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ENGLISH VERSION..........

Utilisation of sea sand as partial replacement of fines in resin bonded cement concrete

Utilización de arena marina como reemplazo parcial de finos en concreto de cemento adherido con resina

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Abstract

The usage of aggregates has caused serious ecological problems leading to the requirement of an alternative material to meet the demand. The alternative construction material for the upcoming graduates thus chosen for replacing cement and aggregates should not only meet the design and strength requirements but also the ecological criteria. The present research work tries to improve the service life of sea sand concrete by using them in combination with epoxy resin. The scope of the work revolves around the extended to earlier assessment of the properties of concrete manufactured using sea sand as replacement for natural river sand upto 50% and 12% epoxy resin as partial substitute for cement.

Keywords: *Sea Sand; Epoxy; M30grade; ambient curing* |

Resumen

El uso de áridos ha provocado serios problemas ecológicos lo que impulsa a buscar materiales alternativos para cubrir su demanda. Los materiales constructivos alternativos para las futuras granulometrías necesarias para sustituir el cemento y los áridos no solo deben cumplir con los requisitos de diseño y resistencia sino también con los criterios ecológicos. Esta investigación buscar mejorar la vida útil del hormigón preparado con arena de mar combinada con resina epóxica. El alcance del trabajo gira en torno a una evaluación ampliada de las propiedades del hormigón preparado con hasta un 50% de arena de mar en reemplazo de la arena de río y un 12% de resina epóxica como sustituto parcial del cemento.

Palabras clave: Arena de mar, epóxico; granulometría M30; ambiente de curado

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1. Introduction

The behavior of concrete with respect to long-term drying shrinkage, creep, fatigue, morphology of gel structure, bond, fracture mechanism and polymer modified concrete, fibrous concrete are some of the areas of active research in order to have a deeper behavior of these materials (Hashemi et al., 2018). In India the annual production of cement is about 212.5 million tons in the financial year 2011 (Harder and Joe, 2012). Mining of sand from their natural environment has also caused serious impacts and damages on the ecology which is irreparable (Jafari et al., 2018). At present the global production of cement has been reported to be about 4billion tonnes (Naqi and Jeong, 2019). The usage of industrial wastes and by-products has also been found to increase the strength and stability of concrete to great extent. Some of the commonly used fine aggregate replacements include silica fume (Sasanipour et al., 2019), slag (Singh et al., 2015), fly ash and ferrochrome ash (Mohanty et al., 2019). Reducing size of sea sand aggregates generally can produce high strength polymer concrete by acting as fillers (Fliert, 1968). The contaminants in the form of organic matter may also be present in the river sand. The use of appropriate ingredients in polymer concrete can result in high strength concretes which are about 4 to 5 times greater than the normal concrete (Reis, 2010). Several structural members that require high durability are produced using polymer concrete (Ferdous et al., 2020). The invention of new technologies has also lowered the cost of sea sand extraction. It has been estimated that the cost of sea sand come only to about half of the cost the river sand (Sonak et al., 2006). Dredged marine Sands (DMS) are now being commonly used as a construction material (Wang, 2009). There are several issues arising globally due to over consumption of sea sands for several other applications (Limeira et al., 2011). (Dias et al., 2008) showed that dredged sands obtained from offshore can effectively be used for reinforced concrete constructions. The disability of concrete is highly affected due to the chloride present in sea sand thus making it unsuitable for reinforced concrete structures. Chloride induced corrosion of concrete is the most common damage that can occur to the concrete. Apart from the chloride present in sea sand, chlorides also get added to the concrete through admixtures, cement and water (Mahasenan et al., 2003). According to (Neville, 1995), the sea sand when subjected to repeated washing is devoid of harmful salts and hence can be used as potential construction material. So that corrosion can set up in concrete is about 0.1% by the total weight of the binds in a concrete containing various types of binds (Oh et al., 2003). (Dias et al., 2008) advocated the permissible limit for chloride in concrete to 0.3% by weights of cement considering the previously established works. Research carried out by (Chandrakeerthy, 1994) has established that the usage of beach sand in concrete does not affect the strength and absorption characteristics of concrete. Some researchers have also tried to characterize the difference between natural aggregate used in concrete and the marine dredged sea sand (Chapman, 1968). The effect of using fillers on the properties of polymer concrete was performed by (Arda Küçük et al., 2019). The results showed that doping of polymers improve the thermal, electrical and mechanical properties of concrete. Polymer concretes, in recent years is produced using polymers, micro materials and nano additives. Polymeric latex has also been used to produce 3D printed concretes modified using polymers (Moodi et al., 2018). This research work is thus aimed to examine the nature of polymer concrete containing epoxy resin at weight percentage of 12% (by weight of binder) and sea sand as micro-filler. The combined use of polymers and fibers was studied experimentally on fresh and hardened properties earlier (Sakthieswaran et al., 2019). However, In this work, it is necessary and therefore extended to describe briefly the separate effect of polymers and fibers in concrete.

2. Materials

The cement used for the production of concrete mixes is Ordinary Portland cement of grade 53. The chemical composition of the oxides were within the limits prescribed by Indian standard 12269-1987 The epoxy resin used in the present study was obtained from the ASTRAA chemicals, Tamilnadu, India. The epoxy resin is generally a two part polymer based mixture containing epoxy resin (Epichlorohydrin based resin) and a hardener (Bisphenol A based). The mixing ratio of the hardener and epoxy resins was at 1:1 ratio by weight. The fine aggregate used in the study included river sand conforming to zone II grading as per the Indian Standard BIS: 383 1970. Locally available natural river sand is used as fine aggregate in this study. The value of specific surface area is found to be 11.89. Sea sand has been obtained from the coastal areas of Tuticorin, Tamilnadu. The sea sand of properties rounded particle with fineness modulus 1.98 and specific gravity 2.69 was tested as per Indian standard IS-2386:1997 and the specifications were further compared to the guidelines of IS-383:1970. The properties of 20mm coarse aggregate conform to standard IS 383:1970 having fineness modulus 7.13 and specific gravity 2.62. In this study, potable water free from oil, acid and other organic impurities is used. Superplasticizer disperses the concrete ingredients making them highly workable. The commercially available Viscocrete, SIKA product is used as a water reducing agent of dosage 1-2% of weight of cement in the present study.

3. Methodology

The mix design proportions and the weight proportions of the epoxy-sea sand concrete for 1 m3 of concrete is shown in (Table 1) and (Table 2).

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***Table 1**. Mix proportion of the M30 grade control concrete*

Water	Cement	FA	CA
158 kg/m^3	376 kg/m^3	741 kg/m^3	1228 kg/m^3
0.42	**1**	**1.97**	**3.26**

***Table 2.** Mix proportion*

Mix ID	Binder		Fine Aggregate	
	Cement %	Epoxy resin %	River Sand %	Sea sand %
CM	100	0	100	0
M1	90	12	95	5
M2	90	12	90	10
M3	90	12	85	15
M4	90	12	80	20
M5	90	12	75	25
M6	90	12	70	30
M7	90	12	65	35
M8	90	12	60	40
M9	90	12	55	45
M10	90	12	50	50

