CHAPTER - 06

RED MUD-GGBFS GEOPOLYMER

6.1 General

Present-day scenarios for the utilization of industrial waste have become more significant. In line with such utilization of waste, one of the major wastes produced by Aluminum manufacturing industries is red mud. This chapter discusses the effect of alkali activation on Red mud-GGBFS mixes and investigates the potential use of Red mud as a raw material in the development of high-strength geopolymers. To analyze the impact of GGBFS on red mud mixes has been designed by replacing the red mud with GGBFS at the rate of 10 %. Then the designed mixtures were activated with an alkaline activator (sodium hydroxide) at various concentrations. After synthesizing, the mixes of Red mud-GGBFS samples were kept for curing for different curing periods (7, 28, and 56 days). After completing the curing period these prepared samples were tested for analyzing the UCS. The broken samples collected from UCS tests have been used in small quantities for analyzing the microstructural analysis (XRF, FTIR and SEM).

6.2 Specific Gravity of Red mud – GGBFS Mixes

Table 6.1 and Fig 6.1 show the specific gravity of Red mud – GGBFS mixes. Initially, the red mud value was found as 3.125. The overall result of adding the GGBFS in red mud has decreased the specific gravity. When 10% Red mud has been replaced with GGBFS the specific gravity of the mix $R_{90}G_{10}$ has decreased to 2.87. Replacement of Red mud with 20% GGBFS the specific gravity of the mix $R_{80}G_{20}$ decreased to 2.80. Some improvement has been observed in the specific gravity (3.01) of the mix $R_{70}G_{30}$ on replacing the Red mud with 30% GGBFS. When Red mud replacement is above 30% a slight decrement has occurred in the specific gravity (2.90) of the mix $R_{60}G_{40}$ when further replacing the Red mud with 40% GGBFS. 50% replacement of Red mud with GGBFS the specific gravity of the mix $R_{50}G_{50}$ marginally improved to 2.96. Further, a minor decrement has been observed in the value of specific gravity (2.94) of the mix $R_{40}G_{60}$ when 60% Red mud was replaced with GGBFS. Further, a sudden decrement has been noted on the 70% replacement of Red mud with GGBFS in the mix $R_{30}G_{70}$ (2.80) and on adding more GGBFS in the mix no significant improvement has been observed. 90% replacement of Red mud with GGBFS the specific gravity of mix $R_{10}G_{90}$ becomes 2.74. Overall, the specific gravity of mixes with the addition of GGBFS has not followed any specific trend.

Table: 6.1 Specific Gravity Analysis of Red mud-GGBFS Mixes

Designed mixture	**Specific Gravity**
$R_{100}G_{0}$	3.125
$R_{90}G_{10}$	2.87
$R_{80}G_{20}$	2.80
$R_{70}G_{30}$	3.01
$R_{60}G_{40}$	2.90
$R_{50}G_{50}$	2.96
$R_{40}G_{60}$	2.94
$R_{30}G_{70}$	2.80
$R_{20}G_{80}$	2.86
$R_{10}G_{90}$	2.74
$R_{0}G_{100}$	2.75

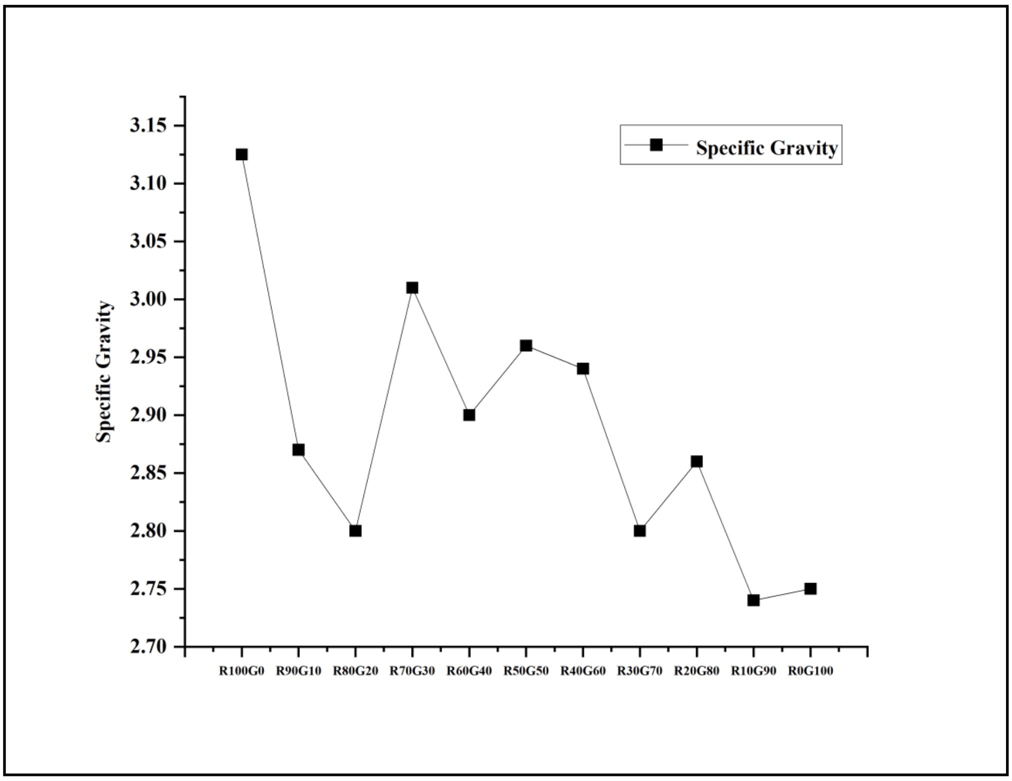


Fig: 6.1 Specific Gravity of Red mud-GGBFS Mixes

6.3 Grain Size Analysis of Red mud-GGBFS Mixes

The percentage of sand, silt and clay of Red mud – GGBFS mixes has been determined by grain size distribution. To analyze the effect of GGBFS on Red mud in terms of grain size distribution parameter, the grain size of each red mud-GGBFS mix has been calculated and presented in Fig 6.2 and Table 6.2. The percentage of sand, silt and clay in Red mud is 32.8%, 53.5% and 3.15% respectively determined as per the IS: 2720: Part-4 (1985). When 10% Red mud replaced by GGBFS the percentage of sand and clay have been decreased to 31.08% and 1.75% respectively in the mix $R_{90}G_{10}$ and the percentage of silt has been increased to the value of 59.88%. On the 20% replacement of red mud with GGBFS the percentage of sand slightly increased to the value 35.92% and the percentage of silt and clay decreased to the value 57.40% and 1.14% respectively. The percentage of sand decreased to 28.68% on 30% inclusion of GGBFS in the mix $R_{70}G_{30}$ and the amount of sand continued to decrease to the value 16.12 on 50% addition of GGBFS in the mix $R_{50}G_{50}$. While the percentage of silt has been increased to 59.32% in the mix $R_{70}G_{30}$ and it continue increasing to the value 79.88% on 50% GGBFS inclusion in the mix $R_{50}G_{50}$.

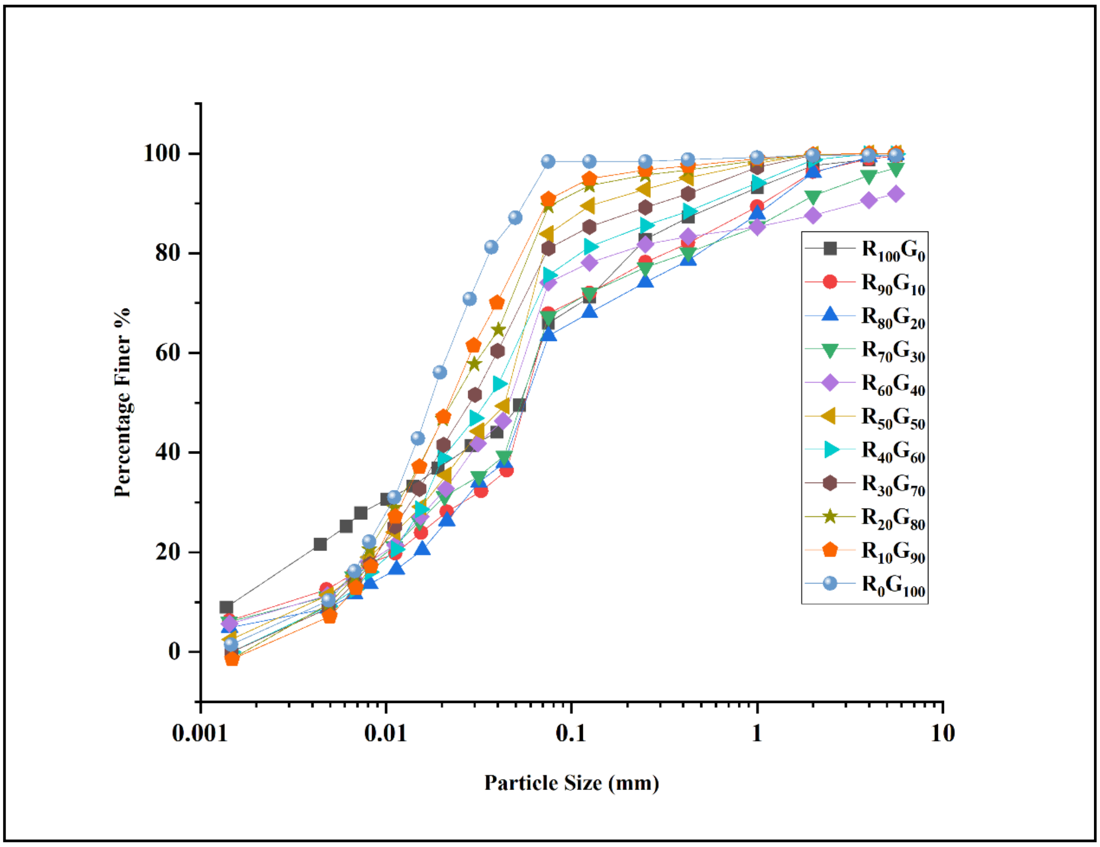


Fig: 6.2 Grain size Distribution of Red mud-GGBFS Mixes

Table: 6.2 Grain Size Distribution Analysis of Red Mud-GGBFS Mixtures

Mixtures	Sand %	Silt %	Clay %
$R_{100}G_0$	32.0	56.0	12.0
$R_{90}G_{10}$	31.08	59.88	1.75
$R_{80}G_{20}$	35.92	57.40	1.14
$R_{70}G_{30}$	28.68	59.32	1.96
$R_{60}G_{40}$	16.88	67.12	1.35
$R_{50}G_{50}$	16.12	79.88	1.47
$R_{40}G_{60}$	24.32	73.56	2
$R_{30}G_{70}$	19.04	78.96	2
$R_{20}G_{80}$	10.56	87.44	2
$R_{10}G_{90}$	9.2	89.8	1
R_0G_{100}	1	95	4

