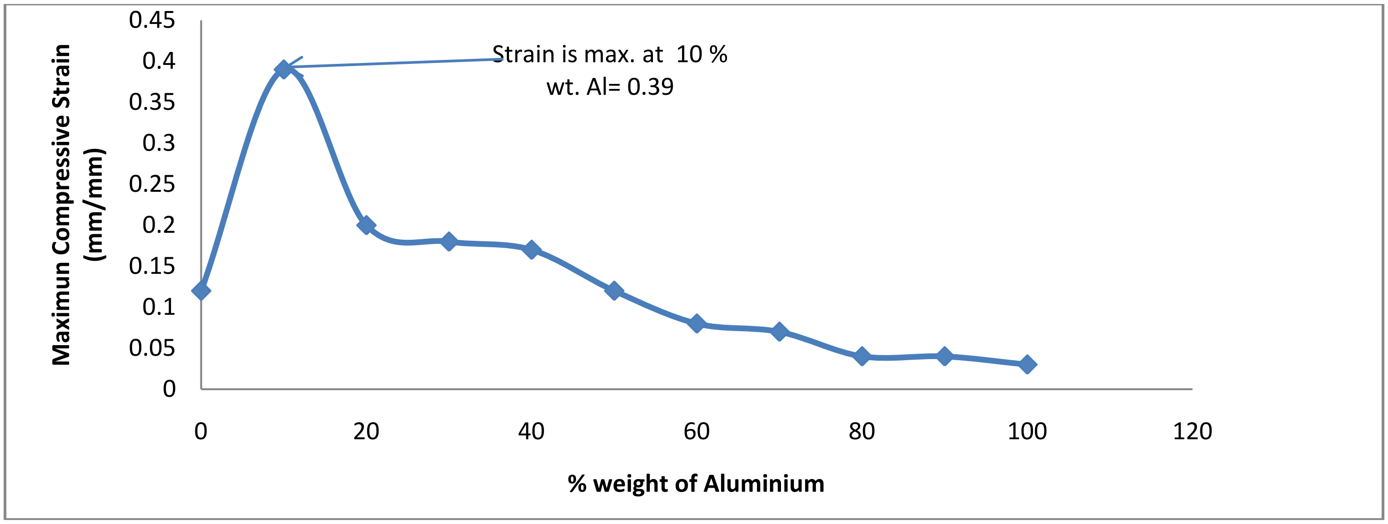

Figure.2. Maximum Compressive Strain Versus % weight Aluminium at 25μm and 500 bars

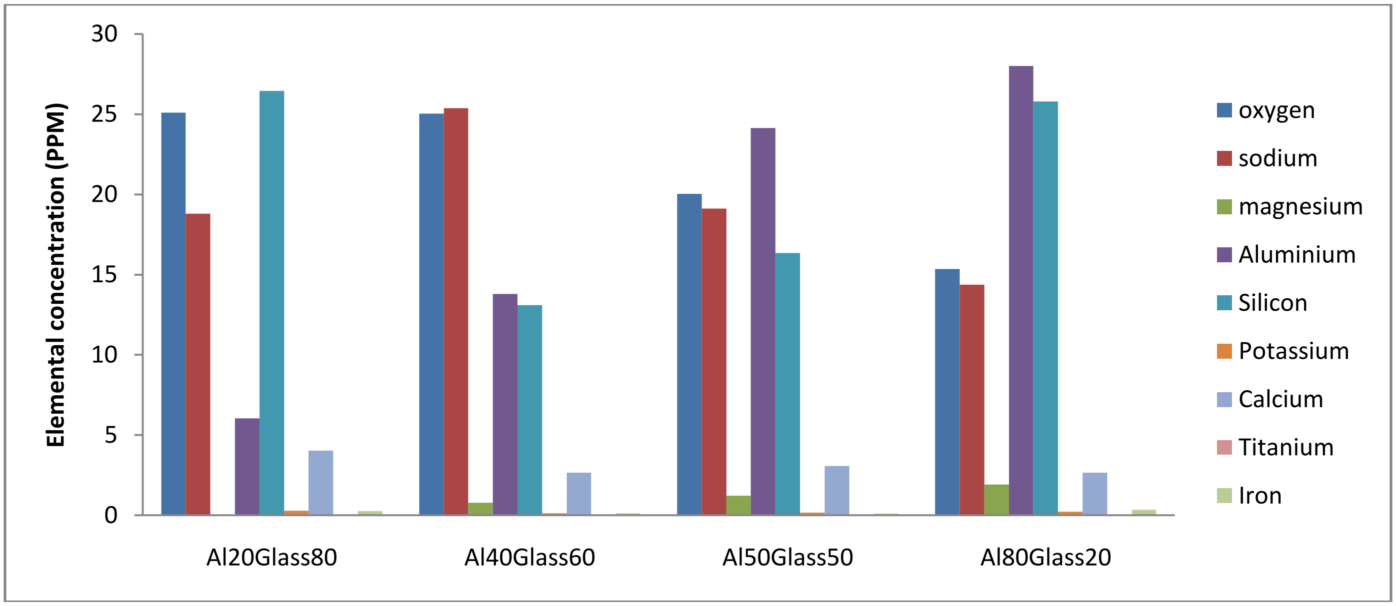

Figure.3. Major Compositions of Al-Glass composites of 200 bars and 25 μm particle size