Tensile strength of the hardened concrete is tested conforming to IS 516-1950 and SP23-1982. The concrete cylinder specimen dimension (IS 10086-1982) of 150 mm diameter and 300 mm height is used for this study. The split tensile strength of the concrete is given by, Split Tensile Strength =2P/(π x l x d), Where,P – Max. applied load; l – Length of cylindrical specimen; d – Diameter of the cylindrical specimen. The flexural toughness test is done as per the procedure stated in ASTM C 1018. The flexural toughness test is carried out on concrete beams of size 150 mm x 150 mm dimension and 600 mm length after curing for 28 days. The impact test was conducted on concrete discs of 152 mm diameter and 62.5 mm thickness as per the procedure recommended by ACI committee 544. The open porosity of the concrete mixes were determined on concrete cubes of size 100 mm x 100 mm x 100 mm after 28 days curing period. The attainment of porosity was done as per the procedure stated in ASTM C 642 and the porosity obtained is termed as water porosity of hardened concrete using saturation technique. Porosity (%) $\frac{W2-W1}{W2-W3}$ X 100, Where, W1= weight of oven dried specimen; W2= weight of saturated specimen; W3= weight of specimen in submerged condition. The total charge that is passed through the concrete is measured by using Rapid Chloride Permeability Test. The electrical conductance of the concrete is then calculated using the relation, $Q = 900 (I_0 + 2I_{30} + 2I_{60} + 2I_{90} + 2I_{300} + 2I_{330} + 2I_{360})$, where, Q = Charge passed in Coulombs, I_0 = Current immediately after voltage is applied in amperes, I_t = Current at t minutes after voltage is applied in amperes. The bulk diffusion test is performed according to the procedure stated in ASTM C 1556. The diffusion coefficient is calculated using the penetration depth values using the relation, $X_D = 4\sqrt{(Dt)}$, where, X_D = depth of chloride penetration (m), D= diffusion coefficient (m^2/s), t= duration of exposure at 90 days (sec). The concrete cubes were immersed completely for a period of 28 days and fresh sulphuric acid solution was replaced every two days. The losses in weight of the cubes were measured after which the cubes were tested for their compressive strength values conforming to IS 516-1999. The setup is checked for the immersive clearance and also for its acidic nature by titrating with alkaline solution. The same setup is conducted for the investigation on hydrochloric acid and sulphuric acid. The salt attack test on concrete was done as per the procedure stated by (Bassuoni et al., 2016). The concrete cubes of size 150 mm were cast, cured and immersed in solution prepared by adding 5% sodium chloride salts in 50 litres of distilled water for 28 days. The difference in weights of different concrete cubes was recorded and the percentage loss in weights is calculated. The compressive strength tests were then conducted on the immersed concrete cubes from which the loss in the strength values is calculated. Similarly, the sulphate resistance of the concrete cubes were determined by immersing them in 5% concentration of magnesium sulphate solution for 28 days. The X-Ray Diffractometer tests were done using XPert Pro

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PANalytical diffractometer in Manomaniam Sundaranar University, Tamilnadu and the patterns were recorded at 2Ɵ angles ranging at an angle of 10° to 70°.

4. Result and Discussions

The investigation initiated earlier presented the output of properties of concrete to study the feasilble use of materials presented (Sakthieswaran et al., 2019) presented that the viscous effect caused by epoxy resin reduced the segregation of concrete and hence workability was reduced whereas the sea sand aggregate substitution improved the slump value by improving the flowability of concrete through the surface properties. The compressive strength was slightly increased due to the addition of sea sand in epoxy concrete. The usage of sea sand in epoxy concrete showed an increase in compressive strength of about 17% and 20% at 25% substitution ratio for ambient curing and water curing respectively. The flexural strength was increased for all the concrete mixes increased when epoxy resin and sea sand is used in concrete. The epoxy resin due to their high flexibility enhanced the flexural strength of concrete. The flexural strength of all the epoxy sea sand concrete mixes depends only on the epoxy polymer and proportion of sea sand and showed that the treatment of sea sand has no effect on the flexural strength. the increased substitution of the fine aggregate by sea sand improved the water absorption of concrete. With the keynotes obtained in (Sakthieswaran et al., 2019), the feasibility of concrete is extended here with influence on energy absorption, attack to sulphate, aggressive salt and acids and reported below.

4.1. Split Tensile Strength

The results obtained from the splitting tensile strength test shown in (Figure 1) highlights that the unmodified plain concrete (CM) exhibited lesser split tensile strength than the epoxy- sea sand modified concrete mixes even though the epoxy composition of the binder remain constant. Thus the measured increase of split tensile strength may be explained by the intrinsic reinforcing ability of the concrete caused due to the substitution of epoxy resin. However the sea sand substitution increases the split tensile strength of concrete only up to a certain threshold. The magnitude of increase the split tensile strength in concrete mainly depends on the type of aggregate and quality of the cement matrix. The substitution of fine aggregate beyond the threshold level always causes an adverse effect on split tensile strength. In all the mixes analysed here the intrinsic increase in split tensile strength was observed with respect to the unmodified concrete. In the M10 concrete mixture which contained 50% sea sand aggregates showed only a slight improvement in the split tensile strength was observed in comparison to the other mixture. This can be due to the heterogeneity in the concrete mix that led to the insufficient compaction with increase in voids. Moreover the increase in split tensile strength showed monotonic relationship and shows that the addition of sea sand contributes strength to the positive effect of the split tensile strength of the matrix.

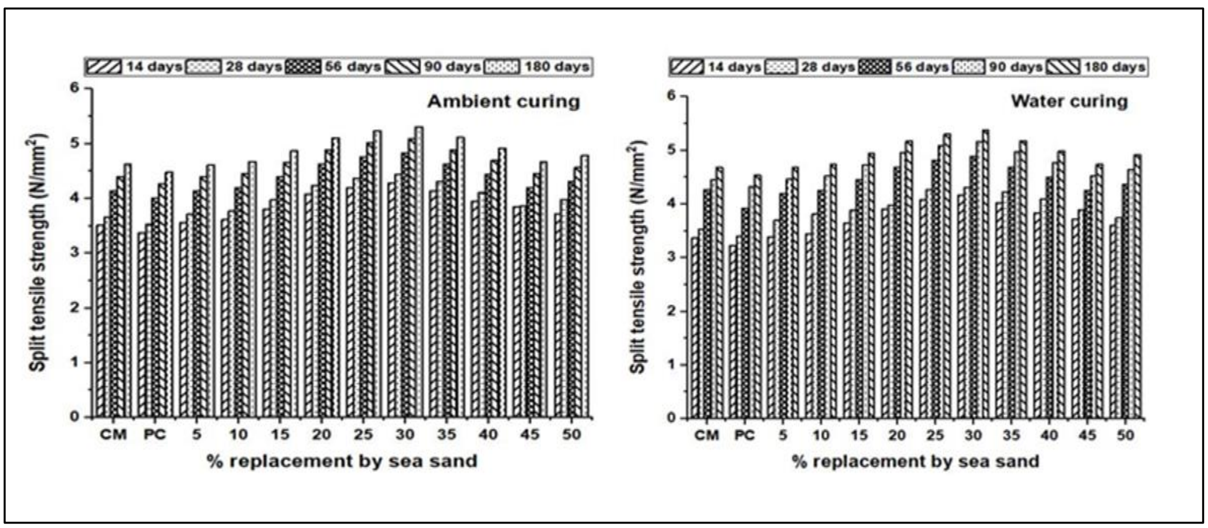

Figure 1. *Split tensile strength of epoxy concrete in ambient and water curing*

4.2. Flexural Toughness

The toughness is essentially a measure of the flexural property of concrete to withstand deflection and loading. The performance of the concrete to resist bending and deformation is essential property that must be assessed before the durability is examined. It can be seen that the flexural strength of the concrete mixes increased for all the epoxy sea sand concrete mixes containing sea sand as fine aggregate and subjected to water curing. From (Figure 2), the toughness value was found to be highest for the water cured concrete mix which contained 25% sea sand as fine aggregate and the value was found to be 20.44% and 19.89% higher than the ambient and water cured control mix. However the toughness value of the ambient cured concrete mixes was also increased for all the concrete mixes compared to the ambient cured normal concrete mix. This improvement in the toughness of concrete attributes to the epoxy resin that functional as adhesive and minimized the discontinuity in the matrix. The difference in the flexural toughness of the ambient cured and *water cured epoxy concrete mixes containing sea sand was almost negligible which shows that the curing method has no significant influence on increasing the flexural strength of the polymer concrete. The load carrying capacity of the polymer concrete beams were also found to be non –linear and intersecting at some places due to the higher percentage replacement of fine aggregate using sea sand. A linear improvement in the flexural strength of the concrete was found to occur only when the percentage replacement of fine aggregate was upto20%. This disruption in the flexural toughness of the concrete was mainly due to the sea sand substitution in the concrete rather than the epoxy substitution. The fines content of sea sand is little higher than the river sand (Cui et al., 2014) and the substitution as fine aggregate at higher levels creates poor bonding between the cement matrix and the aggregate phase.*

