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Properties of nano-alumina Concrete with zircon sand as fines under varied elevated temperatures

Propiedades del concreto de nano-alúmina con arena de circón como finos bajo variadas temperaturas elevadas

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Abstract
The concrete construction materials are now being judged not only from their economical characteristics but also from their serviceability. Advancements in the concrete production now also focus on improving the fire resistant behaviour of concrete. The replacement of fine aggregates is much more desirable when they possess adequate fire resistant characteristics. The present research work understands the urgent need to pay attention to the fire resistant behaviour of concrete simultaneously minimizing the use of Natural River aggregate. In addition to the fine aggregate replacement nano alumina is used as cement additive to beneficially support the concrete durability through their nano characteristics. Zircon sand is used upto 50% of the natural river sand aggregate and nano alumina is used at 2% by weight of the cement binder. This research work focuses on the utilization of zircon sand as fine aggregate to produce concrete.
Keywords: *Nano-alumina; zircon sand; elevated temperatures.*

Resumen
Los materiales de construcción de hormigón ahora se juzgan no solo por sus características económicas sino también por su capacidad de servicio. Los avances en la producción de hormigón ahora también se centran en mejorar el comportamiento resistente al fuego del hormigón. La sustitución de los áridos finos es mucho más deseable cuando estos poseen adecuadas características de resistencia al fuego. El presente trabajo de investigación comprende la urgente necesidad de prestar atención al comportamiento resistente al fuego del concreto minimizando al mismo tiempo el uso del agregado Natural River. Además del reemplazo de agregados finos, la nanoalúmina se usa como aditivo de cemento para respaldar de manera beneficiosa la durabilidad del concreto a través de sus características nanométricas. La arena de circón se usa hasta en un 50 % del agregado de arena de río natural y la nanoalúmina se usa en un 2 % en peso del aglomerante de cemento. Este trabajo de investigación se enfoca en la utilización de arena de zircón como agregado fino para producir concreto.

Palabras Claves: Nano-alúmina; arena de circón; temperaturas elevadas.

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1. Introduction

The structures when exposed to high temperatures undergo a number of physical and chemical changes which causes a loss of chemical nature leading to structural collapse (Yu et. Al., 2004). Concrete is highly resistant towards temperature and can be used as a perfect shield against high temperature (Schneider, 1988). However when the temperature is reached beyond a specific value a progressive breakdown of the chemical gel structure of concrete occur leading to discoloration and permanent deterioration (Poon et al., 2001). The phase transformation of aggregates takes place with the decomposition of carbonates present in the concrete (Khaliq and Hammad, 2015). When exposed to high temperatures a number of chemical, physical and thermal changes undergo in the concrete (Behnood and Ziari, 2008). After subjected to high temperatures the concrete undergo initial cracking due to the incompatibility of the deformations thermally caused to the ingredients of the concrete (Chen et al., 2014). The disintegration of CSH gel which the principle strength giving component gets completed around 600 – 8000C. Gels like structures are decomposed beyond 4000C. Around 6000C the de-carboxylation of $Ca(OH)_2$ occurs causing extreme porosity in the matrix. At 8000C the carbonates in the concrete gets decomposed beyond which the entire structural integrity of concrete is collapsed (Chan et al., 2000). Type of aggregates used in concrete is crucial since it plays a major role in the temperature stability of concrete (Guo et al., 2014). The interfacial transition zone is also strengthened due to the use of siliceous pozzolans that forms Ca(OH)2 increasing the denser packing microstructure (Ling et al., 2012). The interface reinforcements provided by the nano materials in concrete improved the properties of concrete at high temperatures (Morsy et al., 2012). The pore system and void system have also been formed to reduce by creating perfect bond on the aggregates with the cement paste due to nano material addition (Vera et al., 2009). The nano filling capacity of nano materials can also effectively fill the nano spaces occurring between the layers of CSH gels making them highly denser (Yu et al, 2014). Nano silica and nano alumina are the two most widely used nano material in concrete (Alireza et al., 2015). Nano SiO2 can improve the strength and stiffness of concrete by improving the CSH gel formations thereby preventing the leaching of calcium ions (Adak et al., 2014). The nano particle substitution also improved the durability of fibre reinforced concrete pavements containing nano propylene fibre (Niloofar and Kiachehr, 2013). Effect of nano alumina on the durability of fly ash containing self compacting mortar was studied by (Ehsan and Konstantinos 2016). Nano ZrO2 also showed less segregation and bleeding by acting as filler in concrete by providing resistance to the movement of waters in the fresh concrete (Nazari et al., 2010). The use of zircon sand in concrete is still in its infant stage. However the use of zircon based materials in concrete and cementitious mixtures have been widely practised by several researchers (Umarajyadav, 2017). Flexural performance and compressive strength behavior of reactive powdered concrete containing nano zirconia was studied by (Yanfeng et. Al., 2008). The results showed that the use of nano zirconia reduced the stiffness properties of reactive powdered concrete by improving their flexural toughness characteristics (Han et al., 2017). Review of literatures conducted gives a number of information that formed the background of the present research work that Nano alumina can efficiently be used as a cement additive for use in concrete and mortar preparation. The initial study (Sakthieswaran et al., 2020) on properties of fresh concrete, mechanical properties and microstructural studies using SEM and XRD and extended here along with electrical resistivity, tensile, chemical attacks, migration and FTIR.

2. Materials

The cement which is used as the main binder of this study conforms to IS 12269-1987 of OPC 53 grade Coramandel cements. The cement properties were tested as per the requirement of Indian standard 4031-1988 and Indian standard 4032-1985. Nano alumina particle size less than 25mm, spherical in shape, specific gravity of 1.22, pH of 9.4, density of 3600kg/m^3 and thermal conductivity 30W/mk Natural river sand conforming to zone II of BIS 383-1970 is used as fine aggregates in the present study.