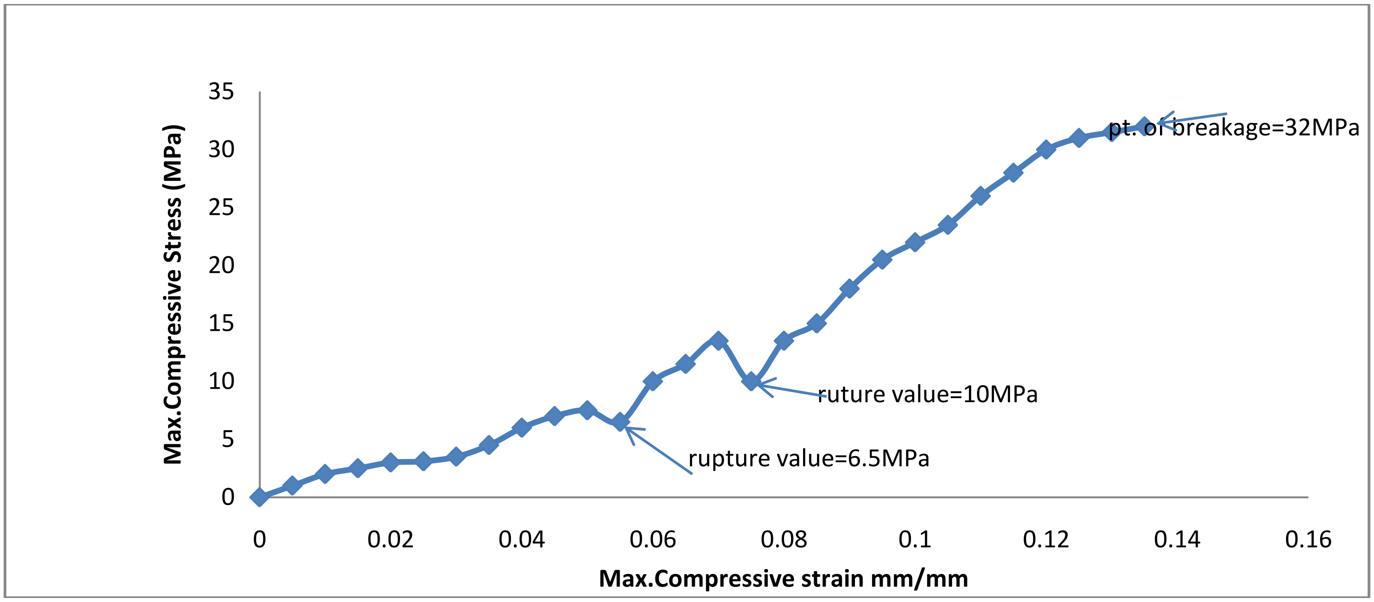

Figure.4. Variation of maximum compressive stress with strain for Al$_0$Glass$_{100}$ of 25 μm and 500bars

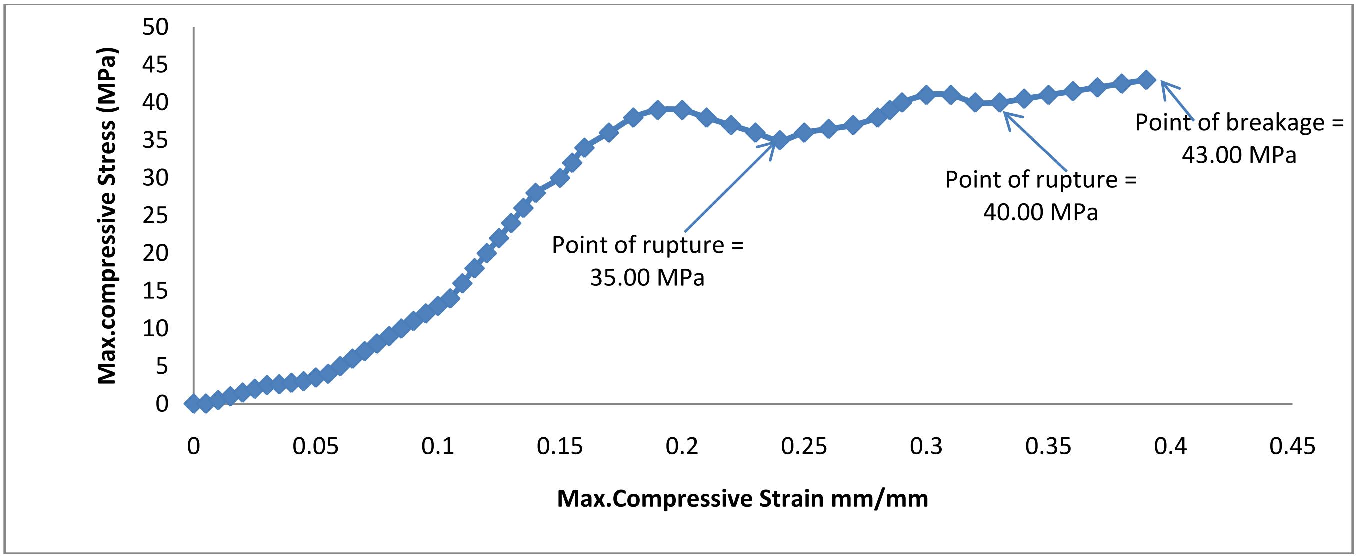

Figure.5. Variation of maximum compressive stress with strain for $Al_{10}Glass_{90}$ of 25 µm and 500bars