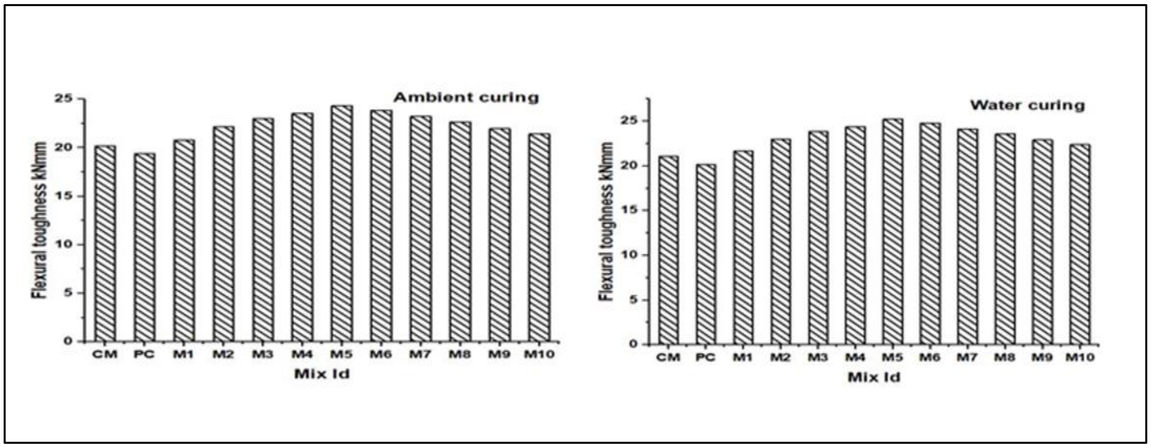

Figure 2. *Flexural toughness of epoxy concrete under ambient and water curing*

4.3. Impact Strength

The impact strength of the polymer concrete containing sea sand aggregates is shown in (Figure 3). It can be clearly seen that the impact strength of the concrete increased with increase in the fine aggregate replacement by sea sand aggregate whereas the polymer concrete mix (PC) showed a lower impact strength value compared to the normal concrete mix. The reduction in the impact strength of the concrete mix containing epoxy resin (PC) was found to be 6.15% and 5.73% lower than control mix (CM) under ambient and water curing conditions respectively. This shows that the epoxy resin has no role to play on the improvement of the impact strength of concrete. But when sea sand aggregates were used the impact strength of concrete was found to be slightly higher than the control concrete (CM). Thus it can be obtained that the combined effect of epoxy resin and sea sand aggregates on increasing the energy required for inducing cracks in the concrete. The highest impact strength was observed for the concrete mix containing 20% sea sand aggregate and the measured increment in the value was about 70.77% and 64.45% higher than the control concrete mix under ambient and water curing conditions respectively. This shows that sea sand has greater influence on improving the impact strength of concrete.

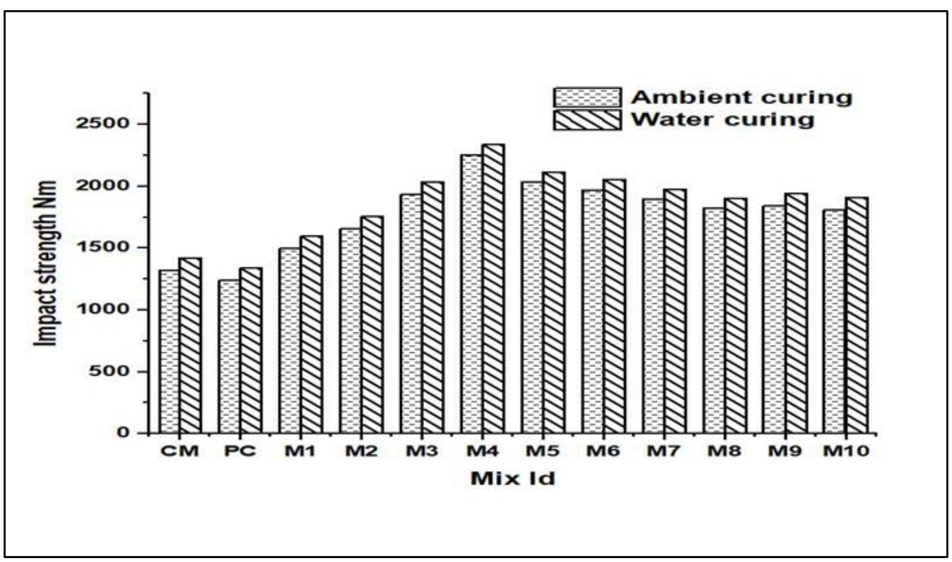

Figure 3. *Impact strength of epoxy concrete under various curing conditions*

4.4. Water Porosity

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The porosity of the epoxy polymer concrete mixes measures on a hydrostatic scale is shown in (Figure 4). This type of porosity measured accounts only for the macro pores and generally micro pores have negligible role in this type of porosity measurement. The porosity results were in line with water absorption results and followed the same trends of increase or decrease. The lowest porosity value was obtained for the mix M4 which is measured to be about 29% and 32% lower than the control concrete under ambient and water curing conditions respectively. The improvement in the pore structure of the concrete mixes due to increment in sea sand substitution clearly signifies the pore filling capacity of the sea sand. However the at higher magnitude levels of substitution of sea sand aggregates in the concrete created water channels leading to the excess amount of free water spaces that has led to the increment in the pores when evaporated. These pores however were filled partially by the epoxy resin and angular river aggregates. The angularity of the river aggregates bonds well to the cement paste mixed with epoxy resin and the sea sand aggregates reduced the micro pores present in concrete due to their higher fineness and pore blocking property. The pore structure refinement is also an inherent property of the hydration product formation. The formation of CSH gels reduced the pores in the concrete by functioning as stable phase of concrete. The higher specific surface area of the sea sand aggregates also formed additional reaction sites that bond with the epoxy cement matrix that aids in porosity reduction. The mechanical strength properties structure of the indirectly depends on the pore structure of the concrete. The increase in porosity of concrete reduces the mechanical performance of concrete and vice –versa.