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Zircon sand is a naturally occurring fine mineral powder which is white in nature. The chemical inertness of the zircon sand and their ability to withstand even concentrated acids makes them a material of choice for use in aggressive environments. The nominal size of the aggregate was composed of 12mm which accounts for about 60% of the aggregates and 10 mm of the remaining 40%. The physical properties conforming to IS 2380-1963 are observed. The water used in the present study is potable drinking water with the pH 7 – 8 without the presence of any organic matter as obtained from the laboratory tests. The salt content present in the water was also much lower which is permissible within IS 546-2000 specification. The commonly used superplasticizer is naphthalene based type which is CONPLAST SP 430. The properties of the superplasticizer is tabulated in (Table 1) and the properties confirmed to the requirements of IS 9103-1999 and ASTM C 494 Type - B and BS 5075 of the high range water reducing admixture.

3. Methodology

The water binder ratio was fixed at 0.43 for all the mixes. The ratio of the cement, fine aggregate and coarse aggregate were taken as 1:1:0.8:273 respectively. The superplasticizer dosage was fixed at 0.75% by the weight of the cement. The details of the mix proportion of the concrete mixes are presented in (Table 1).

Table 1. *Mix proportions of the concrete mixes*

Mix ID	Binder		Fine Aggregate		Coarse aggregate (%)	w/b ratio
	Cement %	Nano alumina %	River Sand %	Zircon sand %		
CM	100	0	100	0	100	0.43
M1	100	2	90	10	100	0.43
M2	100	2	80	20	100	0.43
M3	100	2	70	30	100	0.43
M4	100	2	60	40	100	0.43
M5	100	2	50	50	100	0.43

The concrete specimens after 28 days were taken and then heated in an electric furnace to the desired temperature. The concrete specimens were placed inside the furnace and the temperature is increased from room temperature in increments of 2000C to the temperature of 8000C. The uniform heating of the specimens were ensured through maintenance of the specimens at the target temperature inside the furnace for about 2 hours. The specimens were then removed from the furnace and maintained at laboratory to attain room temperature before the testing is carried out. The cylindrical concrete specimens of diameter 100 mm are used for the measurement of split tensile strength as per the IS code 5816 – 1999. The splitting tensile strength was carried out in a digitized compression testing machine (AIMIL – 20000 kN capacity). The splitting tensile test was conducted on concrete specimens at 4, 28, 56 and 90 days curing period. The electrical resistivity of the concrete was determined using a four point Wenner probe test method. The rapid chloride penetration test was performed as per the procedure stated in ASTM C1202-1995. The cylindrical concrete specimens of size 100 mm diameter and 80 mm thick is placed between the reservoir of RCPT setup. The concrete cubes of size 150 mm size as per the code IS 576-1959 were immersed in solutions of 5% NaCl, 5% Na_2SO_4 and 1% H_2SO_4 for observing studies on chemical attacks. In this research, the Fourier transform infrared spectroscopic test was conducted on Shimadzu IR tracer, Japan equipment. The spectral curves were obtained at a wave number 4500 cm-1 to 400 cm-1at transmission mode.

4. Result and Discussions

In previous attempt of this study, the observations are presented in (Sakthieswaran et al., 2020). The study revealed that the slump was decreased with nano alumina whereas vice versa for zircon sand. The mechanical property was evaluated as increased strength as there was sufficient CSH gel formed in the concrete. The porosity and UPV showed less performance at 8000C. These also observed in SEM, the deformation of

Hydroxides and disrupted CSH gel. The reduced intensity of CH was seen in XRD patterns. In addition to the ealier observation presented (Sakthieswaran et al, 2020), it was overhanged with some more experimental investigations followed so that to study clearly the effects of increased temperature of nan-alumina concrete made with zircon sand as partial fines.

4.1 Split Tensile Strength

The splitting tensile strength of the concrete containing different proportions of zircon sand as fine aggregates at various ages is shown in (Figure 1). From the results it can be observed that the maximum split tensile strength was achieved for the concrete mix with 30% replacement of the fine aggregate by zircon sand. It can also be observed that the split tensile strength of concrete increase with increase in the zircon sand substitution upto 30% beyond which the strength decreases. At 28 days, the splitting tensile strength at 30% replacement of fine aggregate (M3) was measured to be 36% higher than the control concrete mix (CM). The increment in the split tensile strength of concrete despite the substitution of fine aggregate by the brittle zircon sand may be justified by the contribution of nano alumina thus improved the tensile strength of the concrete specimens. The decreasing trend was observed in the concrete specimens beyond 30% zircon sand substitution and the lowest value was observed for the concrete mix containing 50% zircon sand substitution. However the splitting tensile strength of the concrete containing 50% zircon sand was higher than the control concrete. The combined effect of nano alumina and zircon sand imparted tensile characteristics to the concrete thereby presenting acceptable splitting tensile values. The formation of hydration products with relatively higher strength in the concrete mixes when compared to the control concrete mix resulted in the increment of splitting tensile strength of the concrete.