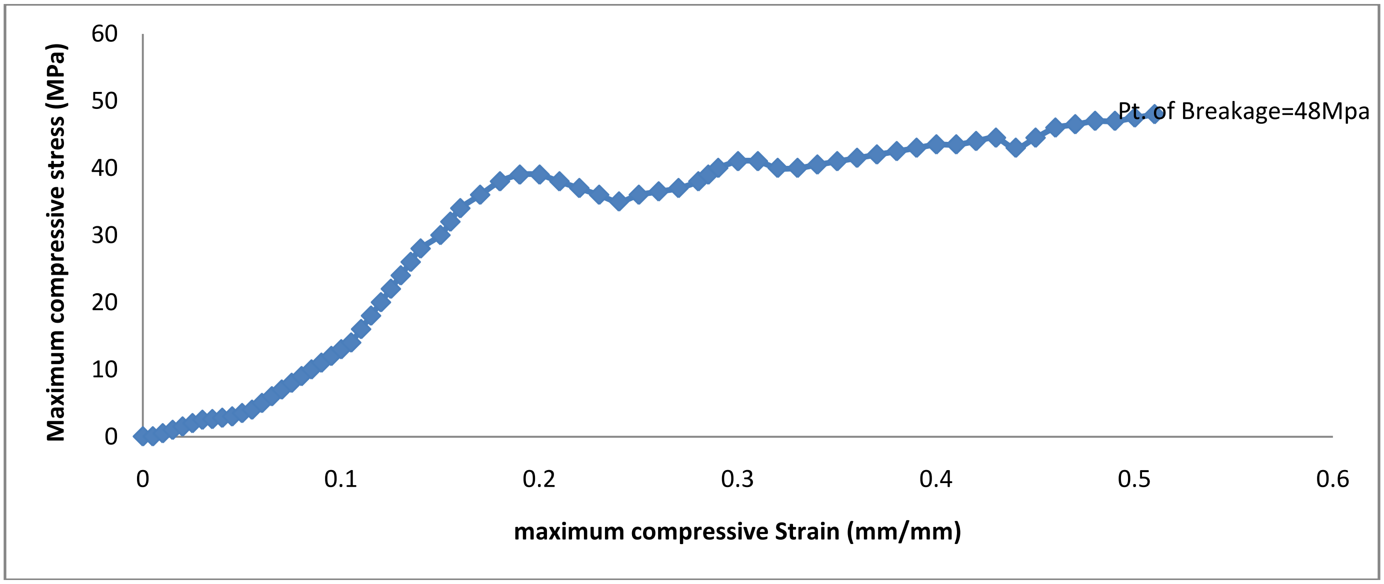

Figure.6. Variation of maximum compressive stress with strain for $Al_{20}Glass_{80}$ of 25 µm and 500bars