6.4 Compaction Characteristics of Red mud –GGBFS Mixes

As per IS: 2720: Part-7 (1980) the compaction characteristic (MDD& OMC) of each prepared mix has been evaluated (Fig: 6.3). As the Red mud was replaced gradually with GGBFS at different percentages at the rate of 10%, the change in their compaction characteristics has been observed. After replacing 10% Red mud with GGBFS the MDD of mix $R_{90}G_{10}$ increased by 0.65% to the value 1.53 g/cc and OMC decreased by amount 2.19% to the figure 30.32%. A 1.97% increment in MDD was observed by replacing 20% of red mud with GGBFS (1.55 g/cc) and the OMC value was reduced by 8.06% in mix $R_{80}G_{20}$ to the amount of 28.5%. Further MDD improved by an amount of 1.57% but comparatively a lower value of 1.544g/cc was observed on further substituting 30% Red mud with GGBFS but no change has been observed in the trend of OMC value, it further decreased to 27.4% by percentage decrease of 11.61%. On further replacement of Red mud with GGBFS up to 50% GGBFS MDD increased to 1.596 g/cc by 5% and OMC decreased to 24.6% by amount

20.64% in mix $R_{50}G_{50}$. It is observed from Fig. 6.4 that the replacement of Red mud with GGBFS leads to an irregular pattern of MDD either increased or decreased. But OMC was continuously decreasing on substitution of Red mud with GGBFS. Mix $R_{50}G_{50}$ presented the highest value of dry density. However on further replacement of Red mud with GGBFS, the change in MDD value was observed at 1.576 g/cc ($R_{40}G_{60}$), 1.556 g/cc ($R_{30}G_{70}$), 1.56 g/cc ($R_{20}G_{80}$) and 1.538 g/cc ($R_{10}G_{90}$).

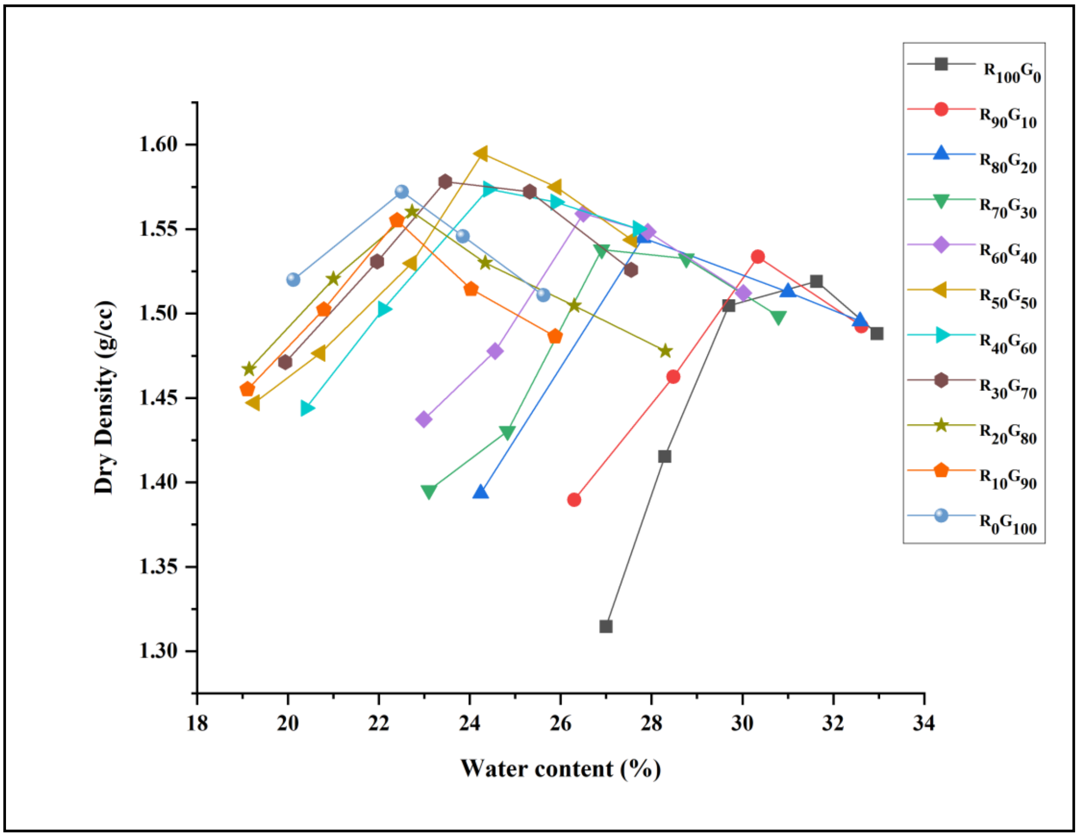


Fig: 6.3 Compaction Curves of Red mud- GGBFS mixes

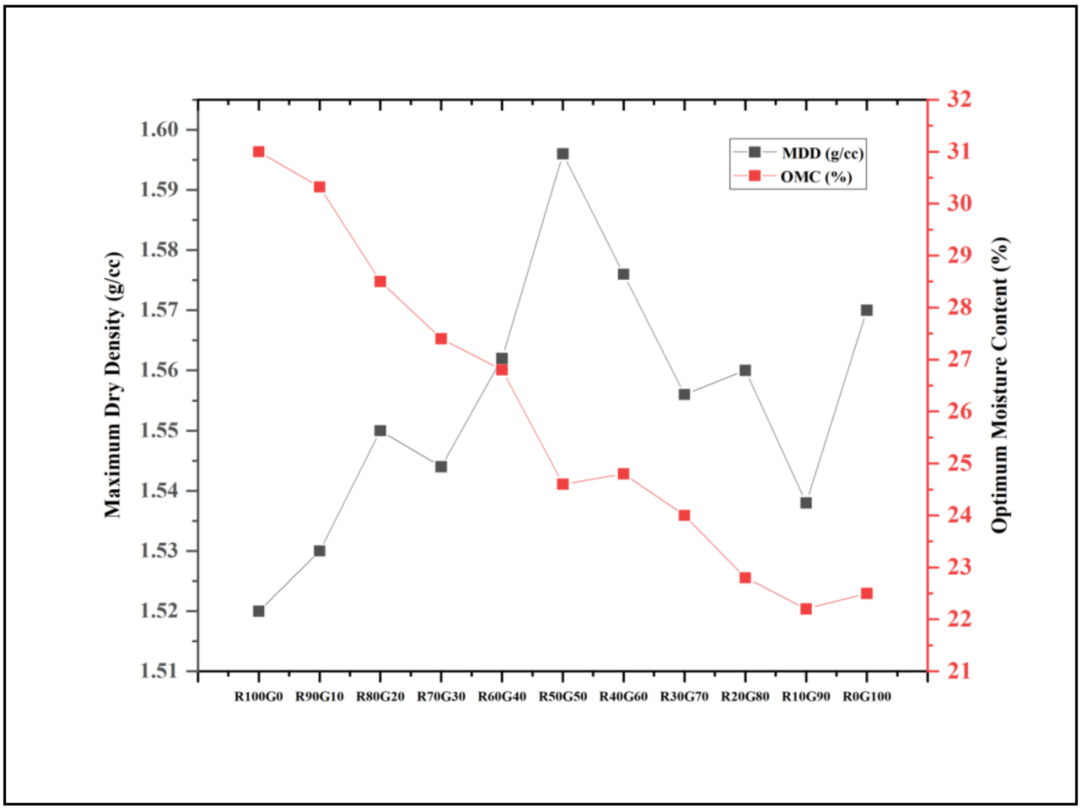


Fig: 6.4 MDD and OMC Curve of Red mud-GGBFS Mixtures

6.5 Permeability Analysis of Red mud-GGBFS Mixes

Permeability is a property of the geomaterial that describes its ability to allow the flow of fluids through it. The falling head permeability tests were performed for all mixes of Red mud-GGBFS using water as pore fluid. As the GGBFS increases, permeability through the mixes shows slow due to the reduction in the size of voids (Fig. 6.5). The coefficient of permeability of Red Mud without GGBFS ($R_{100}G_0$) was found as 2.822×10^{-4} cm/sec. The addition of 10% slag content to Red Mud causes a significant change in "k" values of the mix $R_{90}G_{10}$ is determined as 7.698×10^{-6} cm/sec. A slight increment in the value of permeability (1.461×10^{-5} cm/sec) of the mix $R_{80}G_{20}$ has been observed when 20% Red mud is replaced with GGBFS. No significant changes occur on further replacement of 30% Red Mud with GGBFS. The permeability of the mix $R_{70}G_{30}$ has been increased to 1.978×10^{-5} cm/sec. further replacement of 40% Red mud with GGBFS the value of permeability slightly decreased to 1.468×10^{-5} cm/sec. no major changes have been observed in the addition of more slag in the mix-up to mix $R_{30}G_{70}$. A measurable change has been observed on the 80% replacement of Red mud with GGBFS. The value of permeability of the mix $R_{20}G_{80}$ has been increased to 4.743×10^{-5} cm/sec. Furthermore, this value increased to 5.084×10^{-5} cm/sec on 90% replacement of Red mud with GGBFS. With the addition of GGBFS to red mud the mixes become dense which helps in increasing the geopolymer reactions.

