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Studies on the corrosion resistance of reinforced steel in concrete with CNSL (Cashew Nut Shell Liquid) resin —an overview

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Abstract: *Corrosion is a chemical process of destruction of material because of its reaction with the environmental conditions. Corrosion occurs when the relative humidity of air becomes more than 65%.Corrosion in concrete is the leading cause for the deterioration of structures. The corrosion resistance of concrete is tested after using CNSL resin as an admixture. CNSL resin is added in the proportion of 1%, 1.5%, 2% by weight in sand as an admixture. The corrosion resistance is studied for concrete by using CNSL resin. It has been concluded from the results that the corrosion resistance of concrete for 1.5% CNSL resin shows the best resistance among all the mixes.*

Key words: - Corrosion, CNSL resin, Compressive strength, Pulse Velocity

1. INTRODUCTION

In today's world, a lot of steel is used to strengthen the concrete structures in the form of inserted rods hence the life of those embedded rods bear a persistent problem of corrosion and therefore is a cause of concern for scientists and engineers. Corrosion of reinforcing bars embedded in concrete is the most common cause of deterioration of concrete structures in aggressive environments ***(A.E.K. Jones, 1997)***. Corrosion of steel reinforcement results in cracking and eventual spalling of concrete. In general, good quality concrete provides excellent protection for steel reinforcement. Due to the high alkalinity of concrete pore fluid, steel in concrete initially and, in most cases, for sustained long periods of time, remains in a passive state. Initiation of corrosion occurs either due to reduction in alkalinity arising from carbonation or the breakdown of the passive layer by the attack of chloride ions. The time to initiation of corrosion is determined largely by the thickness and the quality of concrete cover as well as the permeability of concrete. High quality and durable concrete is required to reduce the rapid deterioration of concrete under severe environmental conditions. In this context, the beneficial effects of CNSL resin should be considered. The advantages of using resin are that it possesses high mechanical strengths, long durability, and resistance to chemical attack *(**Rakesh Kumar, 2016**)*.
If the steel which is present in concrete corrodes an expansive force is generated due to increase in the volume of steel which can rupture the concrete. If a crack is being formed due to this expansive force in the structure then the rate of corrosion of steel starts even more rapidly leading to the complete failure of the structural member involved. Therefore worldwide, the chief concern is the early deterioration of reinforced concrete structures which is induced due to corrosion of the embedded steel. The prevention of the steel corrosion can be done by providing a waterproof coating which prevents the entry of salt, water and air. There are many objections from Civil Engineers on these ideas of preventing the reinforced RCC structures from corrosion. It has been found that even after applying waterproof coating the aggressive materials have still entered.
Concrete carbonation is one of the important factors that affect the durability of concrete. With the ever increasing consumption of natural resources, carbon dioxide concentration in the atmosphere has continuously increased. Carbon dioxide reacts with cement hydrates in a process called carbonation, which leads to corrosion of steel bars. Many concrete structures around the world have suffered from the loss of durability due to carbonation, so it is urgent to solve the carbonation problem of concrete (***IS Yoon et al, 2007***).
There is one technique by which we can prevent the corrosion that is by screening the steel itself from the concrete and therefore from the aggressive medium. This is possible by using a non-reaching metal coating, paint or any other kind of coating. We can also screen the steel by creating a non-reactive film by means of inhibitors or polarization methods. The another alternative method of Corrosion Protection is the addition of Sodium benzoate, Sodium nitrate or Calcium chromate complexes to the mix or the application of slurry of Cement Paste over the steel and a layer of an epoxy base placed on the steel.
Corrosion prevention techniques which are relied on addition of constituents in the mixture have been tried entirely for practical and cost-effective results as it can be easily determined if the additives have any compelling harmful effects on the concrete or not. Again methods concerning treatment of the steel in assessment are also much significant concern of probable loss of steel/concrete bond strength, either before or after some minor corrosion has arisen, this phase of the problem has also established consideration.
Due to speedy growth all over the world, there is a necessity to construct and use concrete structures with reinforcement of