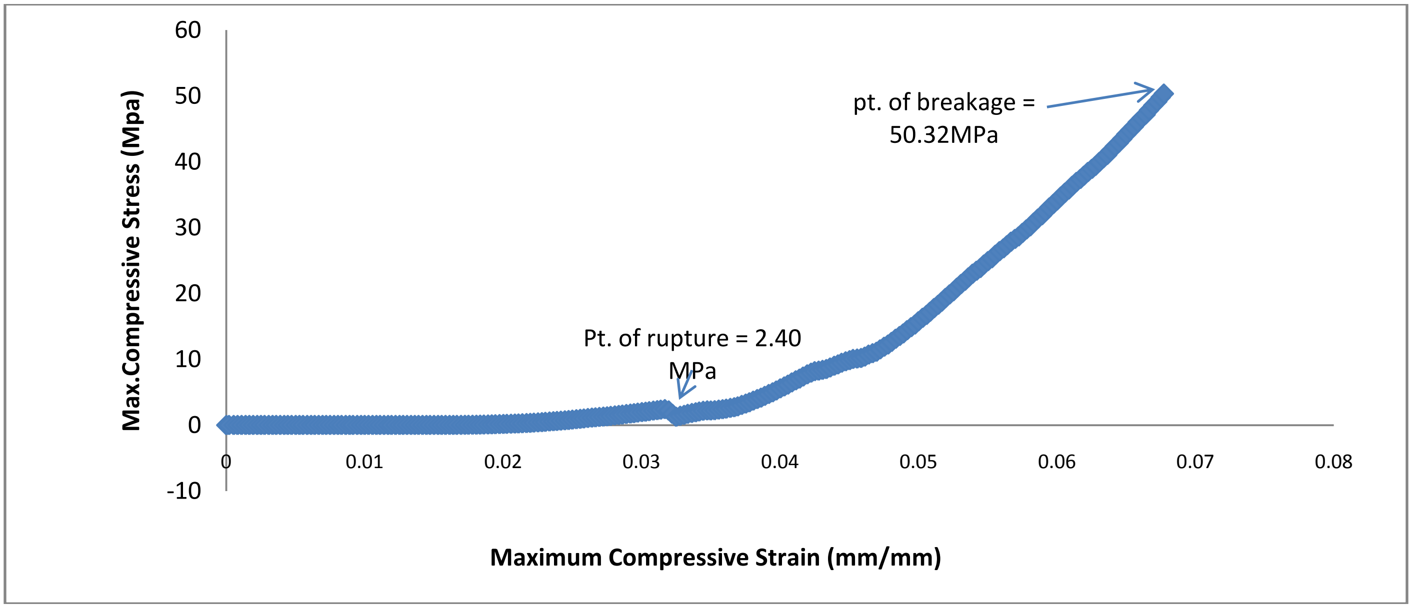

Figure.7. Variation of maximum compressive stress with strain for $Al_{30}Glass_{70}$ of 25 µm and 500 bars

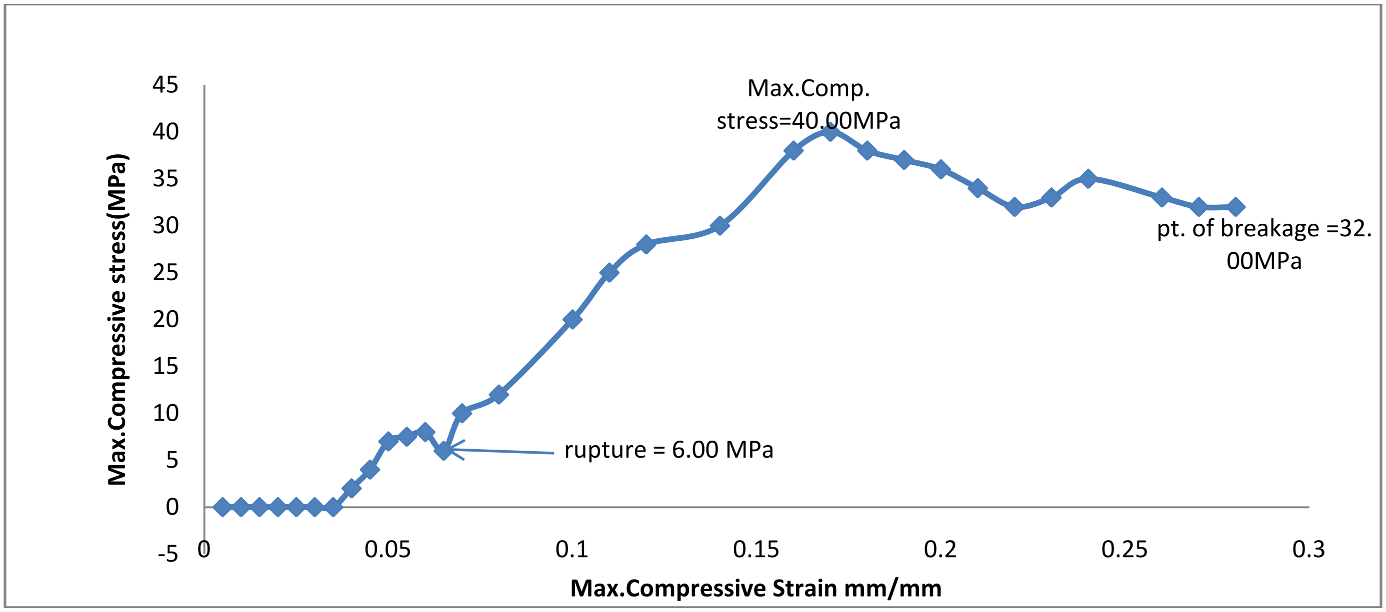

Figure.8. Variation of maximum compressive stress with strain for $Al_{40}Glass_{60}$ of 25 µm and 500 bars