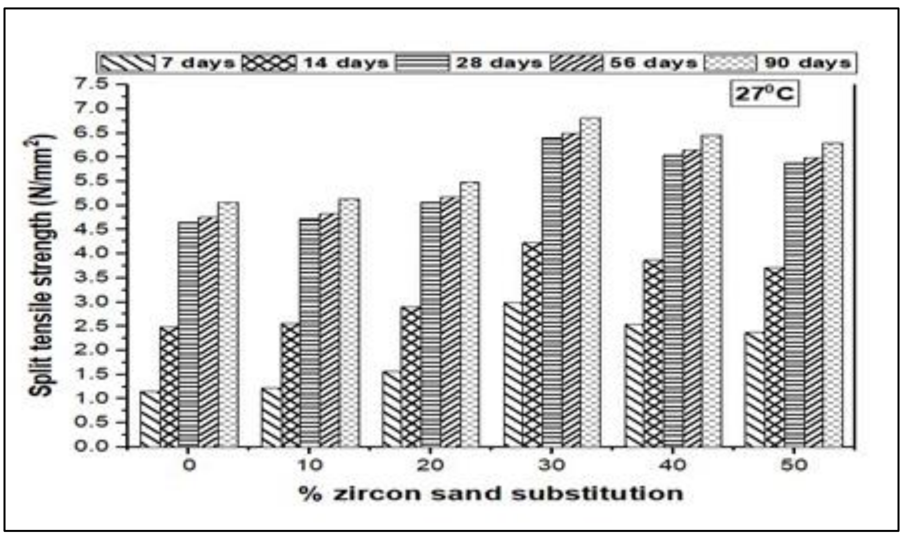

Figure 1. *Split tensile strength values of various SCGM mixes*

The splitting tensile strength of concrete after exposure to various temperatures is shown in (Figure 2). No significant improvement in the splitting tensile strength of concrete was observed with increasing zircon sand substitution at higher temperatures. However the linear trend of increase in the strength value was observed as a temperature increase upto 30% substitution ratio. The loss in the tensile strength was pronounced at higher temperatures due to the loss of chemical water present in the hydration product. The concrete mixes containing zircon sand showed minimal strength loss upto 6000C due to the formation of stable and strong hydration products. The nano alumina addition effectively formed thick hydrate gels which were stable even at 6000C. Hence the reduction in splitting tensile strength was relatively of lower magnitude when compared to the control concrete mix. The glassy zircon sand due to their high thermal stability prevented the transition of

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solid hydration particles thereby stabilizing the concrete to yield greater tensile strength value at all temperatures.

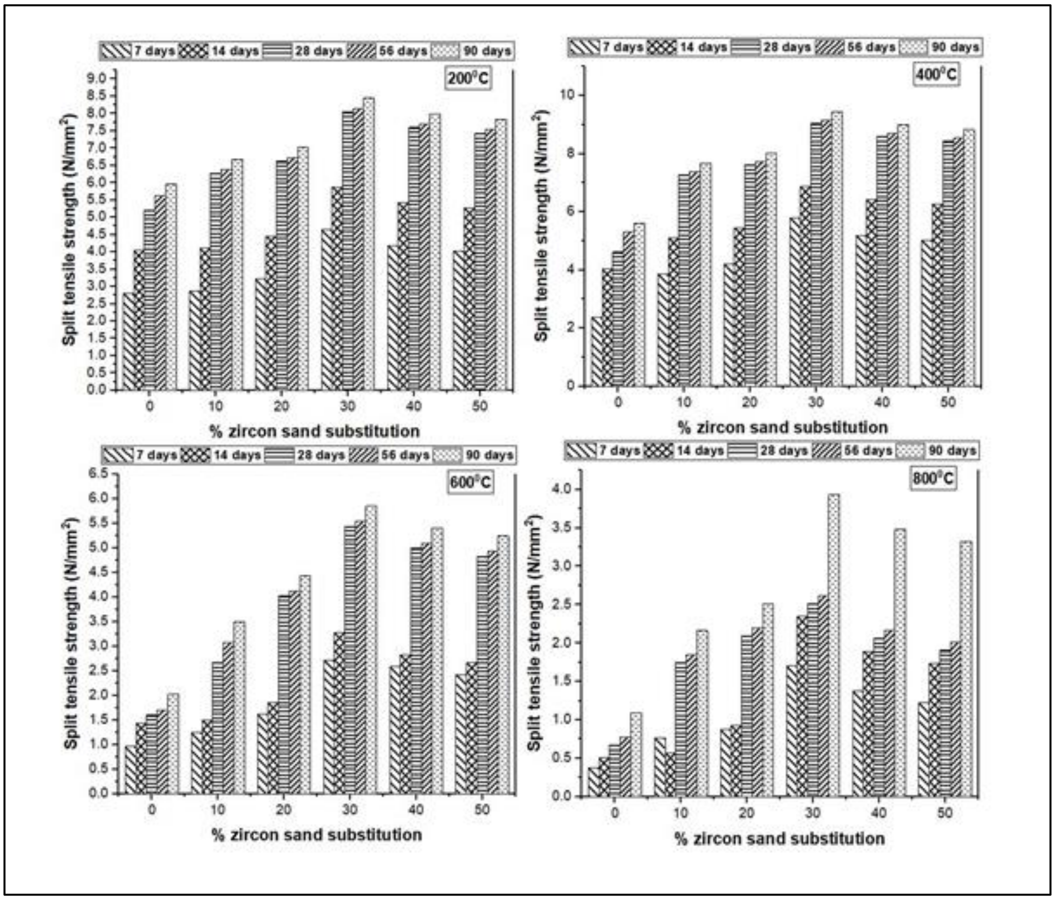

***Figure 2.** Residual split tensile strength of the concrete mixes after subjected to various temperatures*

4.2 Electrical Resistivity

The electrical resistivity is an essential test that indirectly measures the durability of concrete. The ability of concrete to resist the electric current that flows through the concrete is taken as the electrical resistivity.(Sabbag and Uyanik, 2018), The electrical resistivity is generally necessary in concretes when they are used for reinforced concrete structures. The electrical resistance measures the ability to withstand the penetration of ions which also measures the corrosion resistance of concrete (Azarsa and Gupta, 2017). The values of the electrical resistivity of the concrete mixes at normal temperatures and various curing ages are shown in (Figure 3). The results show that the electrical resistivity of concrete increased with increase in the zircon sand substitution of the nano alumina added concrete. The positive effect of nano alumina in increasing the amounts of denser and thicker CSH gels has formed barriers that prevented the ingress of electric charges. The passage of electric current mainly depends on the pore water present in concrete. The nano alumina additions have led to decrease in the quantity of free water available for conducting the electric current. Moreover the increased reaction sites of nano alumina also have led to the utilization of water for the complete hydration of CH and hence no free water can be available. The pore filling characteristics of nano alumina and zircon sand also effectively plugged the pores of concrete thereby removing the spaces through which water can reside. The chemistry of pore solution and the pore network accelerate the charge passing through concrete and in the concrete containing zircon sand and nano alumina the pore networks were completely interrupted *by the finer zircon sand and nano alumina. The electrical resistivity values indicates the high durability of zircon sand substituted nano alumina concrete in comparison to the control concrete (CM).*