steel namely multi-storey buildings, bridges, dams, railway sleepers, tunnels, nuclear power plants, turbo generator foundations, reservoirs etc. Reinforced steel corrosion of the pre-stressed concrete structure is a trouble worldwide and has restored scientific attentiveness in the last few decades. If humidity and oxygen are present there occurs corrosion in the reinforcement because of the entry of carbon dioxide which causes loss of alkalinity. Many progresses regarding to physical properties of entrenched metal and the concrete have come up. However, it's a very complicated task to regularly monitor the health of concrete structure because of the intricate and sophisticated design of structures and use of complicated instruments, this requires specialized knowledge for interpretation of data.
Common materials which are easily available have been utilized to see their functioning on the potential growth at the metallic solution interface-Polystyrene, aluminum paint, red oxide and black Japan paint have been tested. When paint is utilized as an anti corrosive substance the key thing to be kept in the mind is the bond strength in between the reinforcement and concrete. Chemicals like CaCl2 and sodium Hexa-meta phosphate (HMP) were examined for their positive and negative performance of the maintenance/worsening of stable potential.

2. LITERATURE REVIEW

Shirsalkar and Sivasamban (1979) prepared anticorrosive paints based on CNSL, which have been found to be suitable for ships hulls and other such applications. The coating withstands alkalinity normally encountered with cathodically protected steel hulls. Rust inhibiting zinc rich primers can be prepared from CNSL. Coatings giving tough elastic films are reported from CNSL-glycerine reaction products.

Pillai and co-workers (1995) have investigated the phosphoiylation of cardanol and the prospective applications of the products. Urethanes have been synthesized from CNSL as in the case of other hydroxy compounds, by reaction with isocyanates. CNSL can be converted to acetals by reaction with compounds like dimethyl acetal in presence of acids. lsocyanates have been prepared from hydrogenated cardanol.

T.Sundararajan and P.Ravikumar (1997) studies on the strength and other properties of materials using cashew nut shell liquid (CNSL) resin .The potential of CNSL resin as a binder in various forms of materials has been studied. CNSL based compressed earth block stabilises red soil and improves physical properties .Irrespective of the filler material water absorption is very less than conventional clay bricks. Increase in CNSL resin content even for a constant water-cement ratio for polymer –modified concrete as the excess of requirement to coat the fine aggregate in polymer reduces the compressive strength due to inadequate curing as oxidation is the process involved in room temperature curing. The compressive strength of CNSL based polymer mortar depends on the gradation of fine aggregate, type of micro filler, content of resin and microfillers and mix proportioning approach. Fly ash can be used as a microfiller, whereas crusher dust can be used as both fine aggregate and microfiller in polymer mortar. Use of crusher dust as a microfiller reduces the requirement of CNSL resin for polymer mortar, even though there is no substantial variation in the compressive strength of polymer mortar based on the two microfillers.

Talo et al. (1999) investigated polyaniline epoxy blend coatings on mild steel in neutral, acidic, and alkaline solutions using electrochemical methods such as open circuit potential and potentiodynamic polarization method. Polyaniline protonated and polyaniline emeraldine base with camphor sulfonic acid (PANI*CSA) and phenyl sulfonic acid (PANI*PSA) had been tested in epoxy blend coatings on mild steel. Results confirmed that emeraldine base as the most effective form of polyaniline for corrosion protection of mild steel in saline solution. PANI*PSA coating was not able to protect steel surface in NaCl solution. It had been revealed that epoxy blend coatings containing Polyaniline emeraldine base could provide excellent protection by results. Protanated PANI*CSA was more effective in acidic solution than in netural solution.

L.K. Aggarwal et al, (2007) developed epoxy–cardanol resin using epichlorohydrin, bisphenol and cardanol. After the evaluation he found that epoxy–cardanol resin showed comparatively better properties than the epoxy resin regarding elongation, bond with steel, tensile strength and lowering of transmission of water vapor in the film. Paints having micaceous iron oxide in the epoxy–cardanol resin gave the best performance and after that comes the zinc phosphate type paints

Haidar et al*, *(2011) fabricated an epoxy resin reinforced with a graded mixture of coarse and fine sands termed as micro polymer concrete (MPC). It has been reported that the MPC concrete designed with a polymer content of 9% showed the highest physical and mechanical characteristics such as strengths and rigidity. Also for the formation of MPC the amount of epoxy resin taken was slightly lower than for general epoxy polymer concrete.