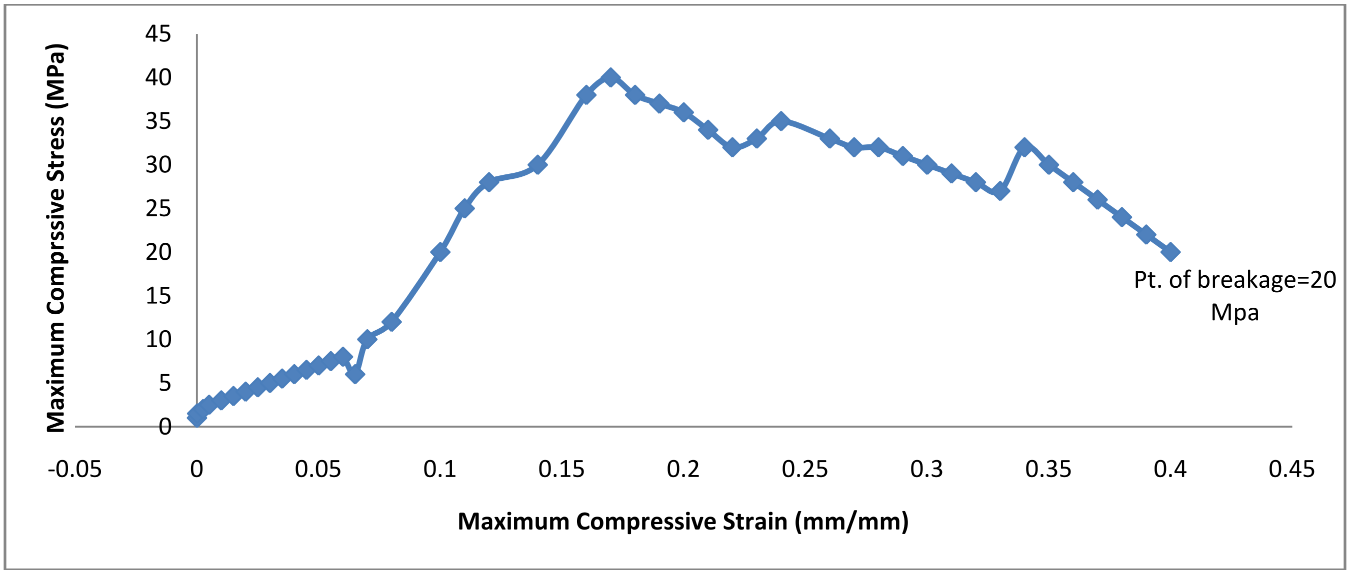

Figure.9. Variation of maximum compressive stress with strain for $Al_{50}Glass_{50}$ of 25 µm and 500 bars

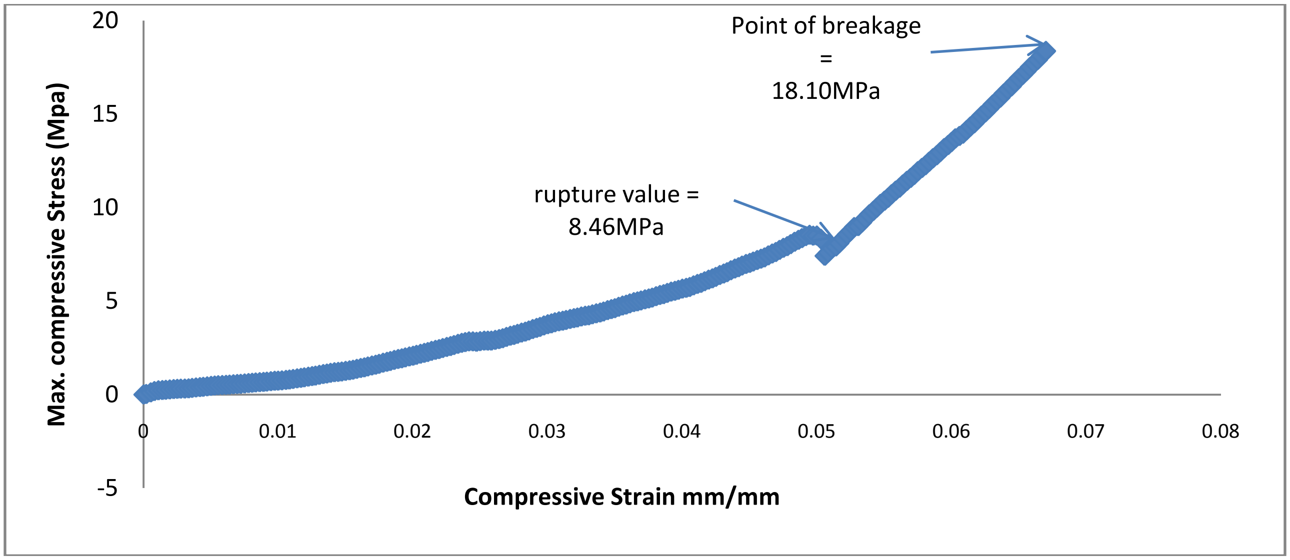

Figure.10. Variation of maximum compressive stress with strain for $Al_{60}Glass_{40}$ of 25µm and 500 bars