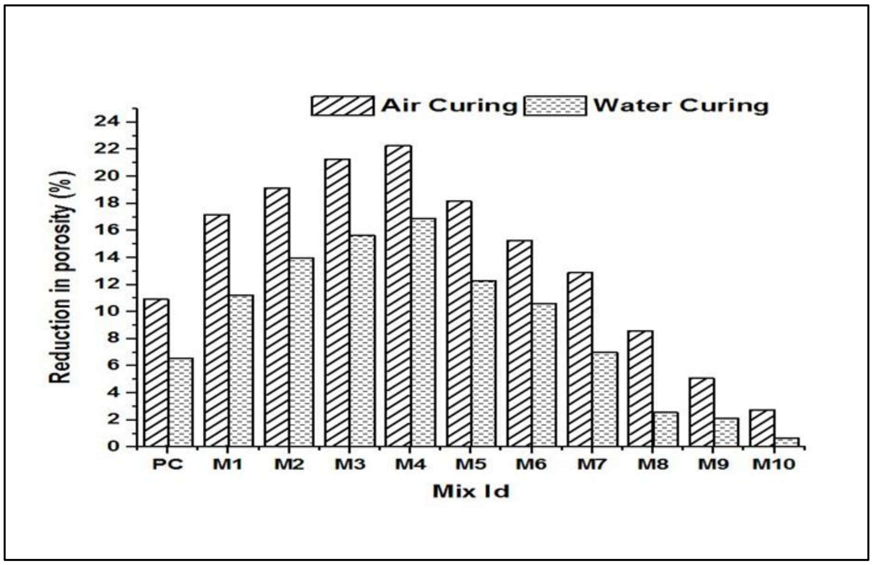

***Figure 4**. Reduction in porosity of epoxy concrete against control concrete*

4.5. RCPT

The rapid chloride penetration values of the epoxy modified concrete with and without sea sand substitution with reference to the control concrete mix (CM) is shown in (Figure 5).The chloride penetration values of the polymer concrete (PC) was highly reduced when compared the control concrete (CM). This may be due to the blocking effect of chloride ions by the epoxy resin. The results clearly signify the beneficial role of sea sand and epoxy in reducing the chloride penetration through the concrete. The total charge passed through the concrete reduced significantly with increase in the sea sand substitution. However no significant variations were found to occur with increasing percentages of sea sand substitution. Comparing the charge passed through the concrete mix containing epoxy resin (PC) and the control mix (CM) the polymer concrete showed significant reduction in the value of total charge passed through the concrete. Thus the chloride penetration is greatly hindered by the epoxy polymer that reduces the charge that can be passed through the concrete. The epoxy polymer is highly resistant towards chemical attack and also reduces the pores in the concrete through which ions can pass through.

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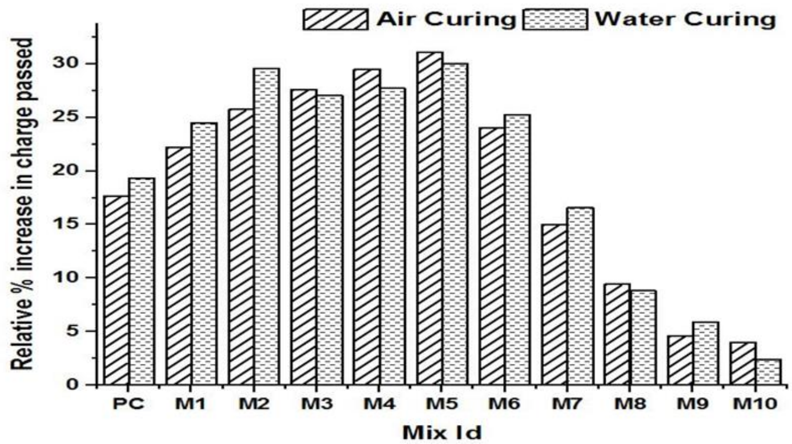

Figure 5*. Relative % increase in charge passed of epoxy concrete against control concrete*

4.6. Bulk Diffusion

The chloride penetration depth of the concrete mixes containing epoxy resin and sea sand aggregates in concrete are shown in (Figure 6). The results shows that the diffusion of chloride ions were significantly reduced in the concrete mixes containing epoxy as cement replacement and sea sand as fine aggregate content. There is no significant variation in the diffusion of chloride contents in the concrete with varying curing method.

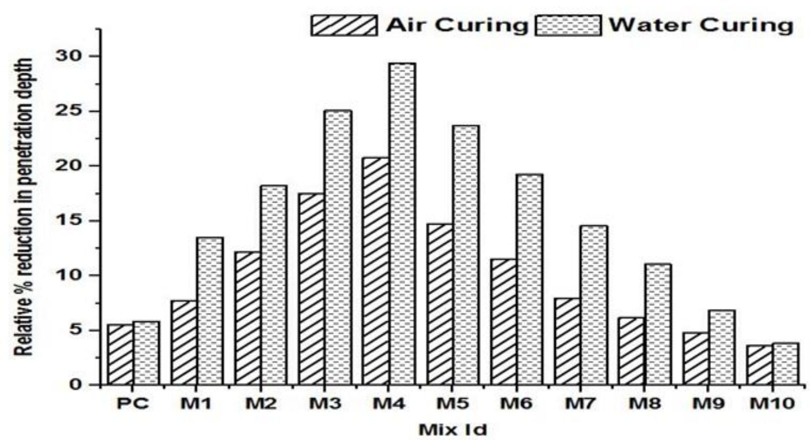

Figure 6. *Chloride penetration depths of epoxy concrete under air and water curing*

4.7. Chemical Attack

The physical and mechanical properties of concrete are high whereas subjected to the attack of acids the strength of concrete deteriorates quickly. Concretes are generally alkaline in nature and hence they are easily susceptible to the attack of acids. Calcium silicate gels Ca(OH)2, Which are the hydration products get easily attacked by acids. The alkaline phase reacts with acids to form calcium salts that gets easily soluble and washed away. This formation of soluble salts weakens the concrete thereby affecting the durability of concrete. Generally hydrochloric acids are less destructive than sulphuric acids since the sulphuric acid forms gypsum which highly disrupts the cement matrix. Reaction between HCL and the $Ca(OH)_2$ *hydration product can be stated as. (Equation 1)*

$$HCL + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O \qquad (1)$$

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The Chloride ions present in hydrochloric acid reacts with the hydration product forming calcium chloride which gets easily transported from the outer layers of concrete the interior regions. The strength loss and weight density loss were shown in (Figure 7).

4.8. Salt Attack

The crystallization of salts on the surface of concrete induces severe deteriorations on the strength properties of concrete. The embodiment of concrete structures in salt rich soil conditions may lead to notable damages on the surface properties of concrete and hence the attack of salts becomes a mandatory study when the durability of concrete structures is considered. (Figure 8) shows the percentage loss in strength and weight of the epoxy polymer concrete mixes under the attack of salts of NaCl. The notable observation can be made from the figure that the original compressive strength was almost retained even after exposure to the NaCl for the epoxy sea sand concrete mix (M8). As expected the unmodified concrete exhibited higher % of weight loss than the concrete manufacture by 12% of epoxy resin replacement for binder.

4.9. Sulphate Resistance Test

The compressive strength results of the epoxy sea sand concrete before and after immersion in the sulphate solution is shown in (Figure 13) for air and water curing respectively. The behaviour of the epoxy polymer concrete mixes containing sea sand after exposure to sulphate attack and the compressive strength results under various curing conditions due to sulphate attack and the loss in weights of the of epoxy concrete mixes after sulphate attack is shown in (Figure 9). The percentage weight loss of the concrete mixes were relatively low in the polymer sea sand concrete mixes when compared to the controlled concrete indicating the reduced formation of ettringite due to sea sand and epoxy substitution. The ettringite is formed as a result of the reaction between the sulphates with the cement which is generally expansive in nature. The reduced formation of ettringite during the sulphate attack may be due to the barrier effect caused by the epoxy resin towards the ingression of sulphate ions.