C. C. Ugoamadi, (2013) while doing research, picked cashew nuts and processed them for extracting the resin content. The final compressive strength for the CNSL Resin was 55MPa and for the polyester resin, ultimate strength was 68MPa. The tensile strength of CNSL resin having ultimate strength of 44MPa was far better than the polyester resin having 39MPa as ultimate tensile strength. Tensile and Compressive strength tests performed showed that composites formed with CNSL resin could be compared to those which were formed with polyester resin.

Ana María Aguirre-Guerrero et al., (2016) tested the performance of 2 hybrid kind geopolymer mortars made of alkaline-activated FA and MK (Metakaolin) as defensive coatings against the chloride-induced rusting in reinforced cement concrete. In both cases, the coated, Portland cement (OPC)-based concretes (substrates) were subjected to accelerated techniques such as impressed voltage and wetting/drying cycles in the company of 3.5% NaCl solution. The open circuit potential and linear polarization involving techniques were used to monitor the corrosion. To protect the structures that are open to marine locations, the geopolymer type mortars can be used.

3. MATERIAL AND METHODOLOGY:-

3.1 MATERIALS

3.1.1 Cement: - Cement is a material that has cohesive and adhesive properties in the presence of water. Such cements are called hydraulic cements. These consist primarily of silicates and aluminates of lime obtained from limestone and clay. The physical properties of cement used for the experimental work was fulfilling all the criteria of IS: 12269 and IS: 4031 are as shown in Table-1.

S. No.	Parameter	Result Obtained	Requirements as per IS:12269(1987)
1.	Fineness-Specific Surface (m^2/Kg) by sieve Analysis	285	Minimum 225.0(m2/Kg.)
2.	Standard consistency in (%)	30%	---
3.	Setting time in Min. (a) Initial setting time (Minute) (b) Final setting time (Minute)	47 min 260 min	--- Minimum - 30 Minute Maximum- 600 Minute

Table 1: Physical property of cement as per IS: 12269(1987)

3.1.2 Aggregates: Aaggregate properties greatly influence the behavior of concrete, since they occupy about 80% of the total volume of concrete. The aggregate are classified as

(I) Fine aggregate

(II) Coarse aggregate

Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. Coarse aggregate form the main matrix of the concrete, where as fine aggregate form the filler matrix between the coarse aggregate. The most important function of the fine aggregate is to provide workability and uniformity in the mixture. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension. According to IS 383:1970 the fine aggregate is being classified in to four different zone, that is Zone-I, Zone-II, Zone-III, Zone-IV. Also in case of coarse aggregate maximum 20 mm coarse aggregate is suitable for concrete work. But where there is no restriction 40 mm or large size may be permitted. In case of close reinforcement 10mm size also used.

S. No.	Properties		
1	Zone of Sand	II	--
2	Water Absorption (%)	1.1	Max - 2 %
3	Sp. Gravity of Sand	2.67	2.6 - 2.7

Table 2: Physical property of fine aggregate

S. No.	Properties		
1	Water Absorption (%)	1.5	Max - 2 %
2	Sp. Gravity of Sand	2.72	2.6 - 2.9

Table 3: Physical property of coarse aggregate

3.1.3 CNSL resin: CNSL is a soft honey comb structure which contains dark reddish brown viscose liquid. The nut containing pericarp fluid which is a by-product of the cashew industry is known as the CNSL Resin. The outer skin of this shell is soft and feathery and the inner skin is thin and hard, and the thickness of this shell is around 0.3 cm. The honeycomb structure which is present in between these skins contains a phenolic material which is referred as CNSL (Cashew Nut Shell Liquid). There is kernel wrapped inside the shell in a very thin skin which is known as testa. lndia is the largest producer of raw cashew nuts in the world. The production of raw cashew nuts was 95,000 MT during 2003-04. The export of CNSL from lndia during 2003-04 was 7215 MT. Among Indian States, Maharashtra comes first in production of cashew nuts followed by Kerala and Andhra Pradesh. Export of CNSL from Kerala was 6784 MT during 2003-04. CNSL resin can be used in the concrete for preventing the corrosion by increasing the density of concrete and also reducing the entry of acids that are responsible for the corrosion of reinforcement. So by using CNSL resin in the concrete not only the strength is increased but also durability of the concrete is increased.