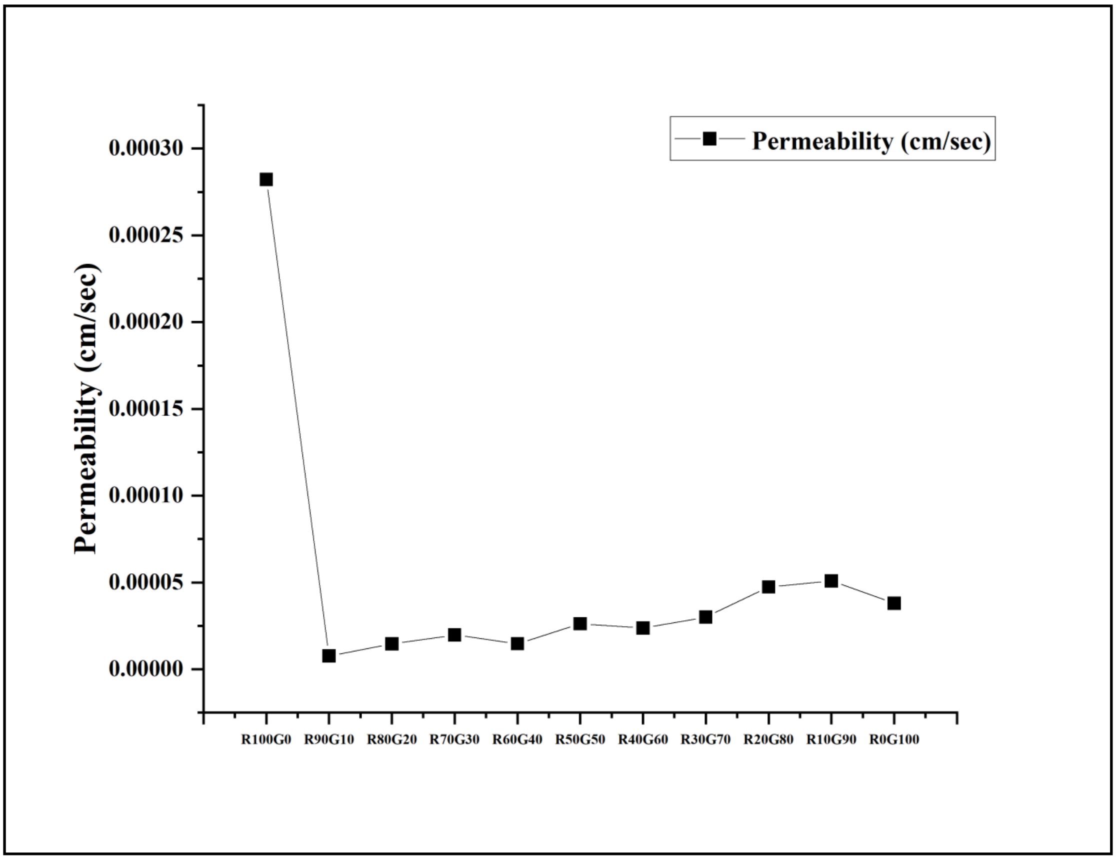


Fig: 6.5 Permeability Curve of Red mud-GGBFS Mixes

6.6 UCS Analysis on Red mud-GGBFS Mixes

Fig: 6.6 UCS Testing of Red mud-GGBFS Mixes

The values of UCS of Red mud – GGBFS mixes are discussed for up to 50% addition of GGBFS without alkali activation for the curing period of 7 days. The mean value of unconfined compressive strength of unmixed Red mud $R_{100}G_0$ without alkali (water) found as 0.39 MPa. The UCS value of 0.41 MPa after replacing 10% Red mud with GGBFS $R_{90}G_{10}$

without alkali activation has been noticed. Further on substitution of Red mud with GGBFS up to 50% weight the value of strength (UCS) was observed as 0.14 MPa. It was observed that without alkali activation of mixes did not yield significant results even on replacing the Red mud with GGBFS. The low values of UCS may be because the amount of self-alkali content present (not added alkali externally) in red mud might not be sufficient to consume alumino-silicates present and unreacted and unbounded GGBFS left out in the matrix that results in a reduction in strength.

On activation of mix with sodium hydroxide unconfined compressive strength of samples kept in polyethene and cured at ambient temperature was observed to increase with substituting the Red mud by increasing GGBFS up to 90%. Figs: 6.7-6.9 shows the unconfined strength of samples activated with 2, 4, 6, 8 and 10M concentrated NaOH at a curing period of 7, 28 and 56 days. From UCS analysis it was observed that 2M and 4M NaOH-activated samples provide the maximum unconfined compressive strength. When mixture $R_{100}G_0$ was activated with 2M NaOH, 0.52 MPa value of UCS was recorded at 7 days of the curing period. When the 10% Red mud has been replaced by GGBFS, this value has been increased to 1.50 MPa at 7 days. As the percentage of replacement of Red mud with GGBFS increases the value of UCS also improved on a significant scale. With 30% replacement of Red mud by GGBFS, the mix $R_{70}G_{30}$ provide the UCS 5.93MPa at 7 days. On 50% replacement of Red mud with GGBFS the mix $R_{50}G_{50}$ recorded the UCS 9.06 MPa at 7 days. As the concentration of sodium hydroxide increases the value of UCS also improved. But beyond 4M NaOH concentration the value of UCS started decreasing activated with higher concentration due to the excess of OH- ions. Mix $R_{100}G_0$ activated with 4M NaOH provide the value of UCS 0.71 MPa. On further increasing the concentration of NaOH the UCS of this mix $R_{100}G_0$ has been decreased to 0.22 MPa activated with 6M NaOH, 0.07 MPa with 8M NaOH and 0.11 MPa with 10 M NaOH. Mix $R_{70}G_{30}$ also follows the same pattern.

The strength of this mix activated with 4M NaOH increased to 7.4 MPa and started decreasing with increasing the concentration of NaOH. About all designed mixes following this trend. To utilize the Red mud, the maximum quantity of which was replaced with GGBFS is 50%. If the Red mud substituted more than 50 % with GGBFS strength will increase but utilization of Red mud did not meet the expectations. The maximum utilization of red mud with good compressive strength is possible with mix $R_{50}G_{50}$. Mix $R_{50}G_{50}$ activated with 4M NaOH provides 13.73 MPa at 7 days. After increasing the concentration (6M NaOH) of alkaline activator the strength decreased to 5.6 MPa in the same mix $R_{50}G_{50}$ at 7 days. Further increasing the concentration of sodium hydroxide the strength slightly increased to 6.7 MPa (8M NaOH) and 7.35 MPa (10M NaOH) but less than the strength which is achieved with 4M NaOH activation. This is due to the excessive concentration of OH ions which leads to premature of geopolymerisation reactions. When the curing period of the prepared samples was increased to 28 days, there were no major changes in unconfined compressive strength. Overall, the strength increased after increasing the curing period but sometimes there was a slight decrement in the strength. After 56 days of curing period, the strength of mix $R_{50}G_{50}$ increased to 14.67 MPa on activation of 4M NaOH and strength decreased on further increasing the concentration of alkaline activator. The strength of this mix $R_{50}G_{50}$ is 10.26 MPa at 28 days of curing period with 4M NaOH, this difference was observed due to the temperature difference of sample preparation. For more utilization of red mud such as embankments cut low strength is required. The mix with more red mud $R_{80}G_{20}$ provided the UCS 4.66 MPa activated with 4M NaOH at 7 days and 3.56 MPa at 56 days. This difference in strength is caused by the temperature difference in sample preparation.