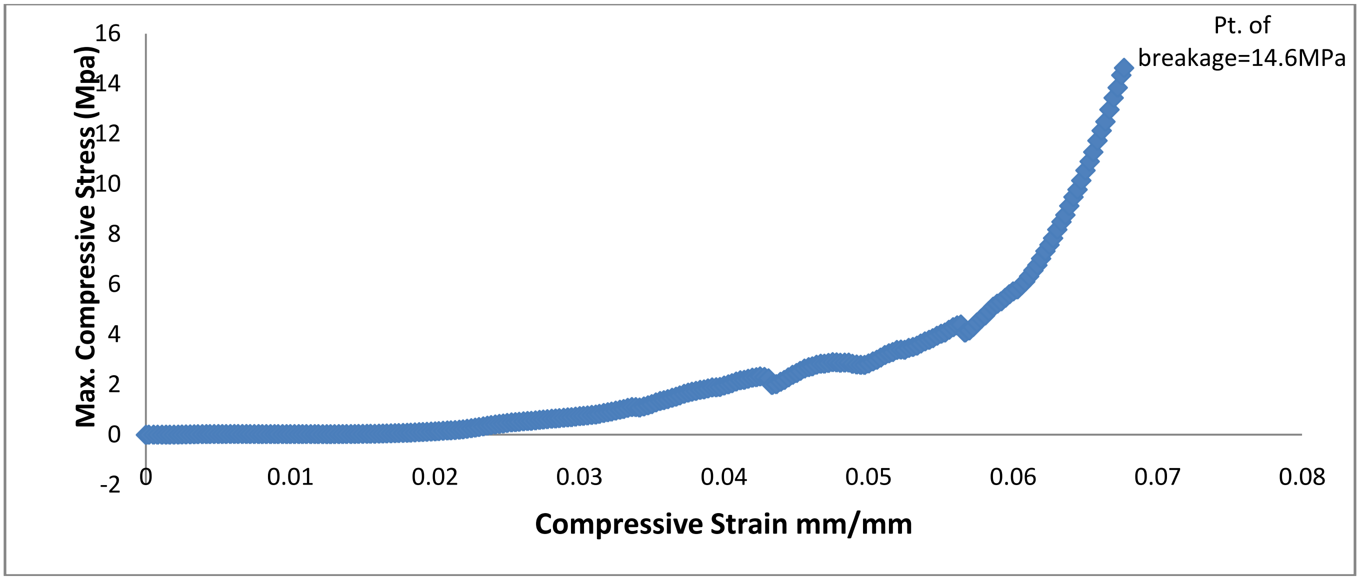

Figure.11. **Variation of Max. Compressive stress with strain for $Al_{70}Glass_{30}$ of 25µm and 500 bars**

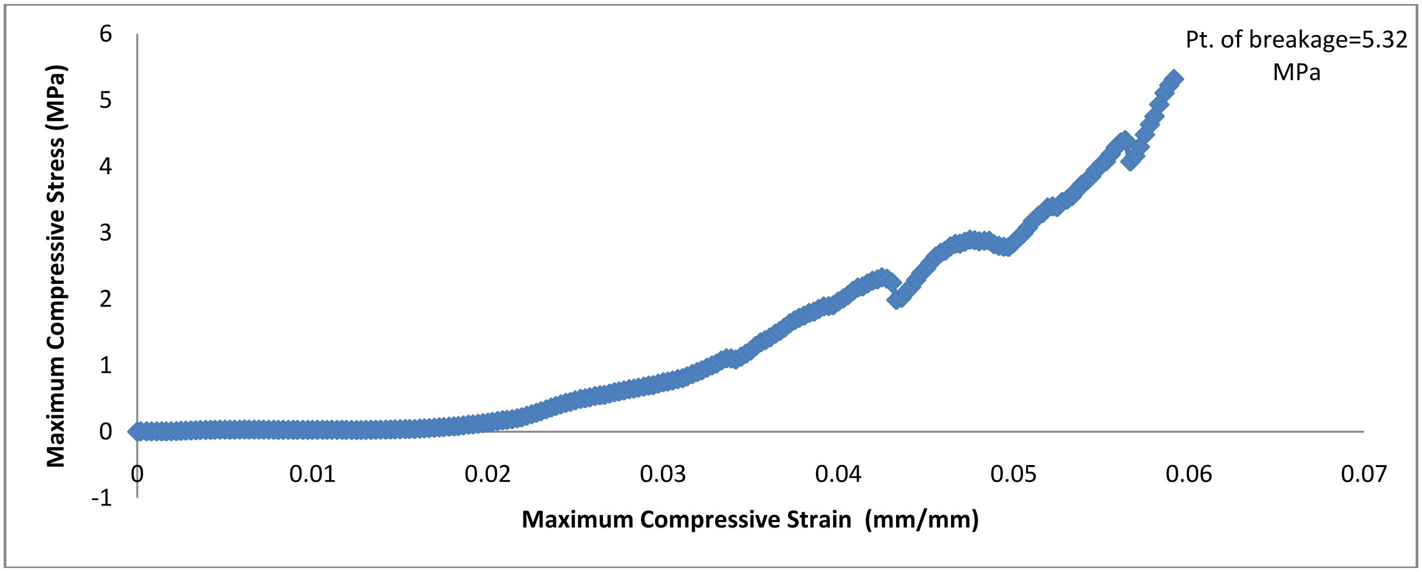

Figure.12. **Variation of Max. Compressive Stress with Strain for $Al_{80}Glass_{20}$ of 25µm and 500 bars**