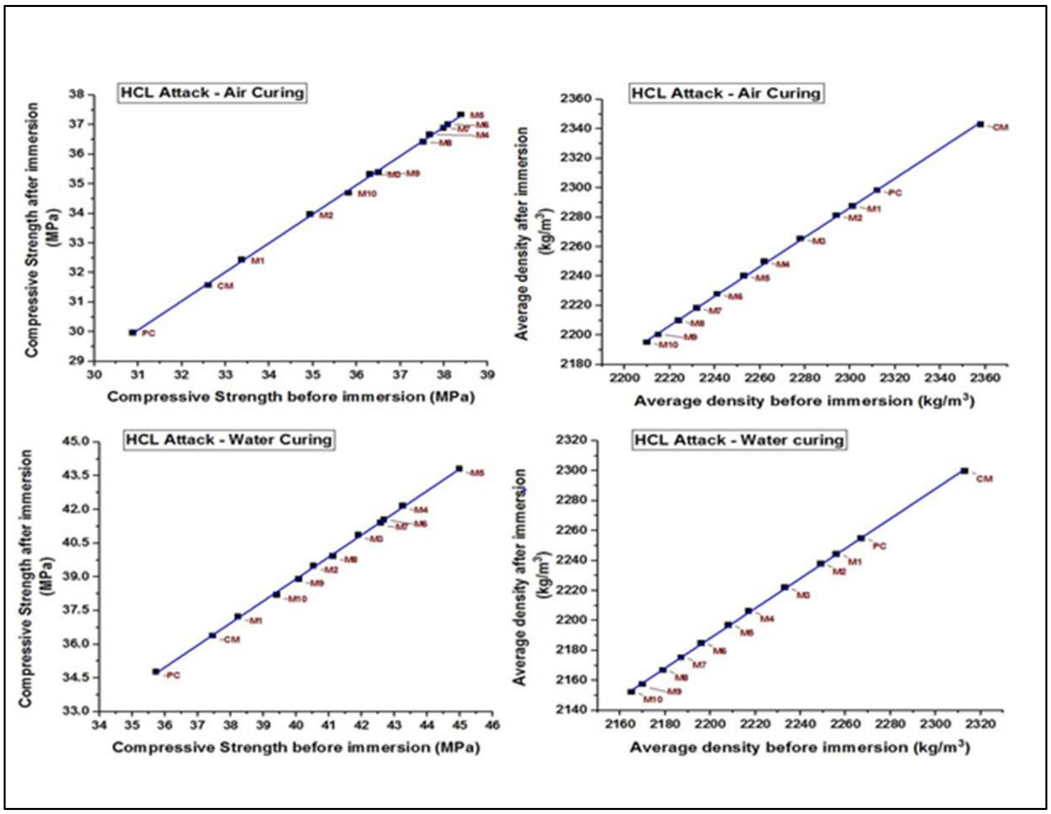

Figure 7. *Compressive strength and Weight density of epoxy concrete before and after immersion in HCl acid*

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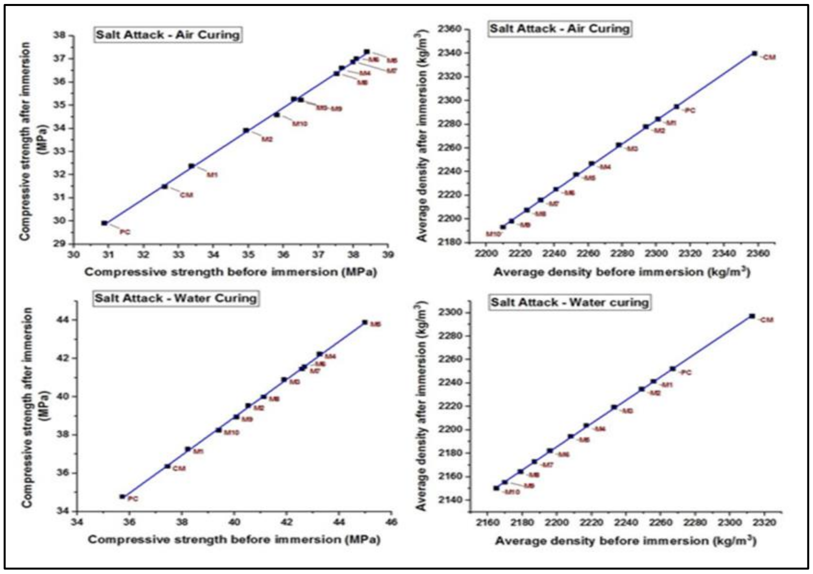

Figure 8. *Compressive strength and Weight density of epoxy concrete before and after immersion in salt solution*

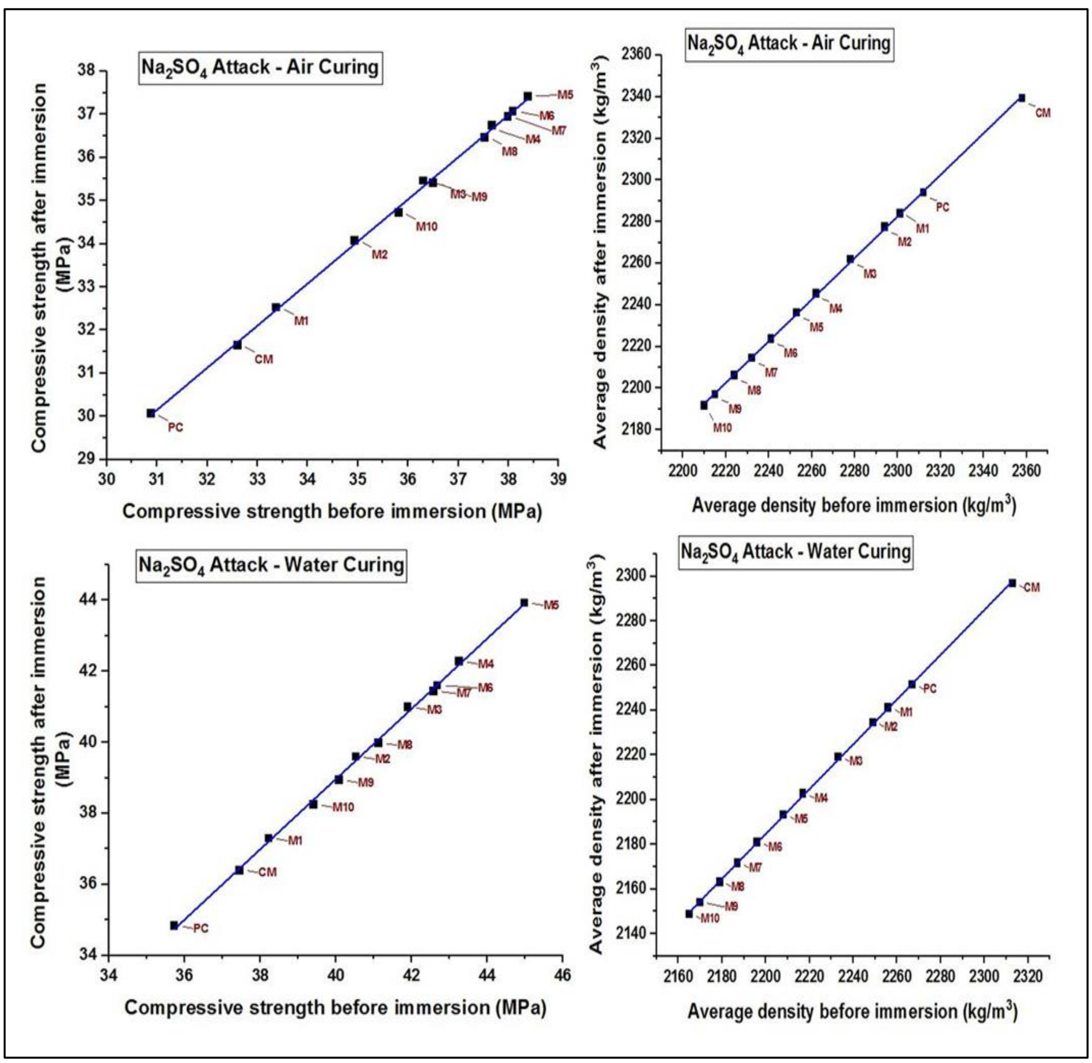

Figure 9. *Compressive strength and weight density of epoxy concrete before and after immersion in sulphate solution*

4.10. XRD Analysis

The X-ray diffraction pattern of the various epoxy polymer concrete mixes under ambient and water curing conditions is shown in (Figure 11), (Figure 12), (Figure 13) and (Figure 14) respectively. The XRD patterns clearly showed major peaks of portlandite and calcium silicate with minor calcite phases. The calcium silicates generally are not obtained directly from the XRD pattern. The presence of CSH gels can be identified from the peaks of alite and belite. The epoxy system addition in concrete generally does not produce new crystalline compounds and hence the XRD patterns of epoxy modified concrete (PC) and control concrete from (Figure 10) showed no major difference. Significant changes occurred in the XRD patterns of epoxy modified concrete containing sea sand as aggregates. The differences mainly occurred in the quartz peak due to relatively lesser higher amount of quartz present in sea sand when compared to the conventional river sand aggregates. The peaks of portlandite (CH) shifted to higher degrees due to the enhanced hydration of the cement concrete. The height of CSH shifted towards lower degrees in the polymer concrete due to the disruption of silicate reaction. However the lower intensities of CSH gel formations were compensated by the addition of epoxy resin that induced the gel formations around the aggregates. The addition of sea sand in the polymer concrete showed no new formations of crystalline peaks thus showing the compatibility of the sea sand aggregates with the polymer matrix.