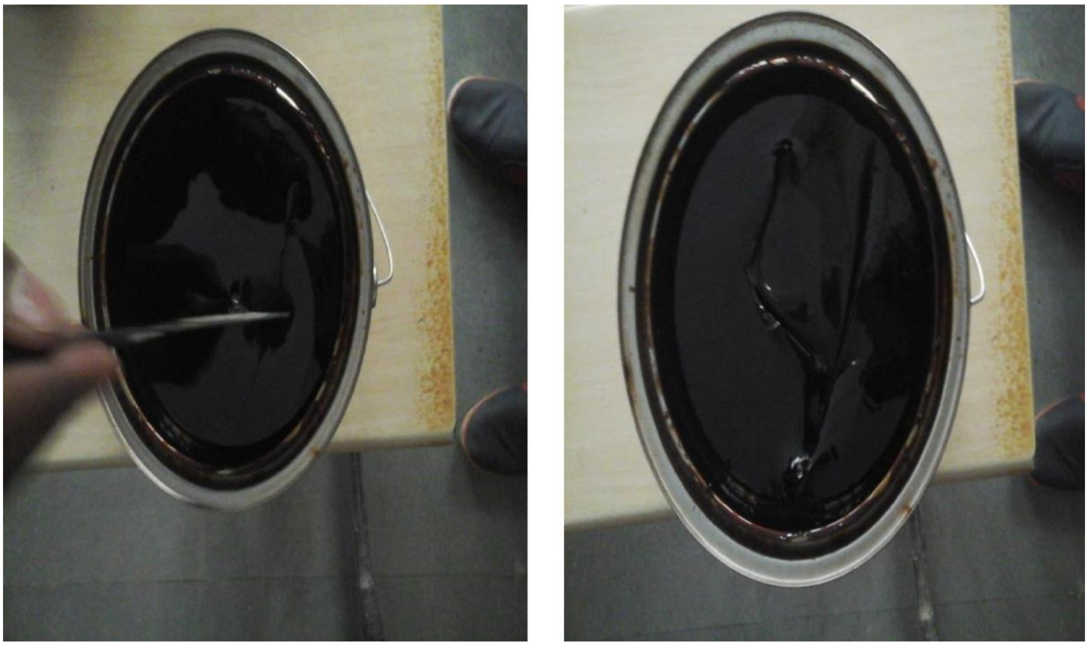

Figure 1:- CNSL resin

3.2 METHODOLOGY: In this research work CNSL resin is added in the proportion of 1%, 1.5%, and 2% by weight in sand as an admixture. It was used in M25 grade of concrete and the 7 days and 28 days compressive strength were determined. Durability test and flexural strength of concrete to that of normal concrete with maintaining the water cement ratio in the range of 0.50.

S. No.	Tests	Specimen	Dimension
1.	Compression test	Cube	(150x150x150)mm
2.	Durability test	Cube	(150x150x150)mm
3.	Flexural test	Beam	(150x150x700)mm
4.	Durability test	Beam	(150x150x700)mm

Table 4: Specimens for tests

4. RESULT AND DISCUSSION:

4.1 Compression Test: - Specimens of size 150x150x150 mm were casted for compression test. Testing of specimens was done after 7 days and 28 days of water curing. Compressive strength for different proportions of cnsl resin and control mix for 7 and 28 days are as follows:

Control Mix Trial	7 days	28 days
1	19.11	31.11
2	18.22	30.66
3	20.44	31.55

MIX	7 days	28 days
0%	19.25	31.11
1%	18.96	29.62
1.5%	19.99	31.7
2%	17.03	26.22

Table: 4 Compressive strength (N/mm^2) of control mix and different proportions of cnsl resin