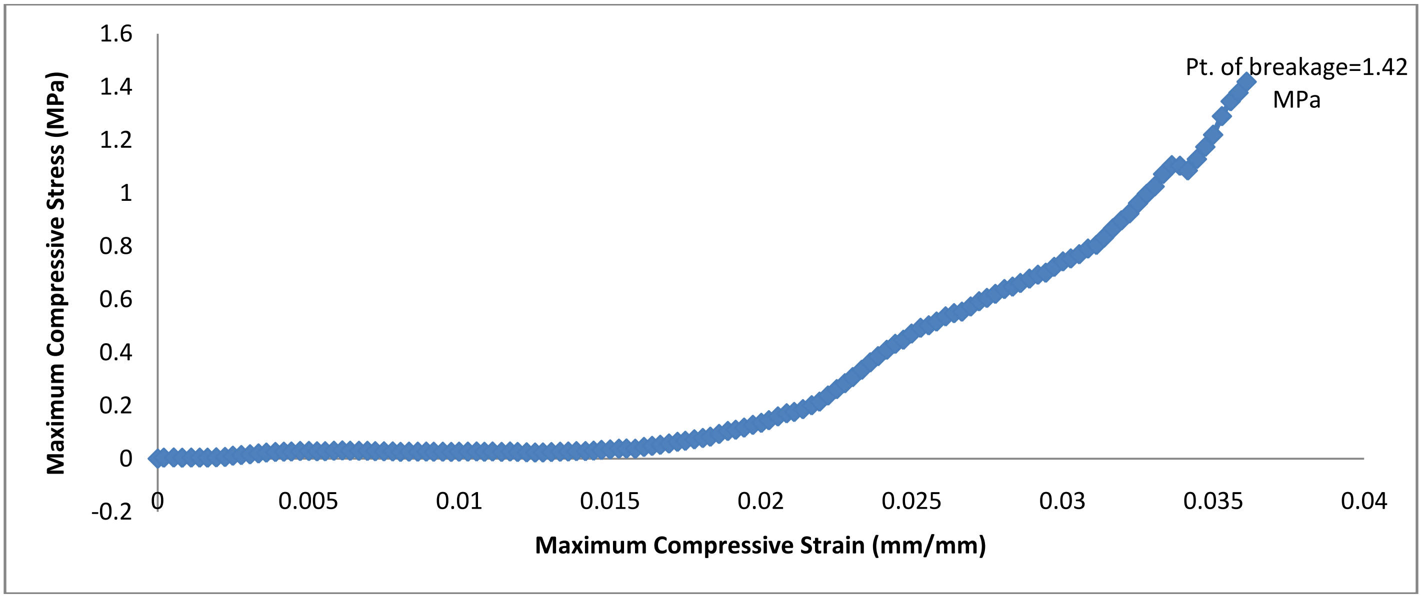

Figure.13. **Variation of Max. Compressive Stress with Strain for $Al_{90}Glass_{10}$ of 25µm and 500 bars**

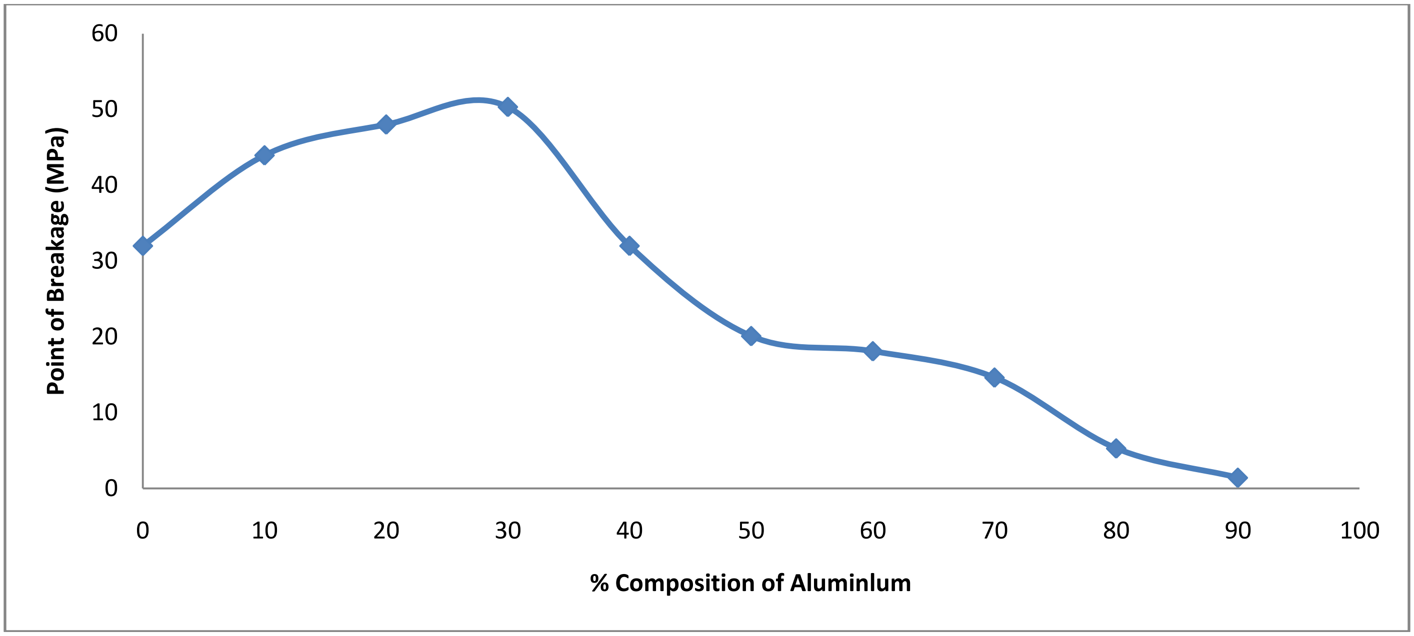

Figure.14. Variation of Points of Breakage with Percentage composition of Aluminium