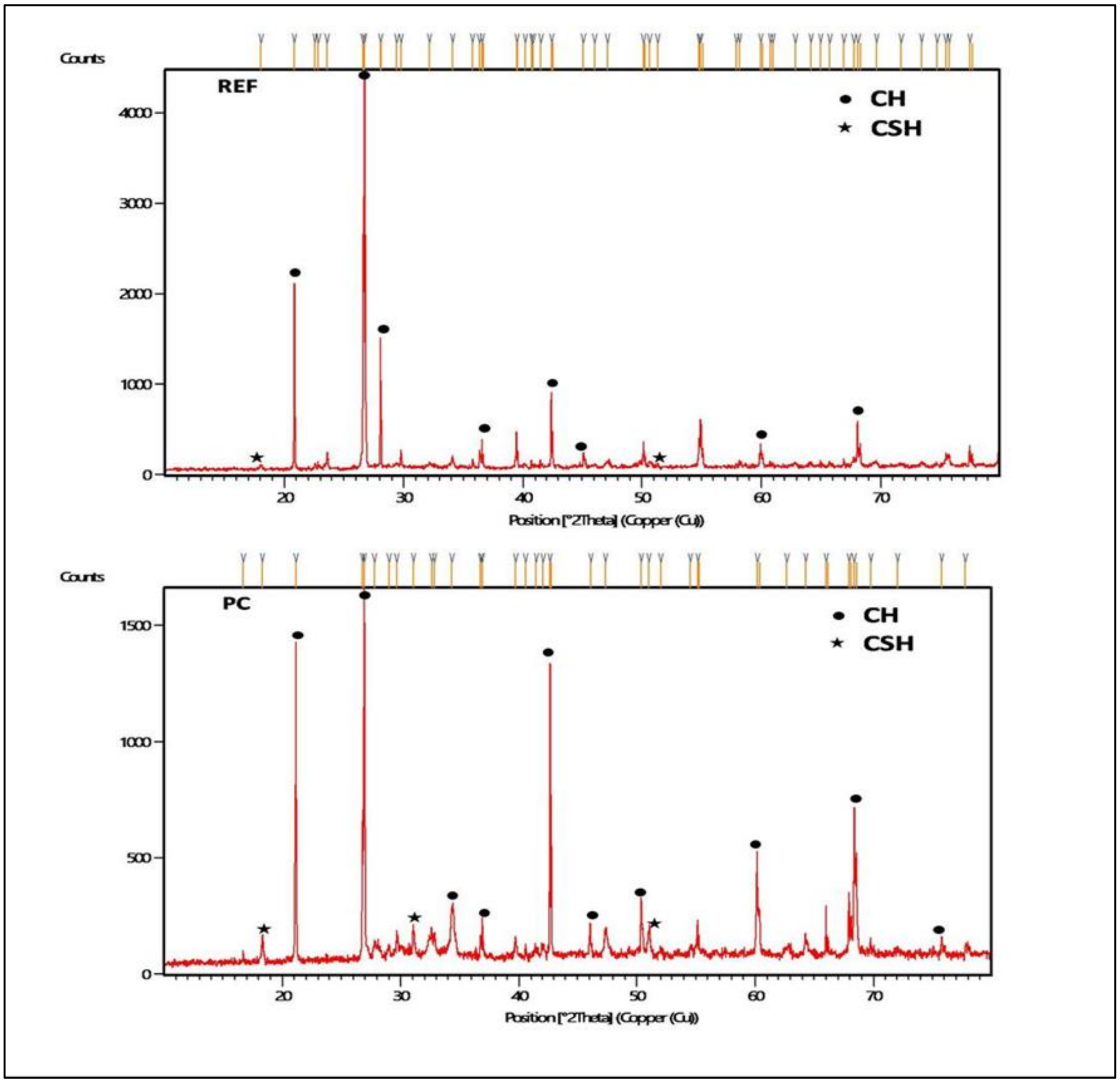

***Figure 10**. XRD spectral curves of control concrete and epoxy concrete mix*

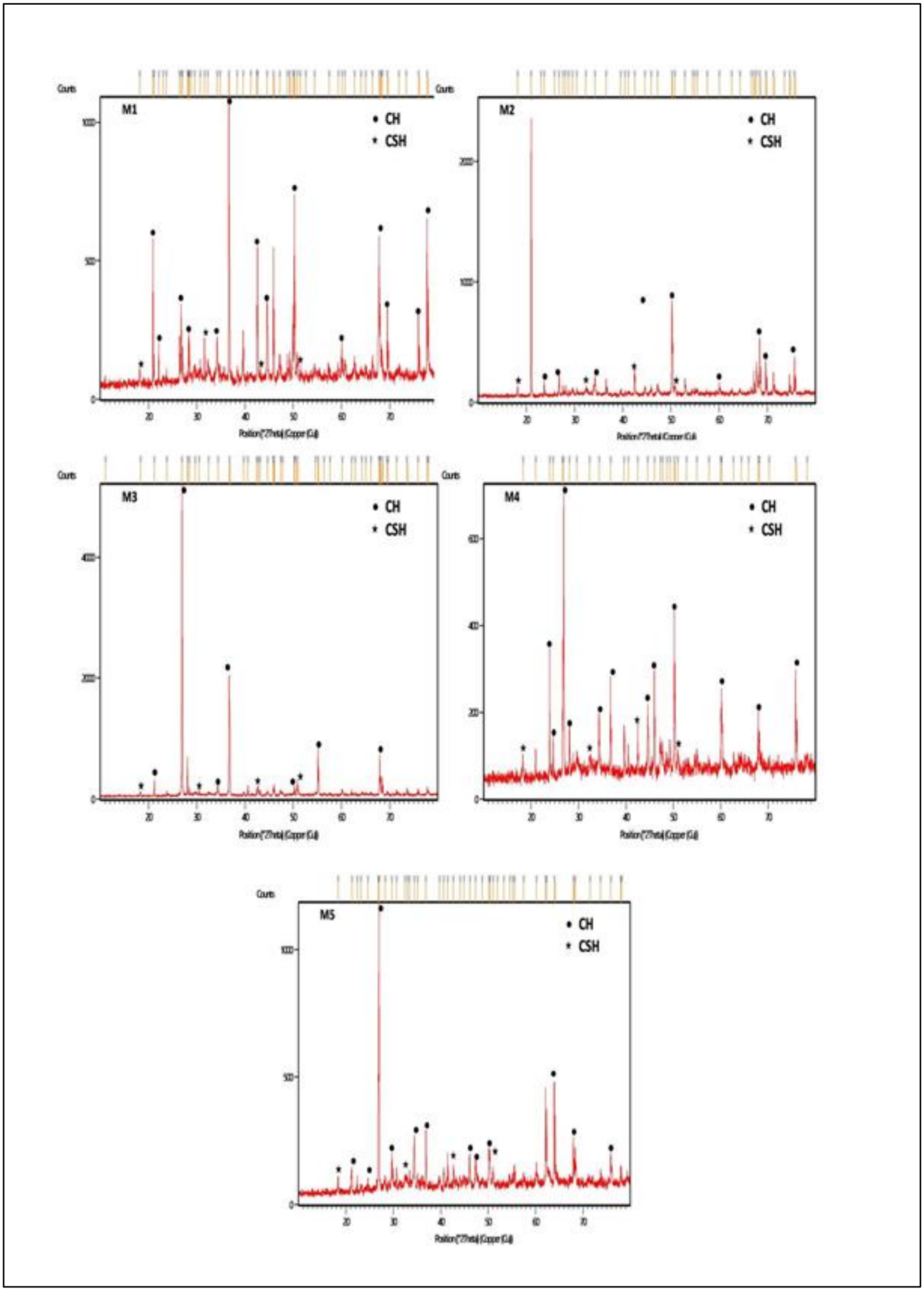

Figure 11. *XRD spectral curves of epoxy concrete mixes under ambient curing condition*