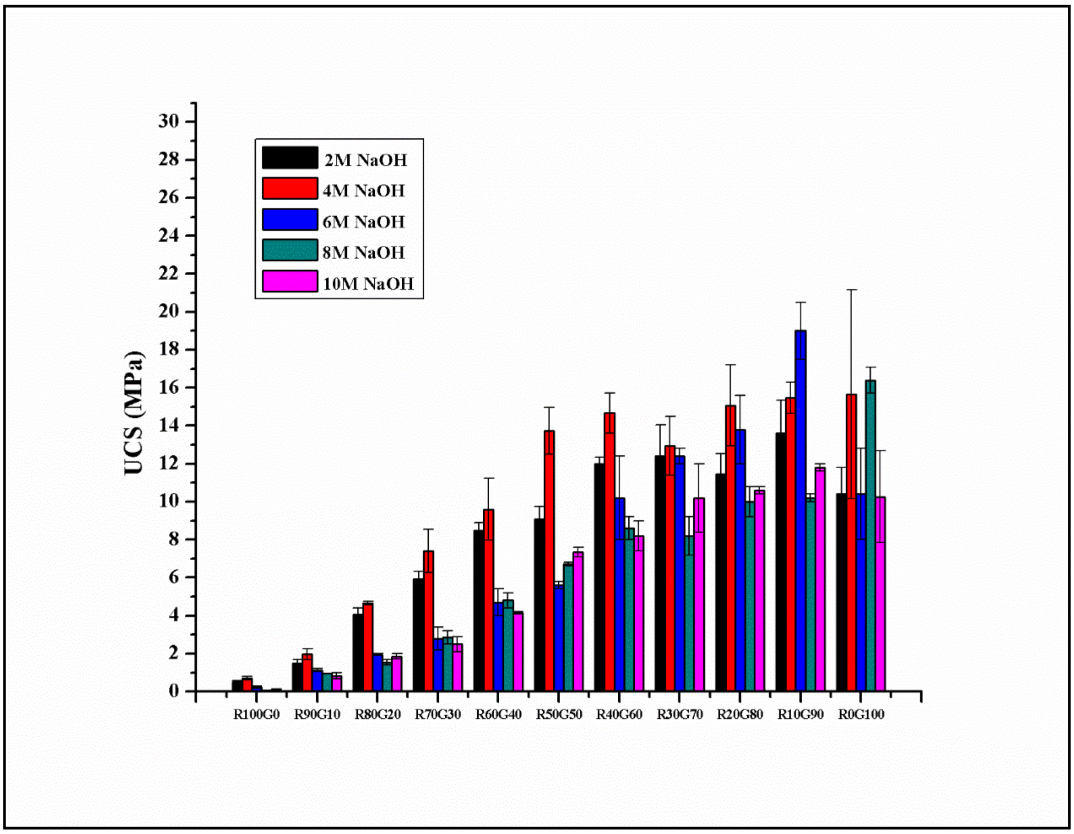


Fig: 6.7 UCS of Red mud –GGBFS Mixes activated with NaOH at 7 days

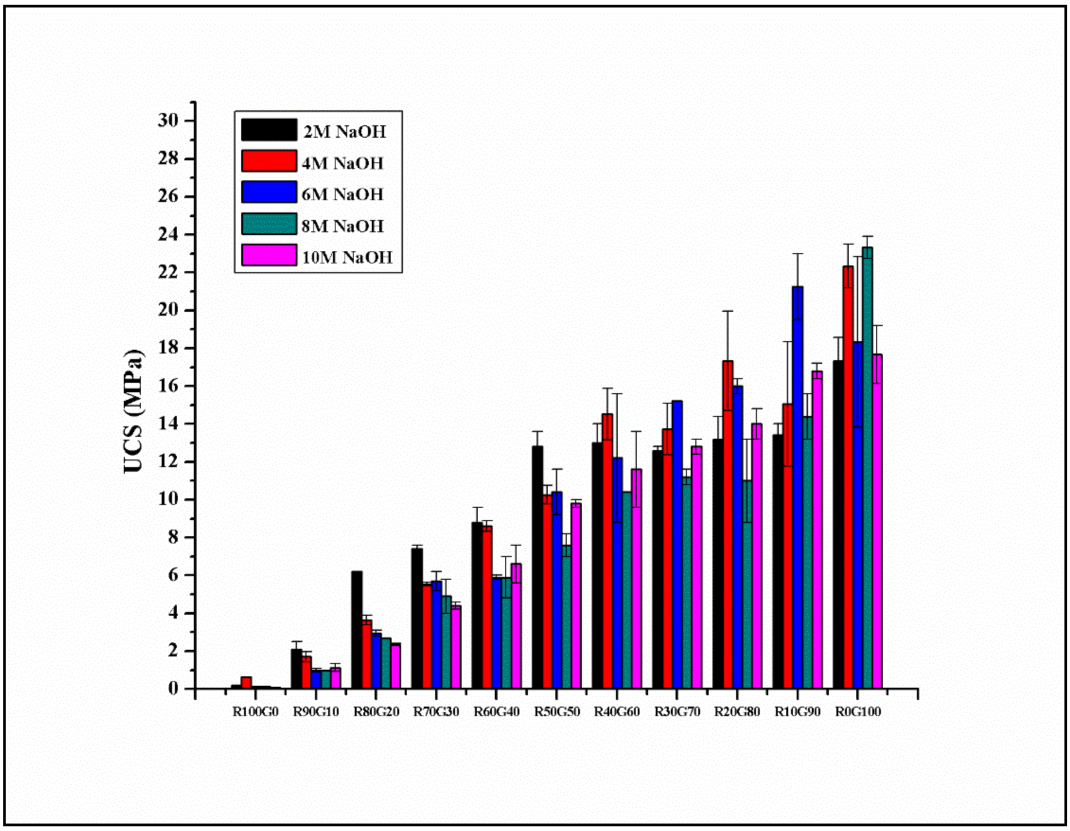


Fig: 6.8 UCS of Red mud-GGBFS Mixes activated with NaOH at 28 days

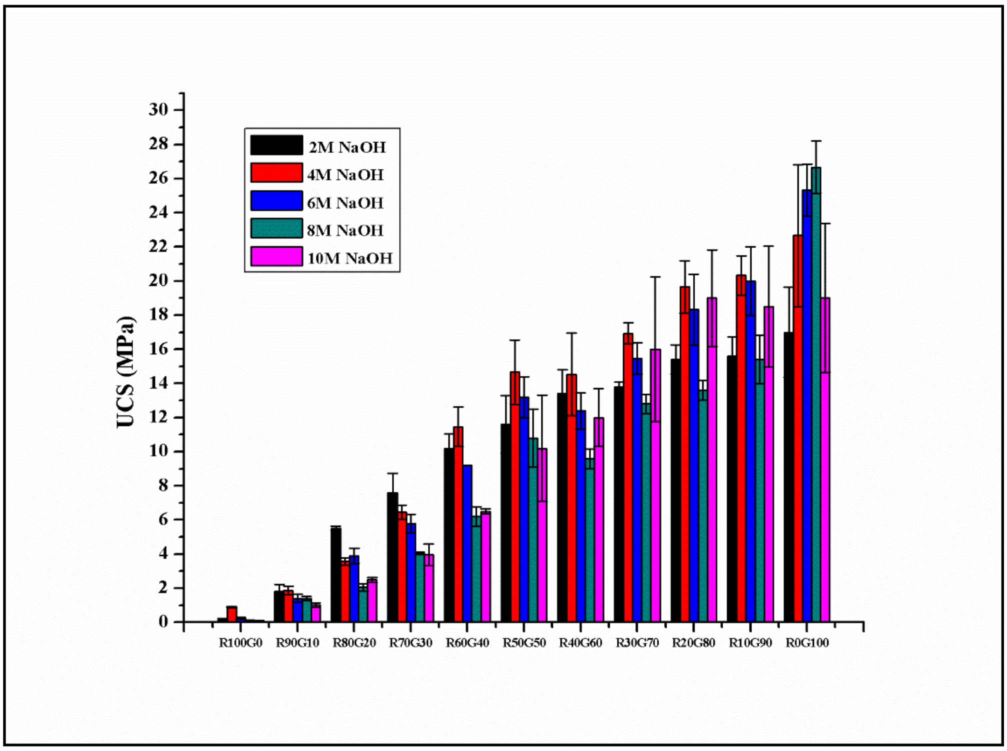


Fig: 6.9 UCS of Red mud-GGBFS Mixes activated with NaOH at 56 days

6.7 UCS of Red mud –GGBFS Mixes in water and Acidic environment

Fig: 6.10 Red mud –GGBFS samples immersed in water

The samples of Red mud-GGBF mixes prepared without alkali (water) have not shown any strength when cured in water. On activation with alkali at various concentrations, the Red Mud-GGBFS mixes provide some significant strength. The samples of unmixed red mud ($R_{100}G_0$) did not yield any strength when cured in water even after activation with sodium hydroxide with high concentration due to the absence of GGBFS in the mix. To evaluate the effect of water curing on the Red Mud-GGBFS mixes are prepared by replacing the Red Mud with GGBFS at the interval of 20% up to 100%. On replacing the 20% Red Mud with GGBFS the UCS of the mix $R_{80}G_{20}$ was found as 3.8 MPa after taking out the sample from water curing kept for 7 days period activated with 4M sodium hydroxide. On increasing the percentage of replacement of Red Mud with GGBFS the strength has been increased. Mix $R_{60}G_{40}$ provides the 7.6 MPa at 40 % replacement of Red Mud with GGBFS activating with the same concentration and same curing period. On increasing the percentage of replacement of Red Mud with the GGBFS the strength increased to 15.6 MPa for the mix $R_{40}G_{60}$. When the concentration of sodium hydroxide increases the strength of the water-cured sample also increases. 6M NaOH-activated sample $R_{80}G_{20}$ provide 4.7 MPa strength at 7 days of water curing. From Fig. 6.11 it can be concluded that on increasing the concentration, strength slightly decreases. 6M NaOH-activated mix $R_{40}G_{60}$ provides a lesser value (9 MPa) than the 4M NaOH-activated mix. Further on increasing the concentration the unconfined compressive strength decreases. 8M NaOH-activated sample provides 3.1 MPa which is lesser than 6M NaOH-activated mix with the same curing condition. Further, the value of UCS has been decreased by increasing the concentration of NaOH to 10 M for the mix $R_{80}G_{20}$ and $R_{60}G_{40}$. But for the mix $R_{40}G_{60}$, $R_{20}G_{80}$, the strength increases compared with the 8M activated sample on increasing the concentration of NaOH to the 10 M.