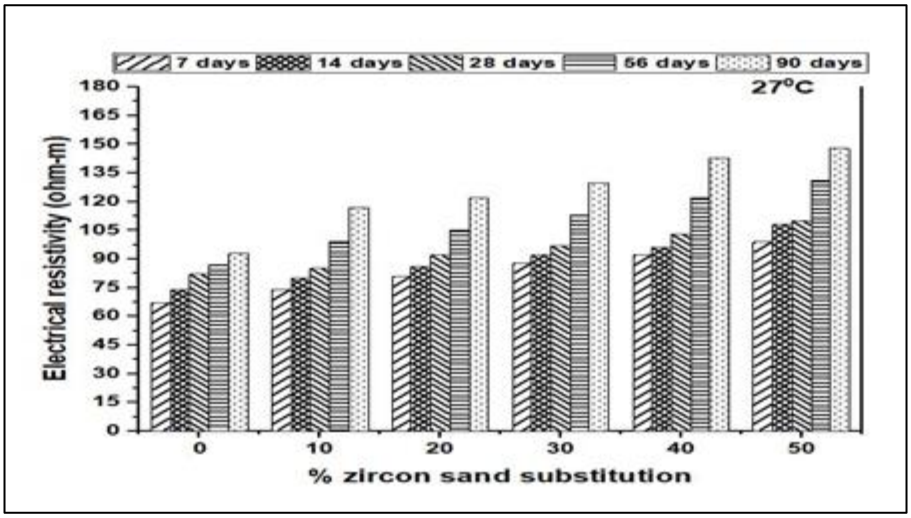

Figure 3. *Electrical resistivity values of the concrete mixes*

The electrical resistivity of the concrete after exposure to various temperatures is shown in (Figure 4). The values show that the electrical resistivity of the control concrete decreased significantly with increase in the temperature. The electrical resistivity values reached the lowest where the temperature increased beyond 6000C in the control concrete (CM). But the zircon sand substituted concrete mixes showed good resistivity values of the concrete mainly depends on the quality of CSH gels produced. The addition of nano alumina acts as thermal activator that produces additional CSH gels at 2000C. Beyond 4000C the zircon sand due to its thermal stability well functioned as inhibitor of passage of ions into the concrete by maintaining the structural stability of concrete.

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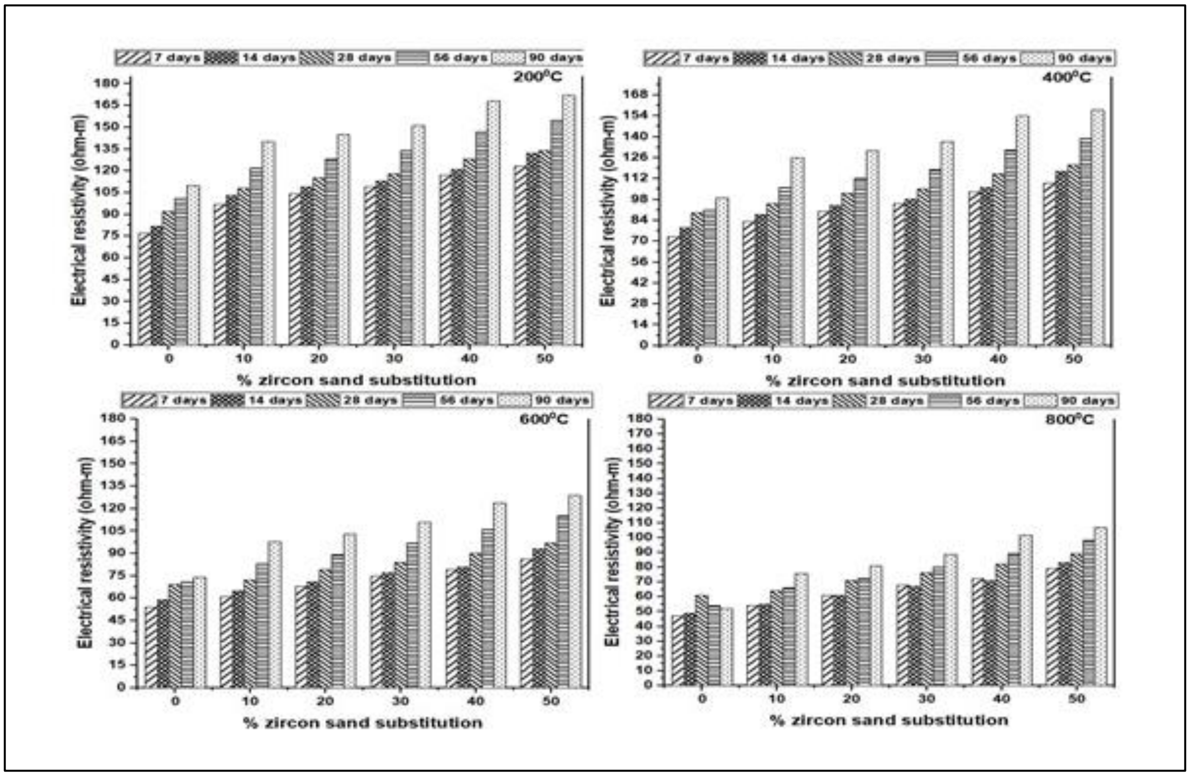