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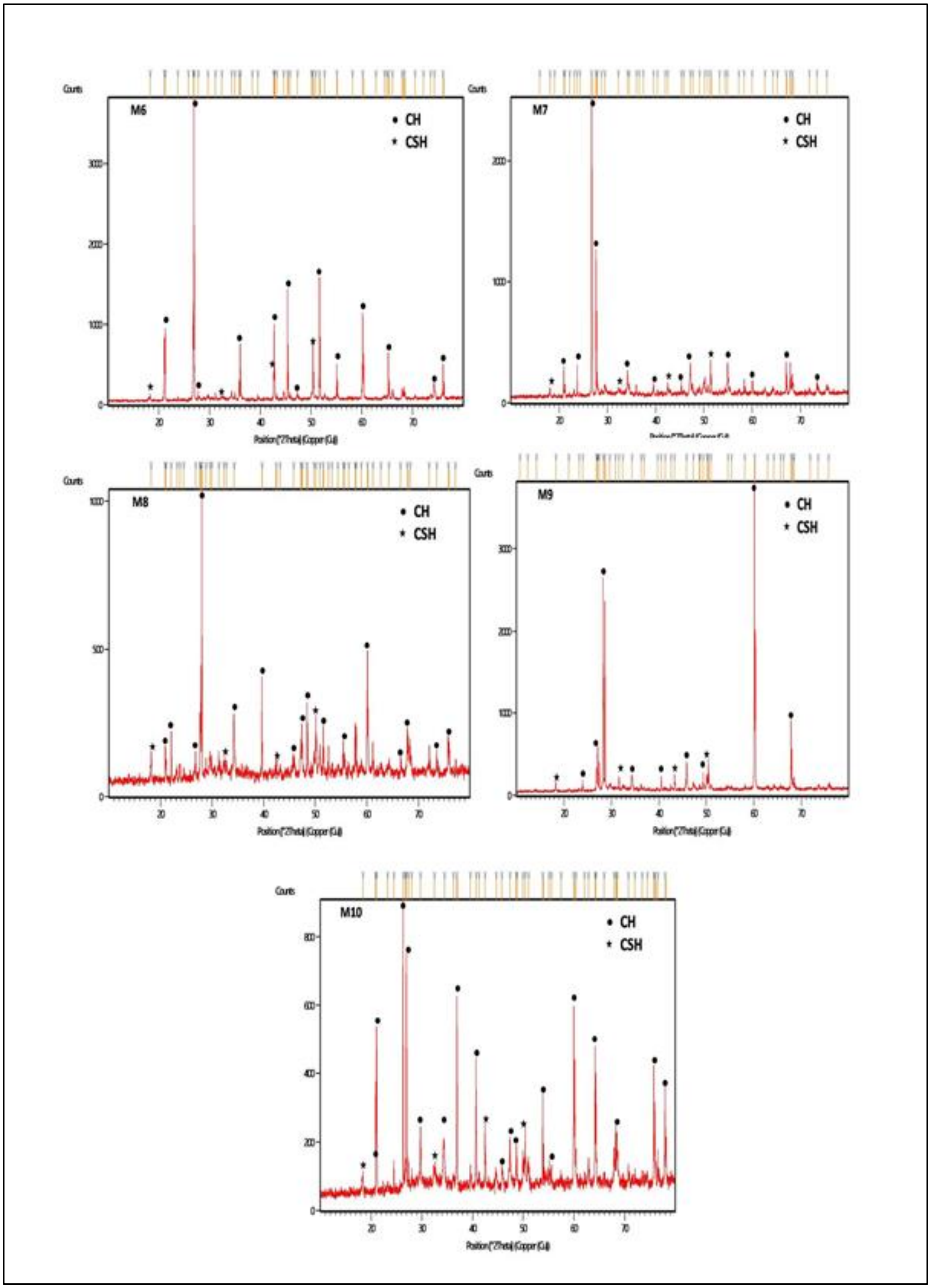

***Figure 12**. XRD spectral curves of epoxy concrete mixes under ambient curing condition*

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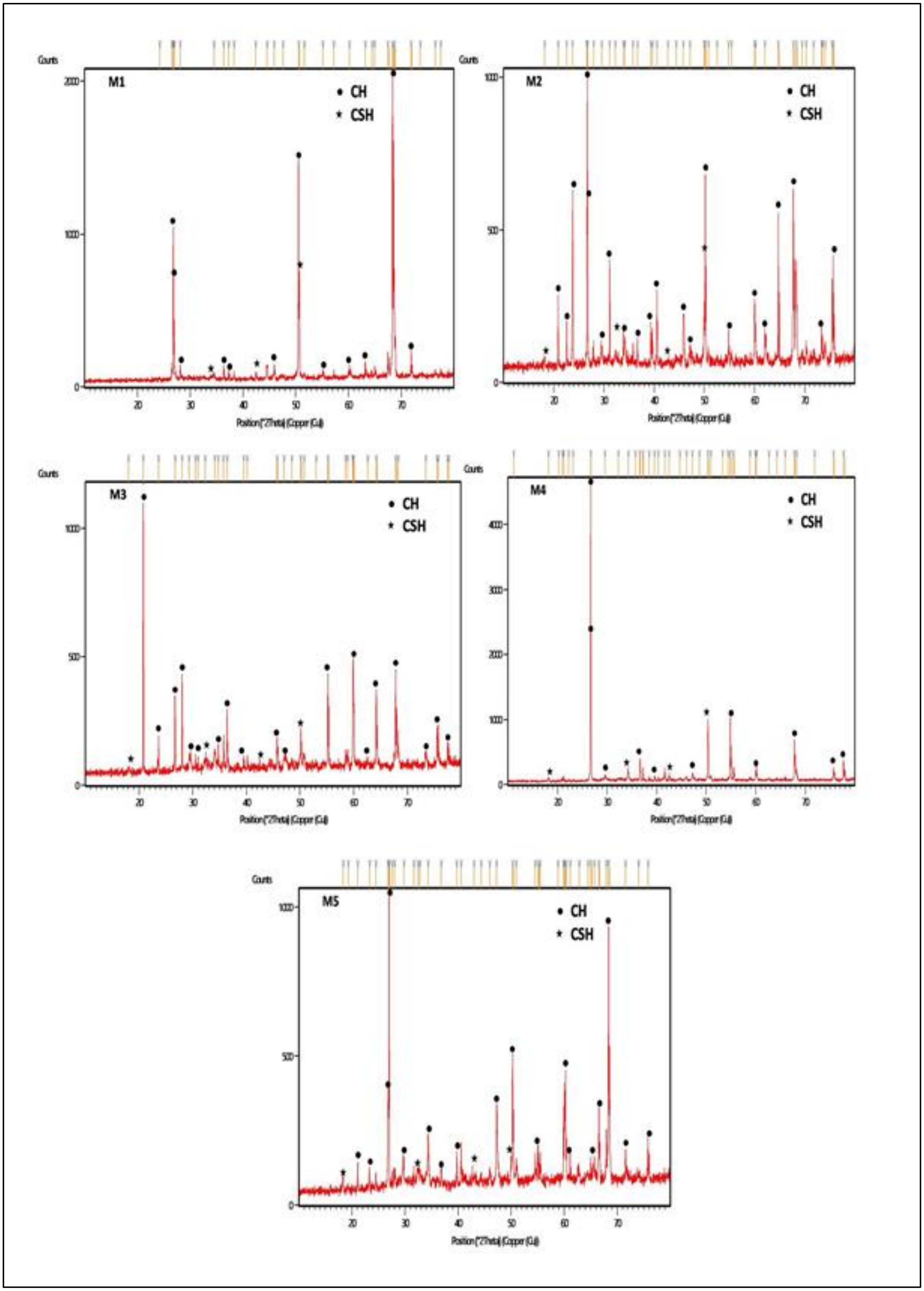