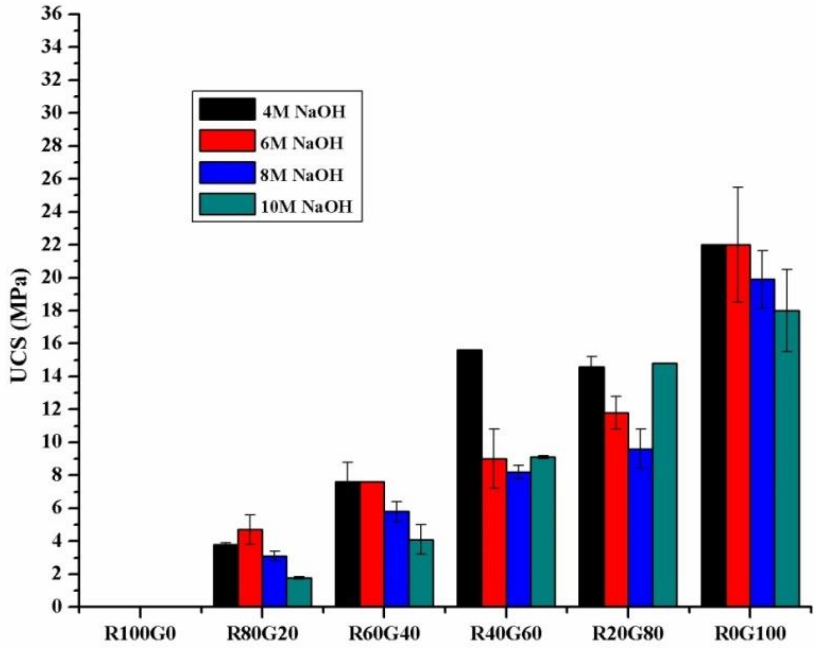


Fig: 6.11 UCS of Red mud-GGBFS Mixes activated with NaOH at 7 days in water

Overall, increase in the curing period of the mixes in water, strength increases. Mix $R_{80}G_{20}$ activated with 4M NaOH register the 4.6 MPa at 28 days of curing in water (Fig.6.12). Further increasing the percentage of replacement of Red Mud with GGBFS, the mix $R_{60}G_{40}$ gives 9.8 MPa with the same curing condition. At 28 days water curing 4M and 8M NaOH activated sample recorded the high UCS. Further on increasing the concentration of NaOH to molarity of 10, the strength decreases due to the excess of OH^- ions.

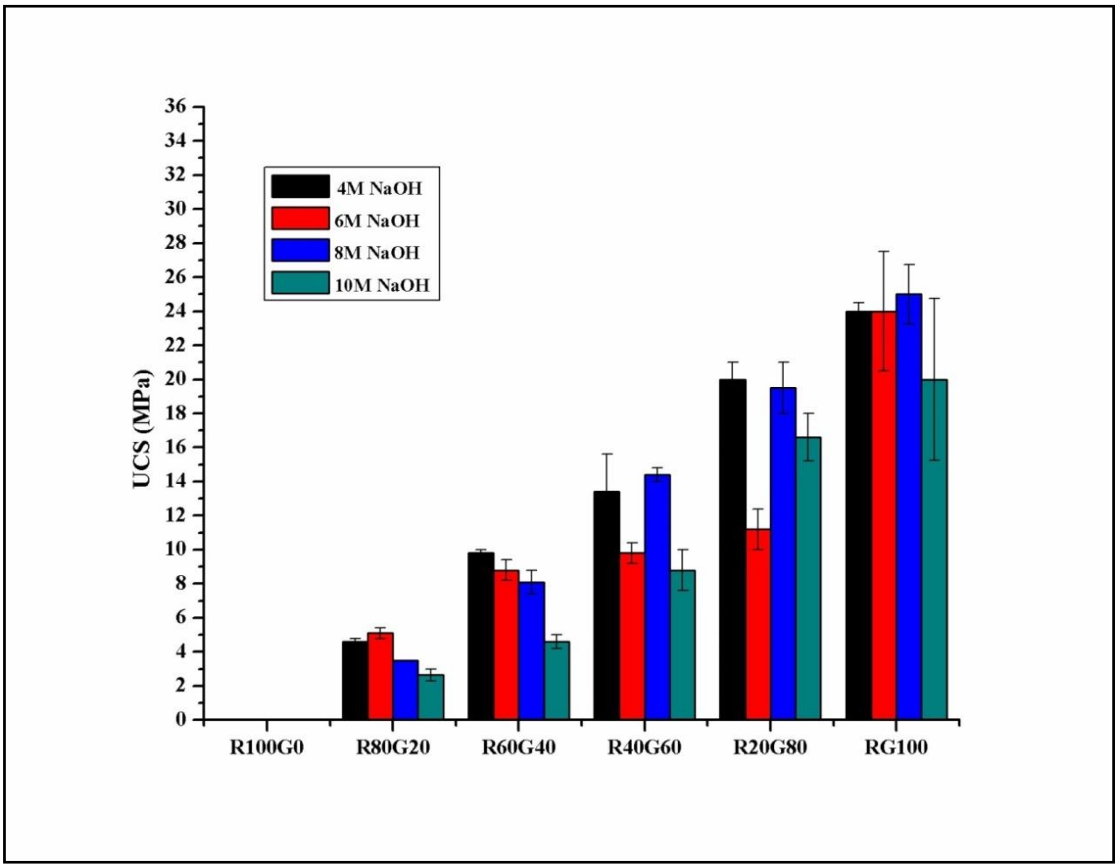


Fig: 6.12 UCS of Red mud-GGBFS Mixes activated with NaOH at 28 days in water

Further on increasing the curing period to 56 days in water, there were no significant changes in the strength. For example, in 6M NaOH-activated mixes, strength increases at 56 days in $R_{40}G_{60}$, but in other mixes, strength slightly decreases at 56 days (Fig. 6.13). The same trend followed in the 8M NaOH-activated sample, strength increases in $R_{80}G_{20}$ at 56 days but in other mixes strength slightly decreases. Strength of mixes of red mud-GGBFS not much affected due to acid immersion for period of 28 and 56 days. From Fig. 6.14 it is understand that the acidic environment did not affect the strength of Red Mud-GGBFS mixes.