Figure 4. *Electrical resistivity values of the concrete mixes after subjected to various temperatures*

4.3 RCPT

The rapid chloride penetration test (RCPT) values of the concrete at normal temperatures and after exposure to high temperatures are shown in (Figure 5). The chloride penetration values measured as the quality of charge passed through the concrete clearly showed increased values with increasing temperature in all the concrete mixes. However the values were in decreasing order with increasing zircon sand substitution. The total charge passed through the concrete containing nano alumina and zircon sand was reduced significantly when compared to the control concrete. The amount of charge passed through the concrete is a main function of the cement paste and the aggregate due to their inert activity generally do not cause the transfer of ions. The addition of nano alumina in concrete effectively formed the hydration paste utilizing free waters available to form CSH gels. Loss in the electrolytic solution inside the concrete significantly contributed to the blockage of chloride ions into the concrete. The ions due to the presence of only solid regions in the concrete also reduced the charge passing through the concrete. The presence of pore solution in any form affects the strength of concrete greatly by increasing their conductivity. The presence of ions in the pore solution also supports the ion migration into the concrete. Na+ and OH- of the electrolytic solution of RCPT make the ions to actively pass through the concrete. The OH- ions present in the waters in the pores of concrete induces the metal ions to penetrate with concrete. The OH- ions also acts as an electrolyte that supports the movement of chloride ions in concrete. The positive metal ions when present in the concrete also stimulates the movement of chloride ions when present in the concrete also stimulates the movement of chloride ions into the concrete which leads to increased charge passing. The modification of pore structure of concrete can be the only be obtained due to the addition of admixtures in concrete. The zircon sand substitution functioned as filling agents by decreasing the chloride penetration. The nano alumina inclusion also effectively held the pore waters together utilizing them for hydration reaction. The compact nature of the concrete can also be visualized as the reason for the reduction in the charge passed through the concrete. The separation of the ingredients in the concrete was prevented due to the usage of nano alumina and the zircon sand were well inhibited in the cement matrix *avoiding the formation of micro voids. The angular surface texture of the zircon sand also strengthened the ITZ of the concrete that reduced the travel of ions in the concrete.*

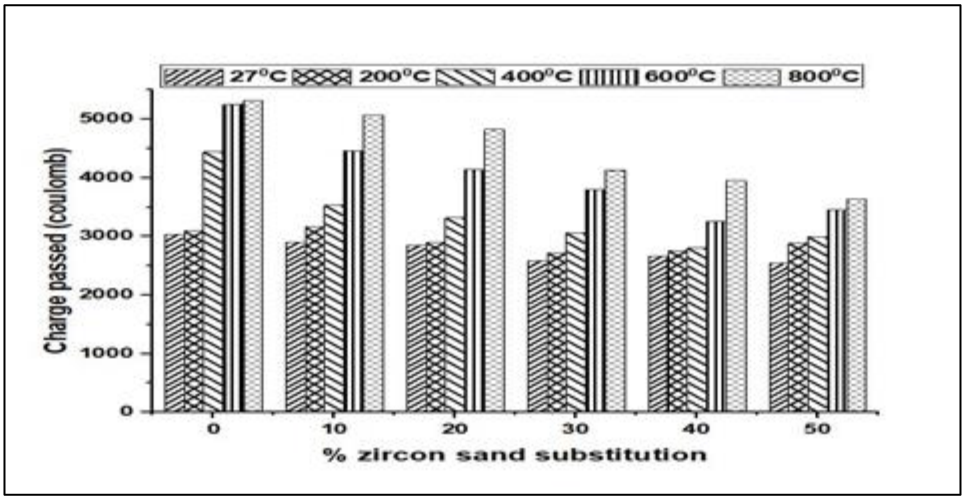

Figure 5. *Charge passed through the concrete mixes at normal temperature and after subjected to various temperatures*

4.4 Acid Attack

The percentage loss in weight and strength of the concrete mixes after exposure to the attack of acid is shown in (Figure 6). The calcium hydroxide present in the cement formed during the hydration reaction can react with the chlorides present in the hydrochloric acid to form calcium chloride which deteriorates the strength of concrete. The formation of calcium chloride salts can cause migration through the concrete structure through the waters present in acid solution. The weight loss occurs due to the leaching of the salts formed during the reaction with the acids. The hydrogen ions present in acid can also etch the surface of concrete causing weight loss. The acids due to their high reactivity can also create pores inside the concrete through which the ion can easily pass through. The weight loss of the concrete mixes clearly showed reduced percentage of weight loss with increasing zircon sand substitution in comparison to the control concrete mix (CM). The minimal porosity of the concrete which prevented the ingress of –OH- ions reduced the loss of weight caused due to acid attack. Moreover the zircon sand is highly inert in nature and shows great stability to aggressive chemicals. The nano alumina also formed dense layers of CSH gels that do not allow the hydrogen ions to pass through. The surface of concrete is also highly resistant to acid due to zircon sand substitution and the weight loss was a result of the surface reaction with the acids. The strength loss of the concrete after exposure to acids was also much lower at all temperatures. The nano alumina and zircon sand effectively reduced the formation of salts which is the reason for the minimal strength loss even at high temperatures. The prevention of material separation by the nano alumina substitution that created additional CSH gels thereby preventing the formation of micro cracks also contributed to the minimal strength loss after subjected to the attack of acids.