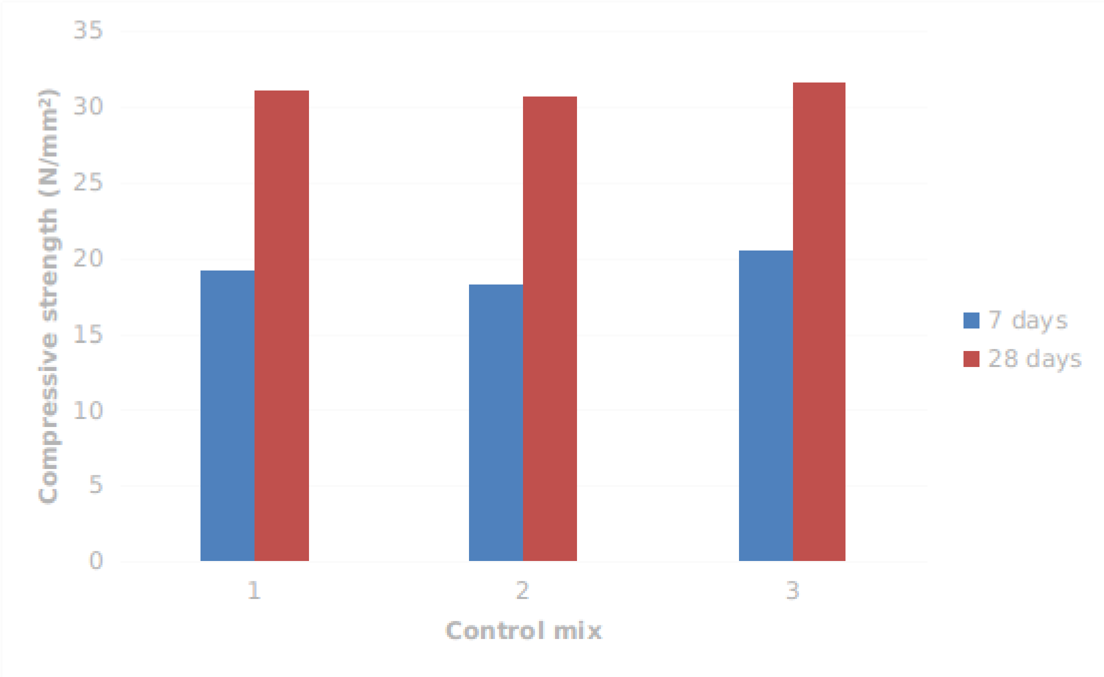

Figure 2:- Compressive strength (N/mm^2) of control mix

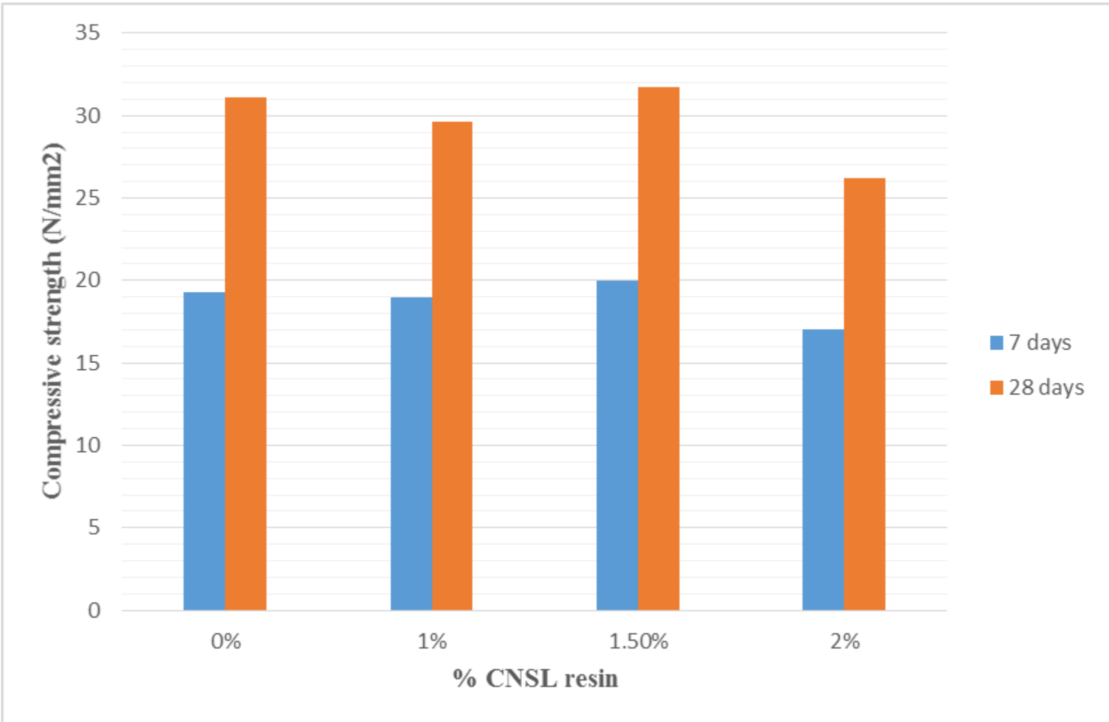

Figure 3:- Compressive strength (N/mm^2) of different proportions of cnsl resin

4.2 Flexural test: Specimens of size 150x150x700mm were casted for flexural test. Testing of specimens was done after 28 days of water and acid curing to check its behaviour against acid.