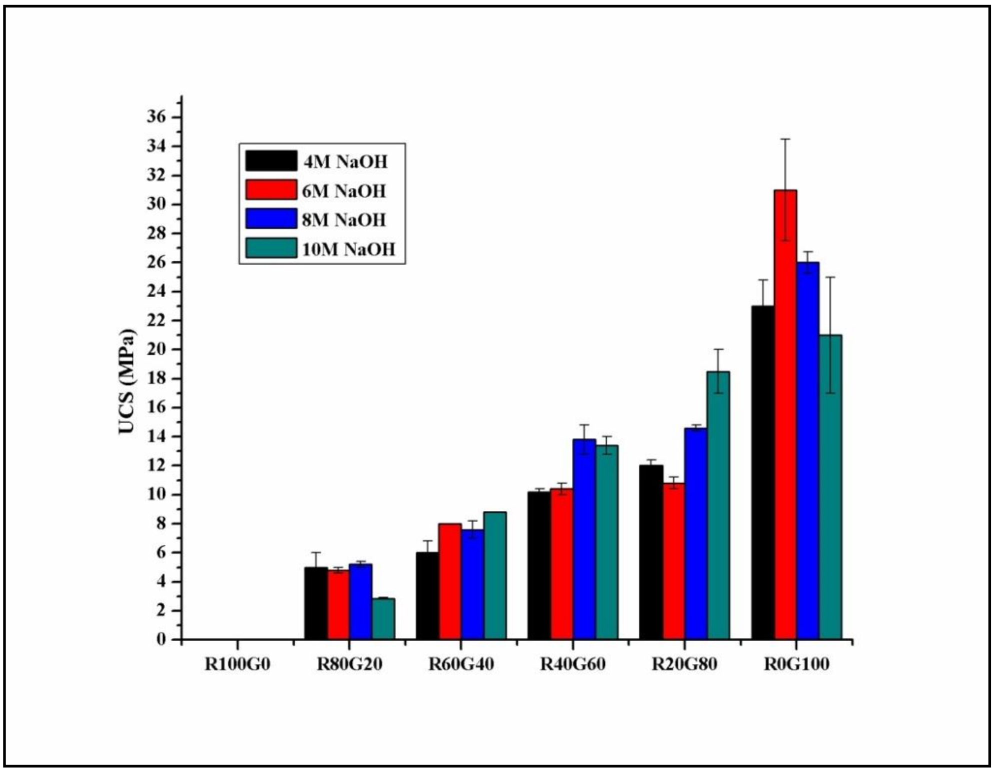


Fig: 6.13 UCS of Red mud-GGBFS Mixes activated with NaOH at 56 days in water

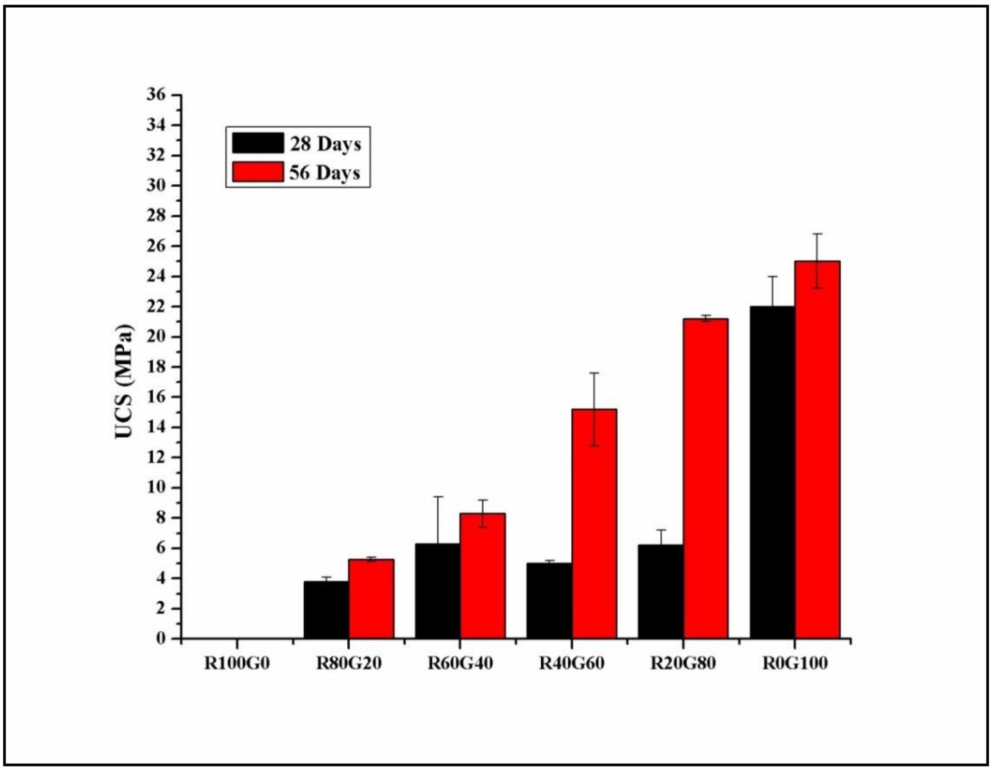


Fig: 6.14 UCS of Red mud-GGBFS Mixes activated with 4M NaOH and immersed in acid

6.8. XRD Analysis of Red mud-GGBFS Mixes

X-ray diffraction analysis technique was used to determine the mineralogical composition of geopolymer specimens prepared at an optimized concentration (4M NaOH) after a curing time of 56 days at room temperature. After alkali activation, some strong phases such as amorphous to semi-crystalline were observed in the geopolymers of mixes. From Figs. 6.15 (a) and 6.15 (b), it is confirmed that the CSH is the important phase that is responsible for maximum strength in the mixes. In Red mud-GGBFS mixes the maximum numbers of peaks are of hematite because of the availability of bulk mass of Fe_2O_3. The peaks of hematite (H) have been detected at the 2θ angle of 24.523^0, 25.547^0, 33.490^0, 36.040^0, 54.310^0, 62.943^0 and at 64.301^0 (Dimas et al., 2009; Kumar and Kumar, 2013; Panda et al., 2016). The XRD pattern of alkali-activated mix $R_{100}G_0$ represented the peaks of NASH detected at 21.659^0 (PDF# 84-0590), NCASH detected at 14.385^0 (PDF# 76-0843), 42.980^0 (PDF# 88-1128), 48.227^0 (PDF# 88-2093) and 49.732^0 (PDF# 75-0736). Mix $R_{100}G_0$ without any GGBFS content did not show any peaks of CSH which ultimately represented low strength. These peaks of NASH and NCASH are constantly observed in all mixtures from mix $R_{100}G_0$ to mix R_0G_{100} because of the alkali activation of the mixes. When the red mud is replaced with 10% GGBFS the XRD pattern of the mix $R_{90}G_{10}$ have been started to reveal the peak of CSH at the angle of 29.101^0 (PDF# 75-1652) which ultimately provides the reason for gaining the strength. On increasing the GGBFS content in the mixtures the CSH peak was also identified at 37.399^0 (PDF# 75-1652) two-theta angles. As the GGBFS quantity increases in the mixes, the intensity of the CSH peak identified at 29.101^0 (PDF# 75-1652) has become strong. When the percentage of GGBFS in the mix is 70%, a hump-like shape is observed which indicates the amorphous state. The peak of quartz (SiO_2) is established at 26.906^0 in all mixtures

(a) **(b)**

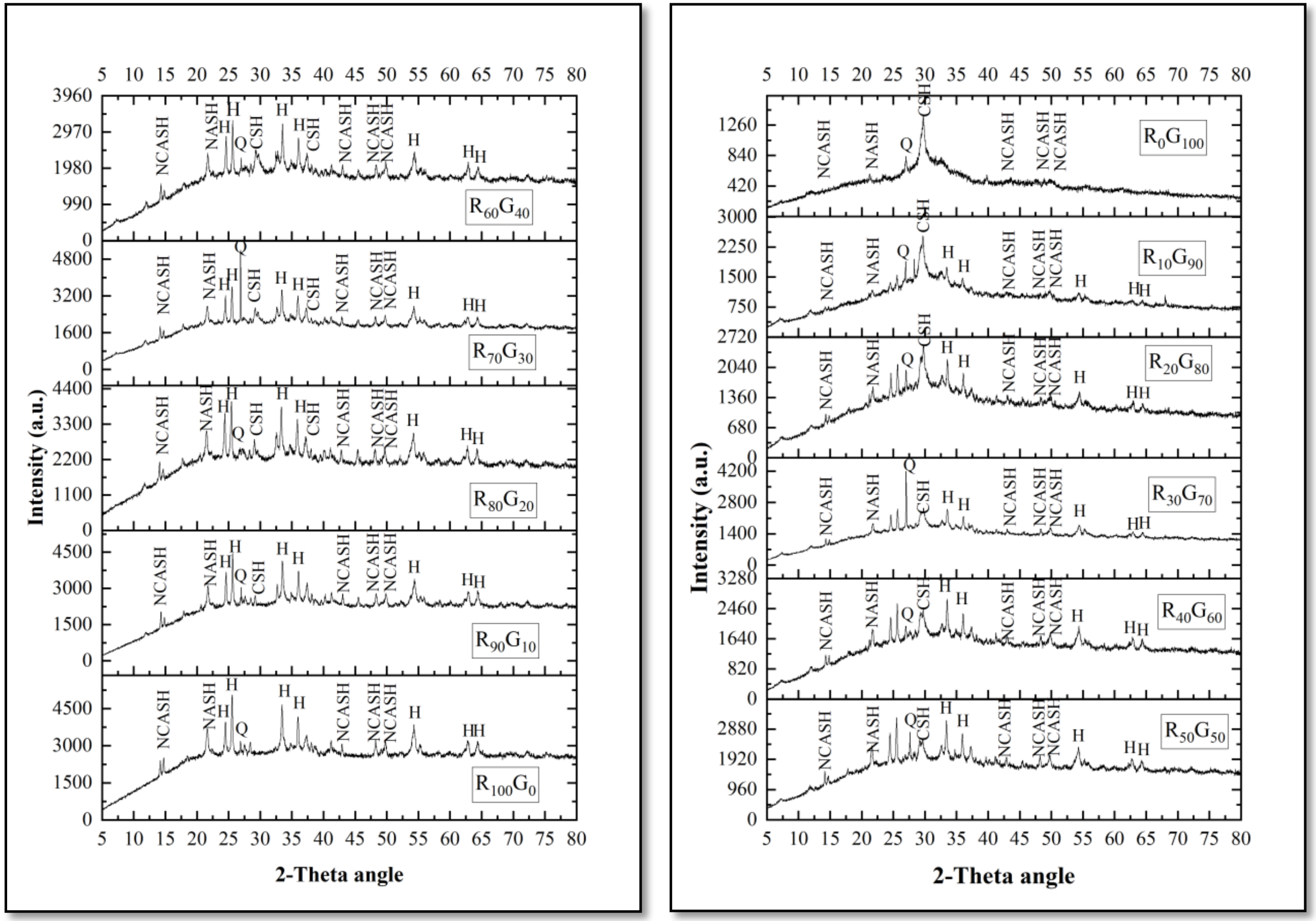


Fig: 6.15 XRD of All Red mud-GGBFS mixes: (a) $R_{100}G_0$ to $R_{60}G_{40}$, (b) $R_{50}G_{50}$ to R_0G_{100}, activated at 4M NaOH at 56 Days

confirmed by the JCPDS file (PDF# 89-7499). As the GGBFS content becomes rich in mixes the peak of silica also become strong.

6.9 FTIR Analysis of All Red mud-GGBFS mixes

When all mixes of Red Mud-GGBFS have been activated with sodium hydroxide, causes the reactions between the raw material and alkaline activator. These changes are recognized by the FTIR analysis. Fig. 6.16(a) and 6.16(b) presented the FTIR study which confirms the changes of mixes activated with 4M NaOH at 56 days curing period. The significant band that centred between 3276 cm^{-1}-3470 cm^{-1} was assigned to the stretching vibration modes of H-OH groups and the band ranged between 1635-1653 cm^{-1} verified the bending vibration of the O-H group. These features indicate that the water molecules are absorbed with the hydration products (NCASH & CSH) in all spectra of mixtures (Ismail et al., 2014; Zawrah et al., 2016). The band ranged between 1415-1459 $cm^{-1}$is attributed to the asymmetric stretching mode of the O-C-O bonds of carbonate minerals which are verified by the presence of residual un-reacted slag (Ismail et al., 2014; Zhang et al., 2017). The main band ranged between 1003cm^{-1}- 957 cm^{-1}in Red mud-GGBFS blends which are key fingerprints for the development of geopolymeric gel (NCASH, NASH and CSH) represents the asymmetric vibration of Si-O-T (T: Tetrahedral Si or Al). However, as the percentage of GGBFS increases, this main band shifts towards the lower wavenumber. The reason behind this change is the reduction of Al incorporated into the NCASH, NASH, CSH or CASH-type gel formed from the activation of the Red Mud-GGBFS blends (Ismail et al., 2014). After this strong band, the spectra detected at 443 cm^{-1}, and 453 cm^{-1}attributed to the bending of Si-O-Si and O-Si-O in Si-rich glass or quartz (Voll et al., 2001; Tochman 1992).