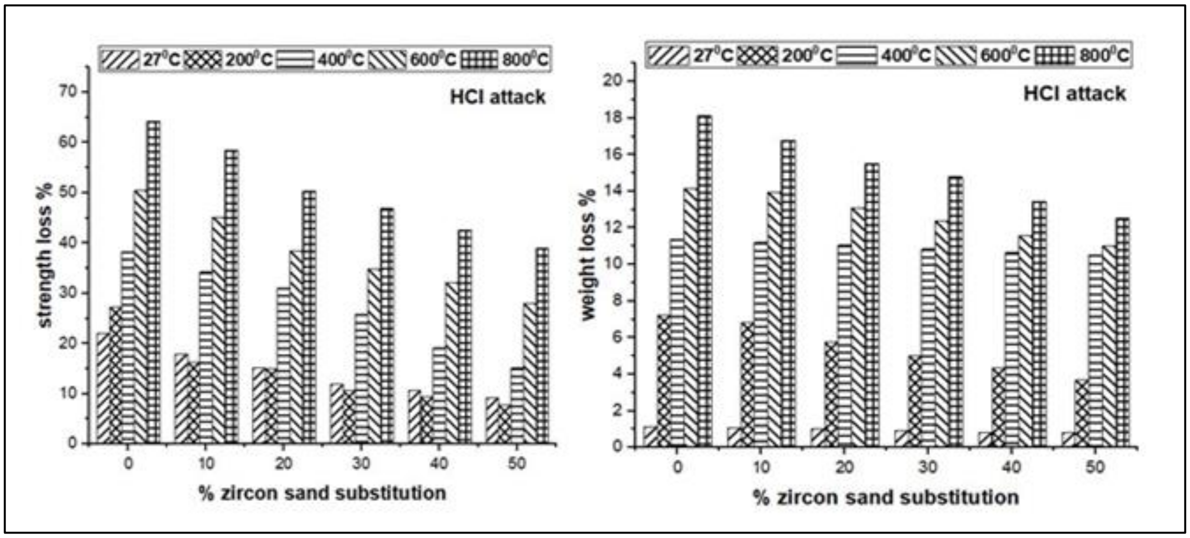

Figure 6. *Strength and weight loss of the concrete mixes at normal temperature and after subjected to various temperatures due to HCL*

4.5 Salt Attack

The concrete structures suffer from a serious deterioration when they are structured near the marine regions. The attack of NaCl is so severe leading to severe disintegration and corrosion problems when it is a reinforced concrete structure. The loss in weight of the concrete mixes when subjected to the attack of NaCl before and after exposure to the elevated temperatures is shown in figure. The weight loss of the concrete mixes decreased with increasing zircons sand substitution. The control concrete showed poor stability towards the attack of NaCl. The chloride ions react with the calcium ions to form calcium chloride that is easily leachable. The concrete porosity reduction minimized the amounts of chlorides that can be passed through the concrete and hence led to reduced weight loss values. The weight loss of the concrete mix (CM) containing no zircon sand and nano alumina was measured to be about 1% due to NaCl attack and the corresponding strength loss was measured to be 16% at normal temperature. The strength loss and weight loss of the concrete mix containing 50% zircon sand was measured to be about 4% and 0.5% respectively at normal temperature. The results (Figure 7) thus infer the stability of concrete towards the NaCl attack and hence the concrete containing zircon sand and nano alumina can efficiently be used for the construction of structures that can be built near the sea shore regions. The concrete can thus serve the purpose of marine structures and structures prone to salt water intrusion.

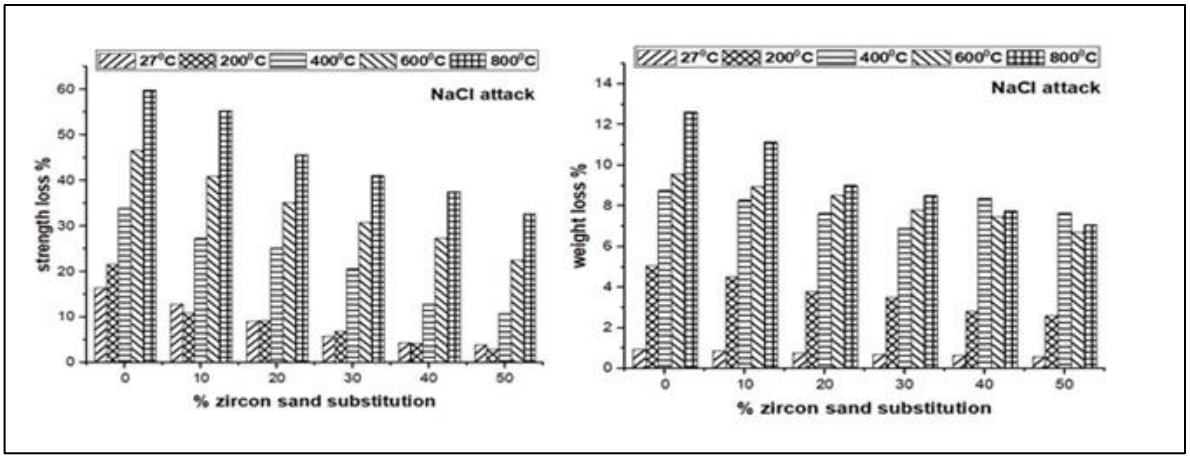

Figure 7. *Strength and weight loss of the concrete mixes at normal temperature and after subjected to various temperatures due to NaCl*

4.6 Sulphate Attack

The concrete mixes after exposed to the attack of sulphates and the corresponding measures of loss in weight and strength of the concretes is shown in (Figure 8). The strength loss of the control concrete mix was measured to be 15% and the corresponding loss in weight was measured to be 3% at normal temperatures. The zircon sand substituted concrete mixes showed greater strength and stability to the sulphate attack. Generally the nano alumina has the potentials to react with alumina to form ettringite. But in the present study the formation of ettringite was arrested due to the zircon sand which did not allow the ingress of sulphate ions. Moreover the nano alumina was well bound to the cement paste minimizing the amounts of free alumina available to react with the sulphates. Hence the formation of ettringite was reduced thereby disruption of matrix is presented. The control concrete mix showed higher strength loss and weight loss due to ettringite formation which created expansion of the concrete leading to failure of the cement matrix.