Figure 13. XRD spectral curves of epoxy concrete mixes under water curing condition

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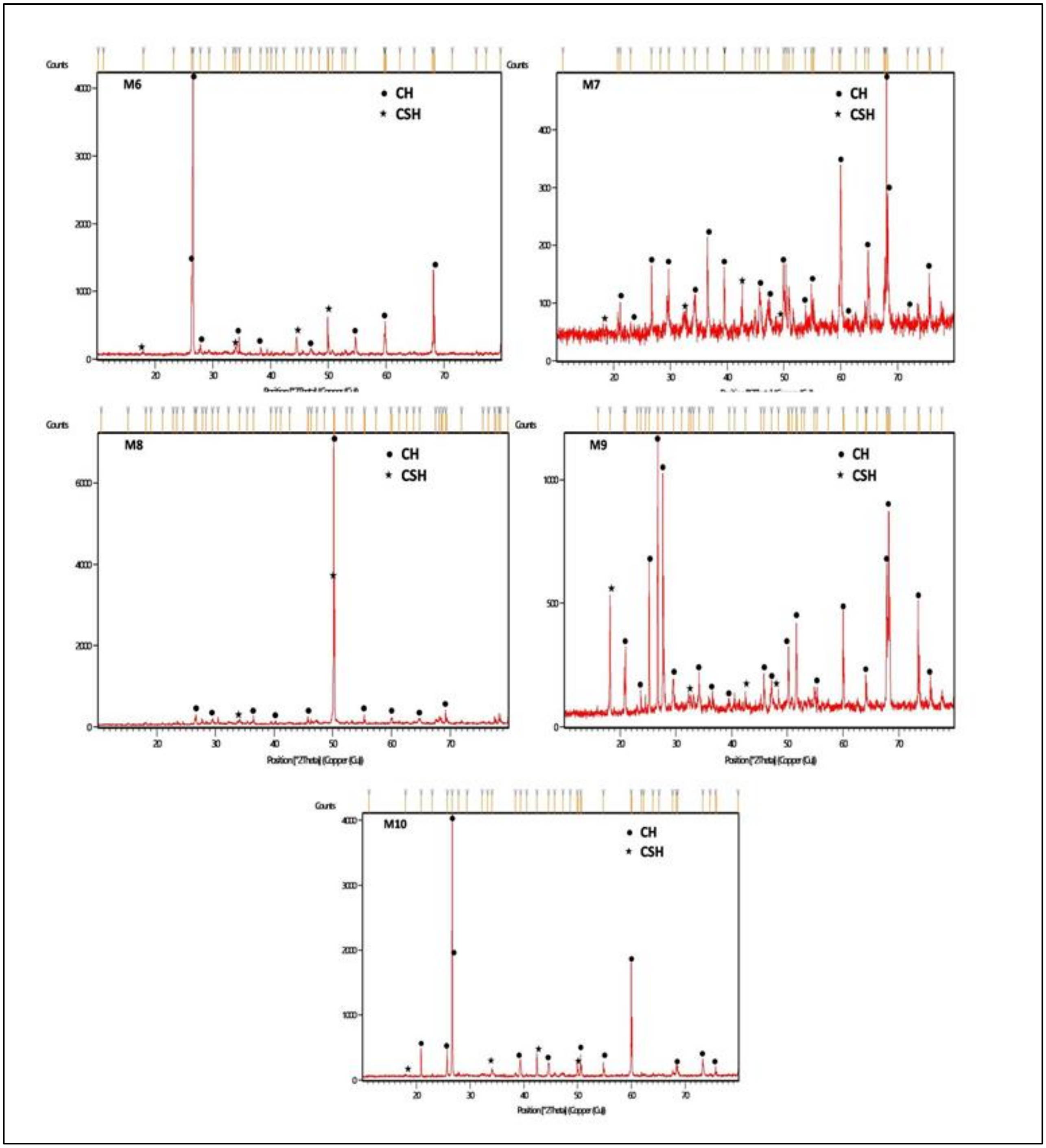

Figure 14. *XRD spectral curves of epoxy concrete mixes under water curing condition*

5. Conclusions

Ever-growing concrete structures all over the world have also caused an ever increasing search of alternate aggregates to meet the environmental concerns. Moreover the restrictions imposed by government on the sand mining has also led to the search for new sand aggregates that can show potentials of replacing river sand aggregates. Sea sand is one such viable alternative material to natural river sand aggregates and is also economically feasible considering from the point of view of their abundant availability and easier mining and transportation convenience. The non-availability of river aggregates also creates transportation issues thus increasing the cost of concrete production. The present study thus tries to substitute sea sand in partial amounts instead of river sand aggregates in the concrete production. Generally sea sand aggregates have to undergo desalting procedures but in this present study the desalting procedure is completely avoided to reduce the extra cost associated with the desalting procedure. Moreover the use of desalting procedures may reduce the green materials efficiency. In addition to earlier study (Sakthieswaran et al., 2019), the concretes produced by 12% epoxy resin as *cement replacement and sea sand as fine aggregate showed that the splitting tensile strength of the concrete mixes increased for all the concrete mixes containing sea sand as fine aggregate upto a certain threshold level between where a decrease in the split tensile strength of the concrete. The flexural toughness of the concrete mixes containing epoxy resin was much increased due to the increase in the flexibility of concrete. The flexural strength was increased for all the specimens with sea sand and epoxy concentration. Moreover the drawback caused by replacement of coarse aggregate by sea shell in concrete was compensated by the epoxy resin. The addition of different percentages of sea sand improved the flexural strength and optimum dose of washed sea sand was found to be 25% and 40% respectively for ambient and water curing respectively. The flexural strength of the entire specimen depends only on the amount of epoxy content and showed that the replacement of fine aggregate has no has only a minimal effect on it. The epoxy resin increase the flexural performance of the concrete by bridging the size of the opening crack and showed high resistance to the loss of continuity of the material during cracking. This effect is beneficial to improve the strength of concrete by allowing the stress redistribution even after cracking whereas the unmodified concrete specimen showed brittle failure. With epoxy resin and sea sand as replacements for cement and fine aggregate respectively, the concrete impact energy up to 70.7% was achieved when compared to un-modified concrete. The use of epoxy resin in the concrete made them become effective after matrix cracking which led to an increased absorption of energy by enhancing the ability of the concrete to withstand the impact load even after cracking. The best performance of the concrete under the impact loading was achieved for concrete containing 20% sea sand under ambient and water curing conditions. The combination of the epoxy resin with sea sand showed better impact performance than unmodified concrete. The acid attack result also indicated that the polymer concrete with sea sand aggregates show insignificant loss in weight after exposure to acids. The reduction in the compressive strength of the residual acid exposed specimen was also reduced. The loss in compressive strength after acid attack was almost negligible for 20% sea sand in ambient cured epoxy concrete and 35% sea sand in water cured epoxy concrete. The results also indicate that the introduction of epoxy resin in concrete has greater potential to increase overall performance of the concrete. The replacement of conventional fine aggregate by sea sand also proves to be feasible solution to minimize the natural resource depletion by efficient utilization of sea shell without compromising the strength parameter. Therefore the use of sea sand is encouraged to be used in combination with epoxy polymer for the production of concrete when the long term usage is considered.*

6. References

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