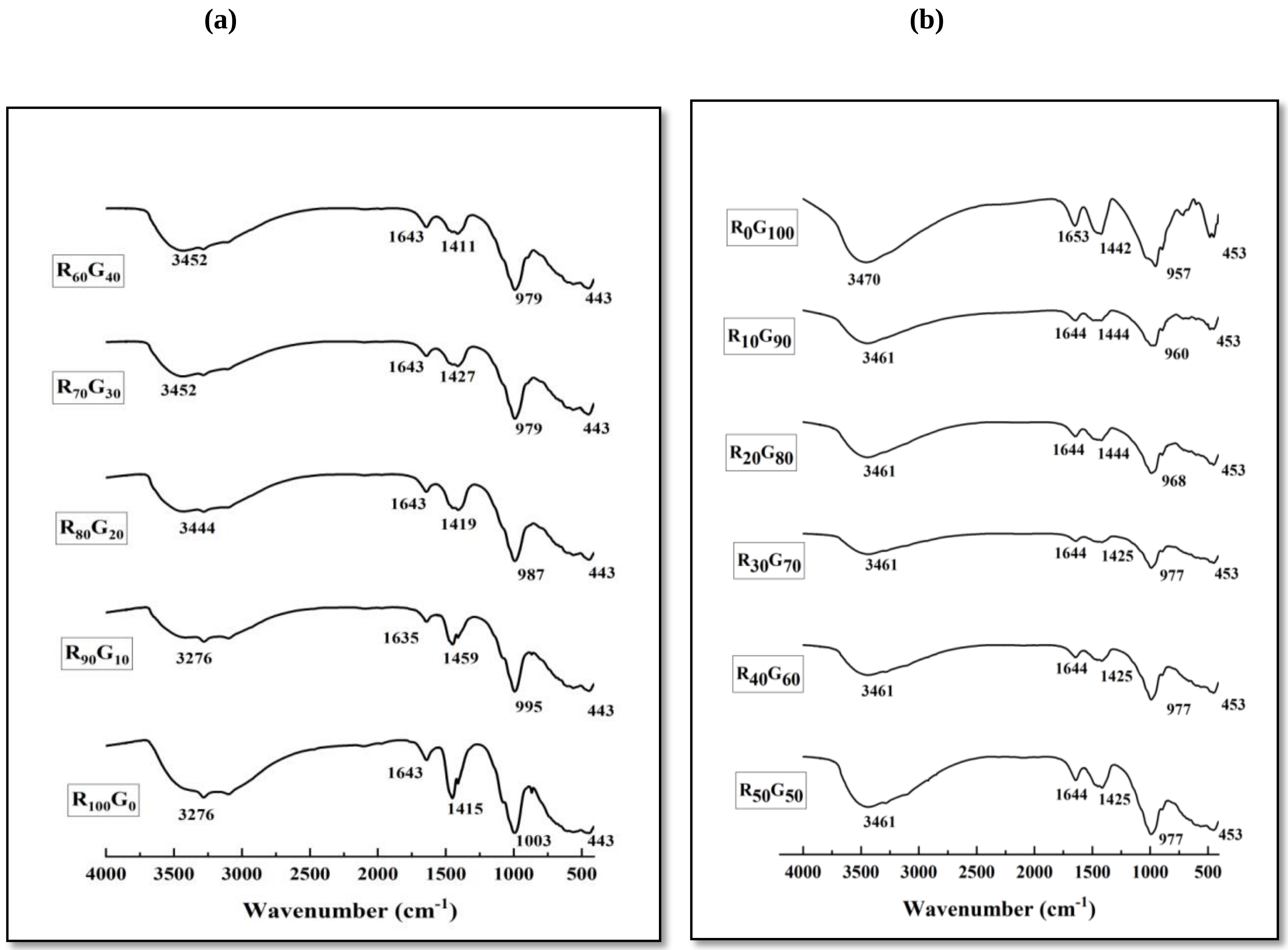
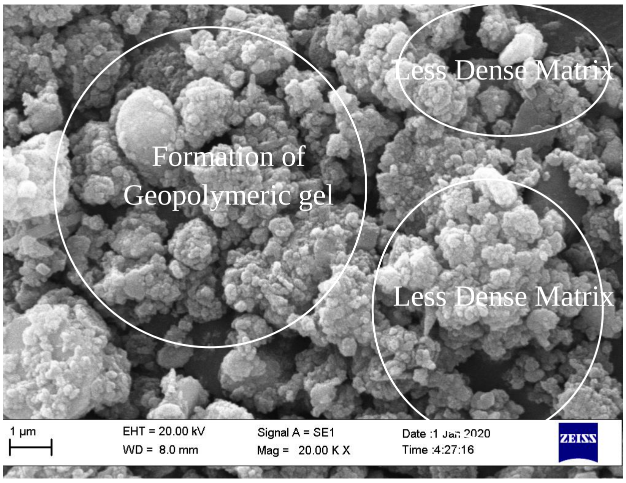


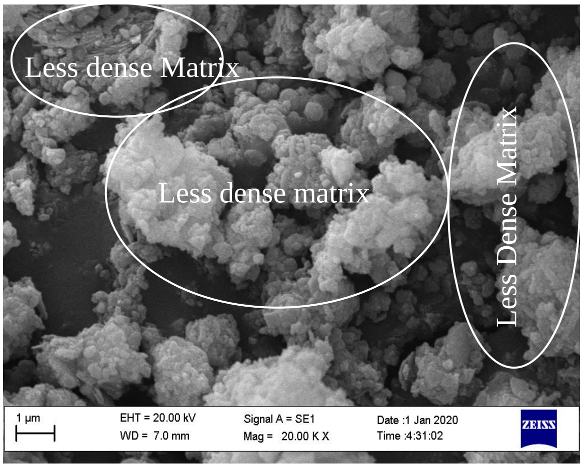
Fig: 6.16 FTIR Analysis of All Red mud-GGBFS mixes: (a) $R_{100}G_0$ to $R_{60}G_{40}$, (b) $R_{50}G_{50}$ to R_0G_{100} Activated with 4M NaOH at 56 days

6.10 SEM Analysis of Red mud-GGBFS Mixes activated with 4M NaOH at 56 days

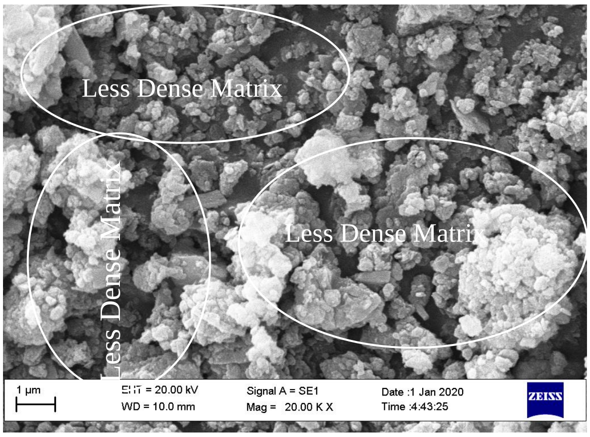
As discussed already in the methodology the microstructure of Red mud represented the irregularly shaped particles. When the mix $R_{100}G_0$ is activated with an alkaline activator, the mix possesses some strength. The reason behind the development of the strength is the production of the geopolymeric gel which is observed in the SEM images of the alkaline-activated mixes. The difference between raw Red mud and alkaline-activated Red mud is observed. The particles of alkali-activated Red mud are looking in binding form. As the quantity of GGBFS increased in the mixes became dense as shown in the Fig. 6.17(A) and 6.17(B). At 10% GGBFS addition in the mix, the mix $R_{90}G_{10}$ possessed 1.86 MPa UCS because of alkali activation which is also confirmed by XRD and FTIR. From the SEM images, it is observed that the growth of geopolymer products has a well-compacted structure. The SEM images of the $R_{90}G_{10}$ showed denser particles of Red Mud and GGBFS compared to the mix $R_{100}G_0$. As more GGBFS are added to the mix, the strength of the mix becomes high. On 30% addition of GGBFS in the mix causes the 6.46 MPa strength of the mix $R_{70}G_{30}$ activated with 4M NaOH at 56 days. The observed high strength of the mix is due to the dense packing and binding of the particles as shown by the SEM of $R_{70}G_{30}$. With the addition of more GGBFS mixes becomes denser due to the development of geopolymer gels. Mix $R_{50}G_{50}$ provides 14.66 MPa because of geopolymer reactions between mix and activator and results in dense packaging of the particles shown in the SEM of $R_{50}G_{50.}$