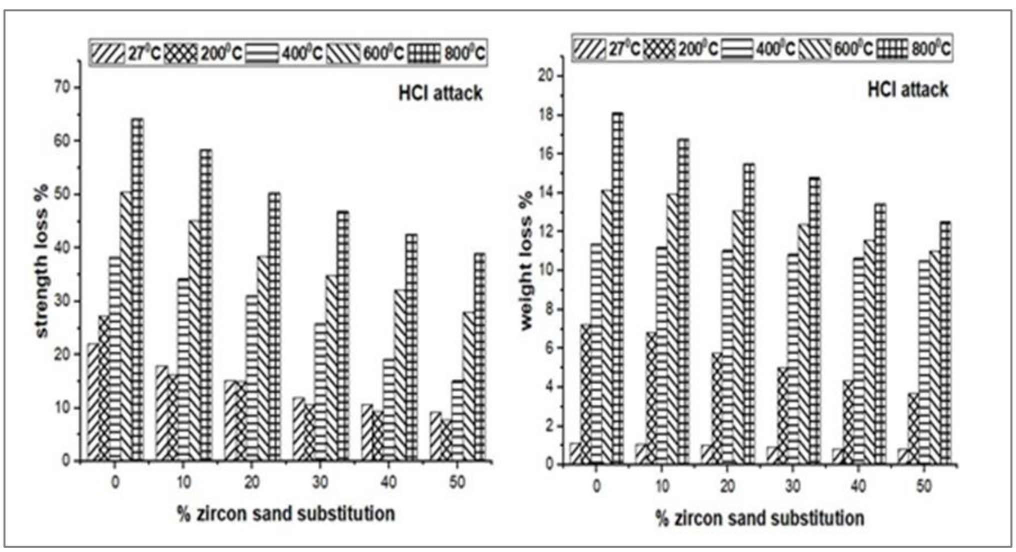

Figure 8. *Strength and Weight loss (%) of the concrete mixes at normal temperature and after subjected to various temperatures*

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4.7 FTIR

The FTIR spectroscopic analysis conducted on the concrete after subjected to 28 days curing is shown in (Figure 9). The broad spectral bond around 3600-3400 cm-1 clearly shows the water –OH bond which occurs in the portlandite ($Ca(OH)_2$). It can be clearly seen that the portlandite phase was broad and clear in the control concrete when compared to the concretes containing zircon sand as fine aggregate. This shows the increased amounts of $Ca(OH)_2$ present in the control concrete than the other concrete mixes. The reduced amounts of $Ca(OH)_2$ also signifies that the nano alumina has significantly contributed to the transformation of $Ca(OH)_2$ forming secondary hydration products. The presence of hydrated silicates of calcium is evident from the bands occurring around 950-980 cm^{-1} which is observed in all the concrete mixes containing zircon sand and nano alumina. The presence of high transmission values with high intensity CSH peaks indicate the complete hydration of C_3S and C_2S phases in the cement forming thick CSH gels. The stretching bond occurring around 500 cm^{-1} also corresponds to the anhydrous calcium silicates present in the concrete. The presence of carbonates is identified through the asymmetrical stretching vibration around 1420 cm^{-1} and 880 cm^{-1}. The carbonate peaks were found to decrease with increasing zircon sand substitution indicating the carbonation resistance of the produced concrete. The evidences of occurrence of high amounts of carbonates are also visible in the control concrete. The H-OH bonding vibration at around 1600 cm^{-1} and presence of molecular water around 3400 cm^{-1} is also seen in all the spectral curves of concrete indicating that hydration of cement has taken place. The stabilization of the hydration products is also identified through the shifting of the SiO peaks from lower wave number to higher wave number at 980/cm. The presence of strong CSH bond was observed around 970 cm^{-1} indicating the strong nature of calcium silicate phases formed in the concrete containing nano alumina and zircon sand substitution. The FTIR spectra of the concrete mixes after exposure to temperatures are shown in (Figure 9). The decreasing broad vibrations of the water molecules around 3400 cm^{-1} were found with increasing temperatures. The spectra diminished with increasing temperatures and was almost absent when the temperature increased beyond 400^0C indicating the decomposition of portlandite. Less intense band around 1600 cm^{-1} also indicates the decomposition of $Ca(OH)_2$. Only crystalline phases of silica were found in the FTIR spectra around 980 cm^{-1} and 780 cm^{-1} in all the concrete mixes after exposure to 600^0C. The spectra thus clearly show the presence of highly stable CSH products in the concrete. The presence of silica also indicates the presence of thermally stable fine aggregates in the concrete. The peak around 980 cm^{-1} which also indicates the CSH gel formations was found to be stable upto 600^0C which at 800^0C showed little disintegration. The modification of the hydration products with increasing temperature causes increase or decreases in the strength of concrete. The decrement of the calcium silicates in the concrete was much lower in the concretes containing zircon sand in comparison to the control concrete as evident through FTIR spectral analysis which supports the results obtained from the mechanical and durability experiments.