IV. DISCUSSION

4.1 Mechanical Properties of the Composite Samples

4.1.1 Maximum Compressive Stress and Strain

In Tables 3.1 and 3.2, silicon and sodium take the lead in elemental investigations of the first two samples. Aluminium was observed to be the highest concentrated element of the composites in Tables 3.3 and 3.4. Composite samples were subjected to increasing load and values of stress monitored until it reached maximum value were noted. Beyond this point, distortion sets in which may cause breakage. Table 3.5 contains the maximum compressive stress and strain over the entire composition range of Aluminium. The strain and stress have maxima at 10 and 30 percent weights composition of Aluminium in composites. The relationship between maximum compressive stress - strain and percent weight of Aluminium in the composites at 25 µm are contained in Figures 3.1 and 3.2. The results denote stress is maximum for Al$_{30}$Glass$_{70}$ with value of 50.32 MPa which gives the highest stress obtainable and it is also the point of breakage. The compressive stress in Figure 3.1 increases gradually to maximum for Al$_{30}$Glass$_{70}$ and further decreases subsequently to minimum for Al$_{90}$Glass$_{10}$. The result reveals that ordinary Glass has maximum compressive strength at approximately 32 MPa compared to Al-Glass composites with strength level of approximately 50 MPa. These have shown improved capacity of the new composites. Figure 3.2 illustrates the relationship between maximum compressive strain with percent weight of Aluminium in the composites. The strain has maximum at 0.38 for 10 % weight of Aluminium in the composites.

4.1.2 Variation of Stress and Strain for Composites

Figures 3.4 – 4.4 show the variations of stress / strain for Al$_0$Glass$_{100}$, Al$_{10}$Glass$_{90}$, Al$_{20}$Glass$_{80}$, Al$_{30}$Glass$_{70}$, Al$_{40}$Glass$_{60}$, Al$_{50}$Glass$_{50}$ Al$_{60}$Glass$_{40}$, Al$_{70}$Glass$_{30}$, Al$_{80}$Glass$_{20}$ and Al$_{90}$Glass$_{10}$ of 25 µm particle sizes and pressure of 500 bars. Samples A$_0$Glass$_{100}$ in Figure 3.4 was discovered with ruptures along the curve with point of breakage at 32.0 MPa. The results revealed that as the strain increases, the stress increases gradually with indication of rupture along each of the curves. Sample Al$_{10}$Glass$_{90}$ in Figure 3.5 was noted with repeated rupture along the variation of stress – strain with point of breakage at 43 Mpa. Moreover, in Figure 3.6 an increase in stress which corresponds to an equal increase in strain was found with fracture. In addition, there is an intuition that for the rest of the samples as the strain increases the stress does not display corresponding increase in Figures 3.7 – 4.4. The increase in strain with stress became observable for these composites before rupture along the curves up to the points of breakage at 50.32, 48.0, 32.0, 20.2, 18.10, 14.63, 5.32 and 1.42 MPa for Al$_{20}$Glass$_{80}$, Al$_{30}$Glass$_{70}$, Al$_{40}$Glass$_{60}$, Al$_{50}$Glass$_{50}$, Al$_{60}$Glass$_{40}$, Al$_{70}$Glass$_{30}$, Al$_{80}$Glass$_{20}$ and Al$_{90}$Glass$_{10}$ composites.

V. CONCLUSION

There are variations in points of fracture, rupture and breakage of samples analyzed of the compaction pressure. The point of breakage increases with increase in Aluminium addition in composites up to reasonable level and it reduces for the rest of the composition. All the samples considered in the research were found to have ruptures and fractures at the observed pressure of the compression results. At the Compacting Pressure, samples were noted with the display of flaws. The strength level of the new material is increased substantially.

VI. REFERENCES

[1]. Wada, T., Zhang, T. and Inoue, A. (2002) Formation, Thermal Stability and Mechanical Properties in Zr-Al-Co bulk Glassy Alloys. *JIM*, *43*, 2843–2846.

[2]. Abodunrin O.W. and Oluyamo S.S. (2017). Structural Stability of Nano Crystalline Al-Glass Composites. International Organization of Scientific Research (IOSR) Journal of Applied Physics, 9 (1), 96-99.

[3]. Abodunrin O.W. and Alao F.I. (2017). Stress Stability of Al-Glass Composites. International Journal of Mechanics, Materials Science & Engineering, ISSN 2412-5954.

[4]. Yokoyama, Y., Yamasaki, T., Liaw, P.K. and Inoue, A. (2007) Relations between the Thermal and Mechanical Properties of Cast Zr-TM-Al (TM: Cu, Ni, or Co) Bulk Glassy Alloys. *Material Transactions*, *48*, 1846–1849.

[5]. Inoue, A., Zhang, W. (2002) Formation, Thermal Stability and Mechanical Properties of Cu-Zr-Al Bulk Glassy Alloys. *Mater. Trans.*, *43*, 2921–2925.

[6]. Chen, D., Takeuchi, A. and Inoue, A. (2007) Gd-Ni-Al Bulk Glasses with Great Glass-Forming Ability and Better Mechanical Properties. *Journal of Material Science*, *42*, 8662–8666.