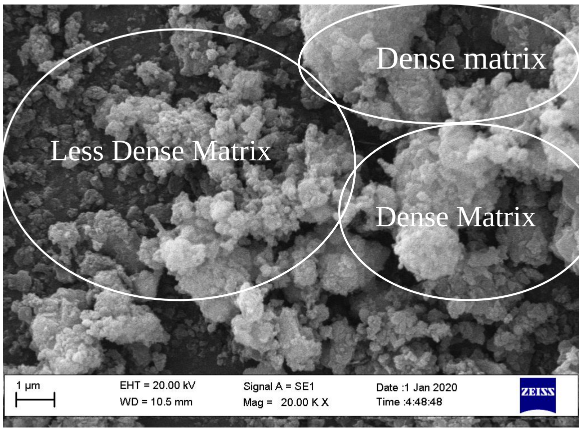
(a) $R_{100}G_0$



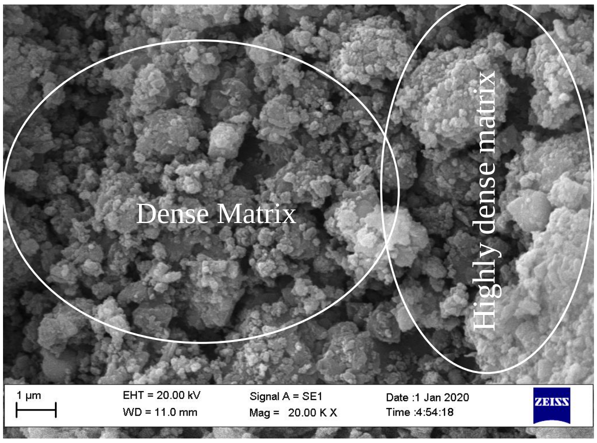
(b) $R_{90}G_{10}$



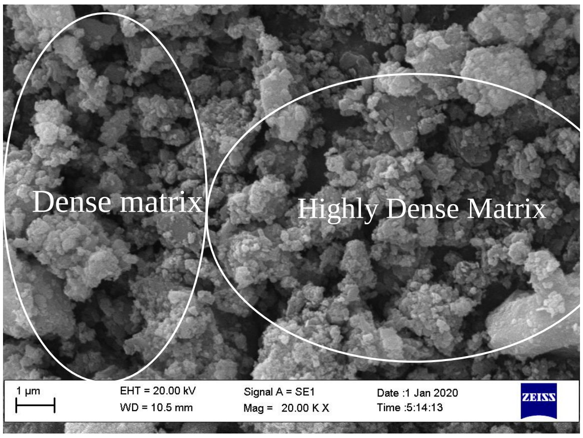
(c) $R_{80}G_{20}$



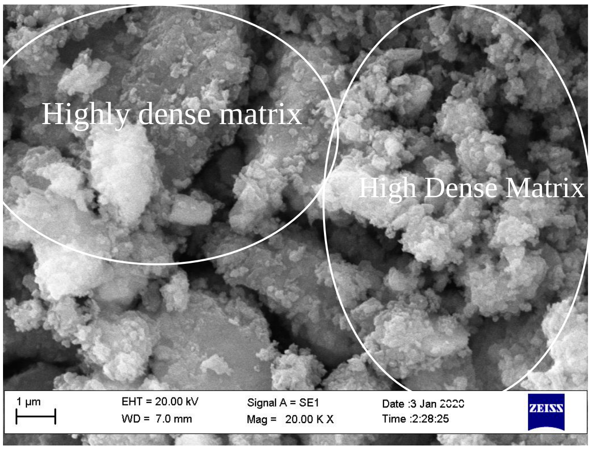
(d) $R_{70}G_{30}$



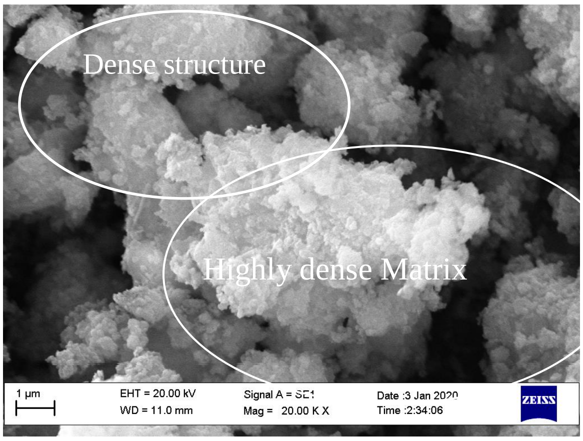
(e) $R_{60}G_{40}$



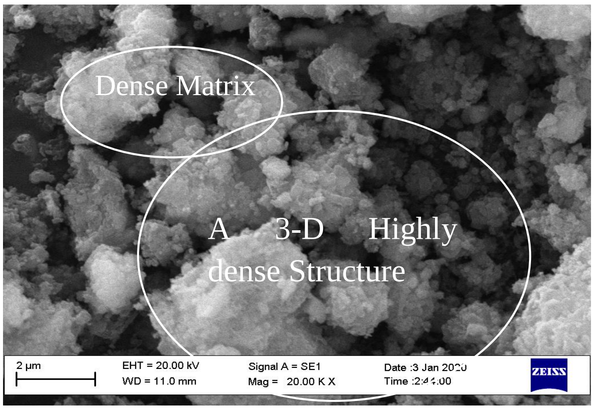
(f) $R_{50}G_{50}$



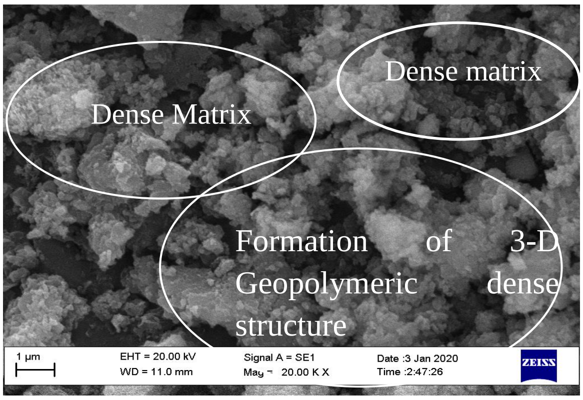
(g) $R_{40}G_{60}$



(h) $R_{30}G_{70}$

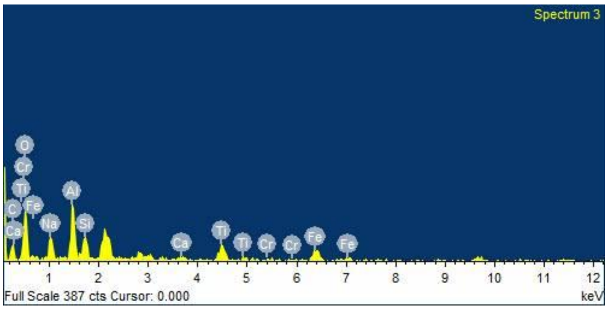


(i) $R_{20}G_{80}$

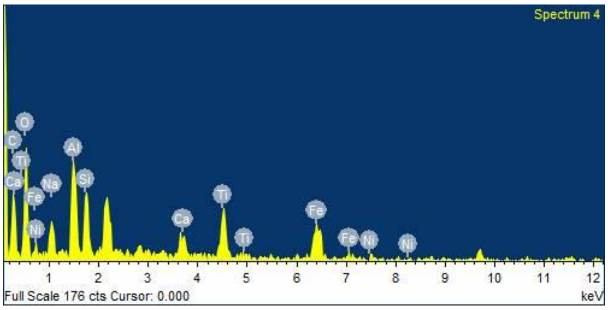


(j) $R_{10}G_{90}$

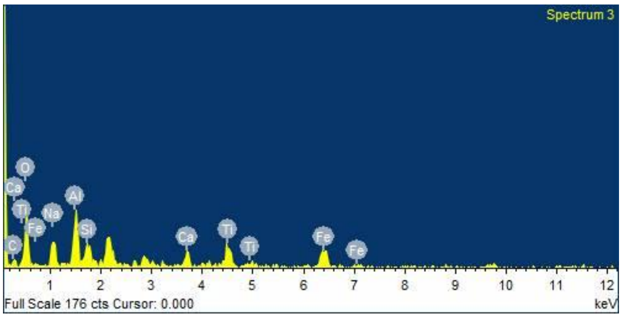
Fig: 6.17 (A) SEM Images: (a) $R_{100}G_0$, (b) $R_{90}G_{10}$, (c) $R_{80}G_{20}$, (d) $R_{70}G_0$, (e) $R_{60}G_{40}$, (f) $R_{50}G_{50}$, (g) $R_{40}G_{60}$, (h) $R_{30}G_{70}$, (i) $R_{20}G_{80}$, (j) $R_{10}G_{90}$,



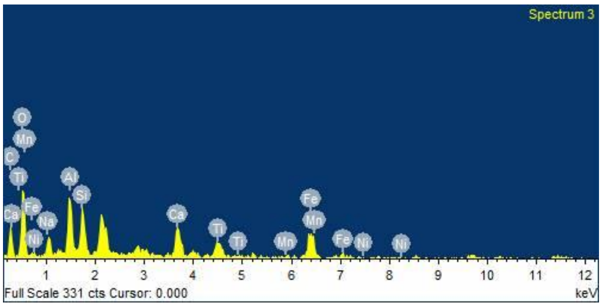
(a) R100G0



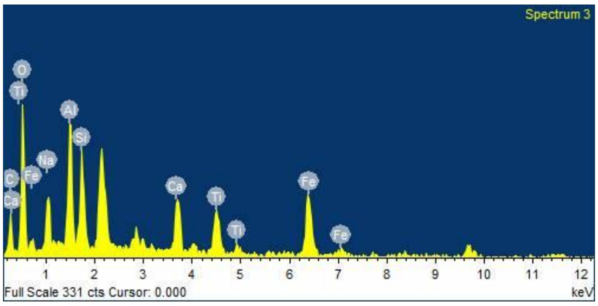
(b) R90G10



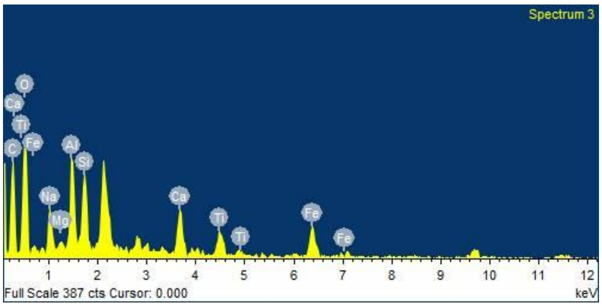
(c) R80G20



(d) R70G30



(e) R60G40



(f) R50G50

Fig: 6.17 (B) EDX Images: (a) $R_{100}G_0$, (b) $R_{90}G_{10}$, (c) $R_{80}G_{20}$, (d) $R_{70}G_0$, (e) $R_{60}G_{40}$, (f) $R_{50}G_{50}$

6.11. Summary

This study on red mud-GGBFS has shown that the unconfined compressive strength has increased with the increase in the concentration of sodium hydroxide. Strength decreases when concentrations exceed beyond 4M due to excessive concentrations of hydroxide ions. These changes have been confirmed by the microstructural analysis (XRD, FTIR &SEM).