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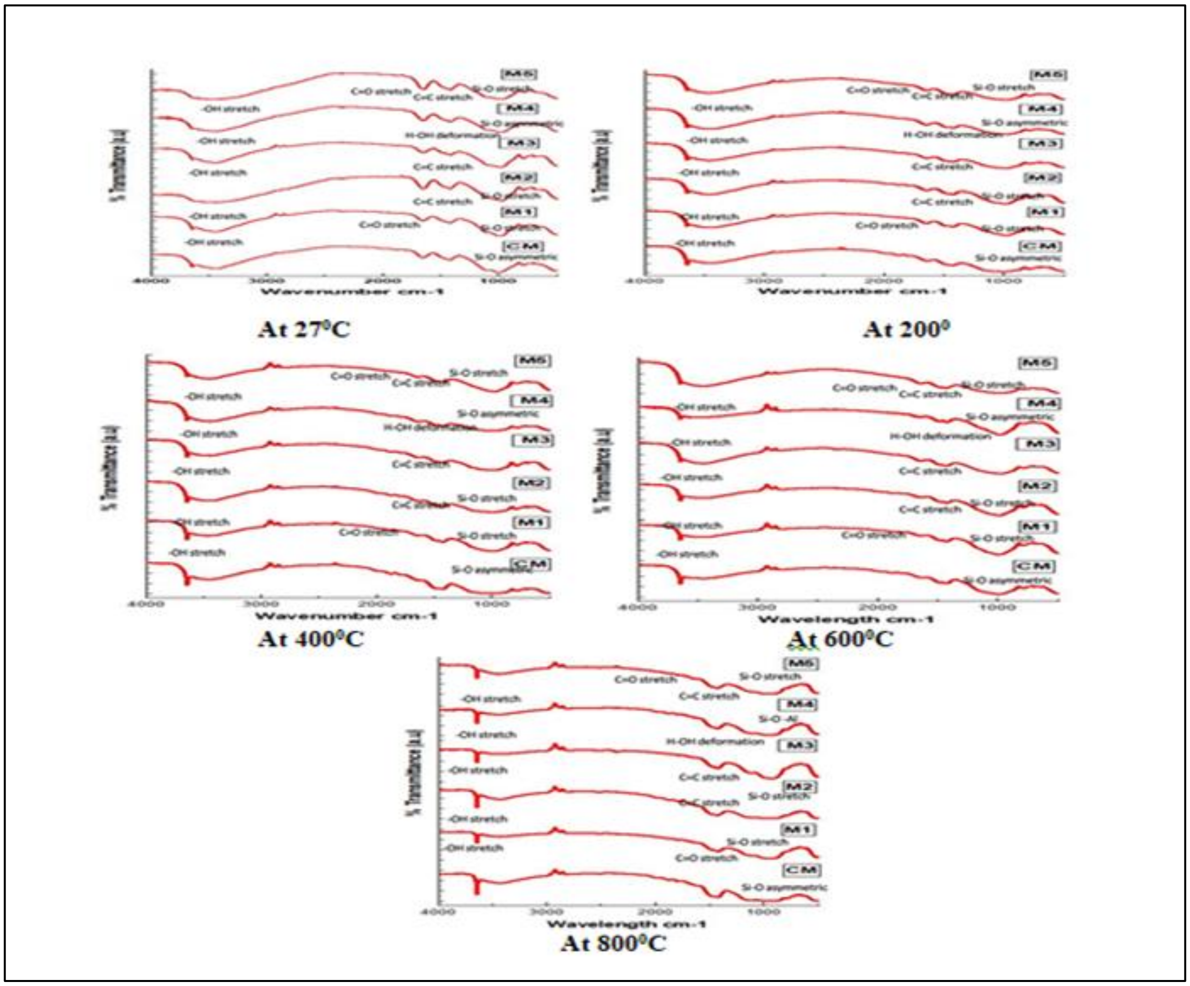

Figure 9. *FTIR spectra of the control concrete and zircon sand substituted concrete mixes at Various Temperatures*

5. Conclusion

Prior concluding the technical summary, the comment for emerging graduates is here to know some of the observation facts of doses of different materials to research on less impact to environment against construction industry is highly the future scope recommended. It is inferred along with previous study (Sakthieswaran et al., 2020), the combined addition of nano alumina with zircon sand proved to be effective in improving the workability of concrete meeting the requirements of concrete. The mechanical strength tests were conducted on concrete at 7, 14, 18, 56 and 90 days. The present stage of research concludes that the splitting tensile strength of concrete also followed the same patterns of increase similar to flexural strength and the values increased with increase in the zircon sand substitution. A saturation point was reached at 30% substitution of nano alumina beyond which no increment in the tensile strength was observed. Contrarily the split tensile strength increased at all temperatures indicating the contribution of zircon sand in increasing tensile strength at all temperatures. The increment in the split tensile strength may be attributed by the addition of nano alumina and zircon sand substitution that increase the strength of interfacial transition zone leading to reduced bleeding and shrinkage. The specimens for the later age testing were caused under water for 28 days after which they were taken out and maintained in open air until the testing days is reached. The durability properties were tested on concrete cubes subjected to 28 days curing. The rapid chloride ion penetration of the *concrete containing zircon sand and nano alumina showed lower values when compared to the control concrete. The chloride ion penetration was also much lower for the concrete at all temperatures due to the increased pore structure refinement due to nano alumina addition. The low transport properties of the concrete aided by the nano alumina addition have contributed to the reduced chloride ion penetration in the concrete even at high temperatures. The temperature increase decreased the electrical resistivity of concrete but was reduced marginally due to the micro pore filling characteristics of nano alumina and thermal stability of zircon sand that made the pores discontinuous. The chloride penetration was much reduced in the concrete due to the nano alumina that caused less number of pores interconnected to each other thereby reducing the void spaces of concrete. The increased compactness of the concrete and dense hydration production has made the concrete impermeable and resistant towards the ingress of harmful agents. The ions thus fail to pass through the dense microstructure of concrete resulting in durability enhancement. The efficiency of nano alumina and zircon sand in improving the denseness of the concrete was analyzed through microstructure studies. The FTIR spectral curves of the concrete containing zircon sand and nano alumina also confirmed the presence of well-developed hydration products. The presence of the bands of silicate at high temperature indicates the high thermal stability of the hydration products formed in the concrete. The maintenance of the chemical structure of concrete is also visible at high temperatures due to the effect of zircon sand and nano alumina. Here it is concluded that the use of zircon sand as partial substitute for fine aggregate and nano alumina at 2% as cement additive positively influenced the mechanical strength and durability properties of concrete at normal and elevated temperatures.*

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