Figure: 4 casting specimen for Flexural Strength test

Flexural strength for different proportions of cnsl resin for 28 days is as follows:

	STRENGTH (N/mm2)	
	Before acid curing	**After acid curing**
0%	**3.15**	**2.73**
1%	**3.46**	**3.03**
1.50%	**3.94**	**3.50**

Table: 5 Flexural strength (N/mm^2) of control mix and different proportions of cnsl resin

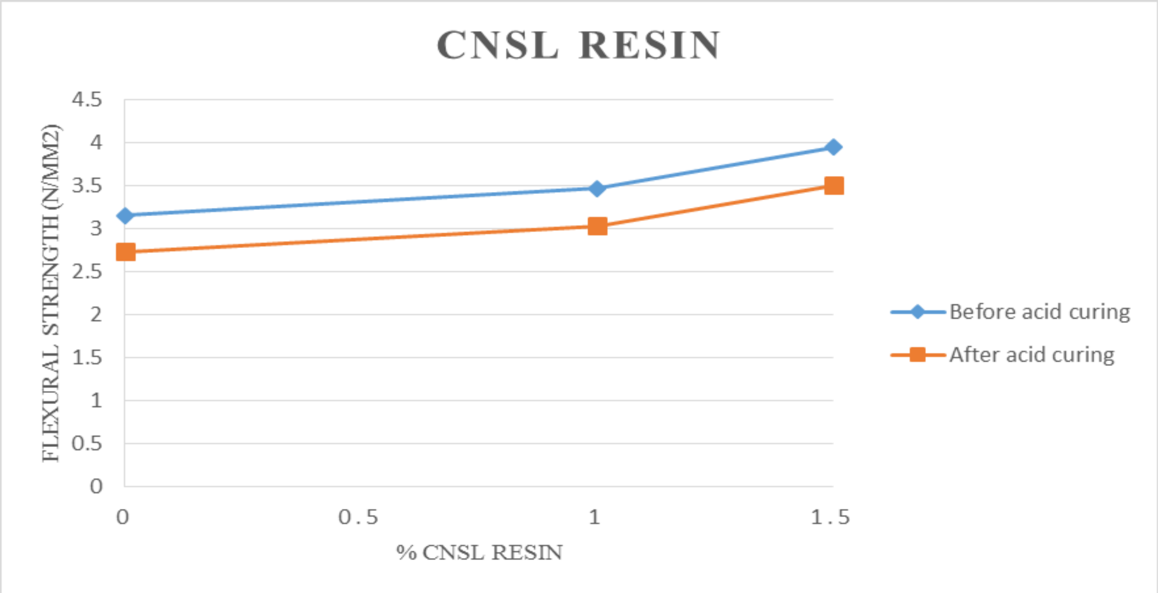

Figure 5:- Flexural strength (N/mm^2) of different proportions of cnsl resin

4.3 Durability test [acid attack (H2SO4 Solution)]:

Cubes of size 150x150x150mm and Beams of size 150x150x700mm were casted for durability test. Testing of specimens was done after a period of 28 days of water curing and then 28 days of acid curing. Specimens were submerged in 10N H2SO4 solution for 28 days.

Following tests were done to check durability test:

4.3.1 UPV (ULTRASONIC PULSE VELOCITY) TEST:

150x150x150mm size cubes were casted for UPV test. Testing of specimens was done after a period of 28 days of water curing and also after 28 days of acid curing. This test is used to check the quality of concrete. This test was performed using UPV instrument.

Pulse velocity (km/s) for different proportions of cnsl resin is as follows:

	Before Acid curing	After Acid curing
	PULSE VELOCITY (km/s)	PULSE VELOCITY (km/s)
0%	4.09	3.79
1%	4.23	3.94
1.50%	4.59	4.31

Table: 6 Pulse velocity of control mix and different proportions of cnsl resin

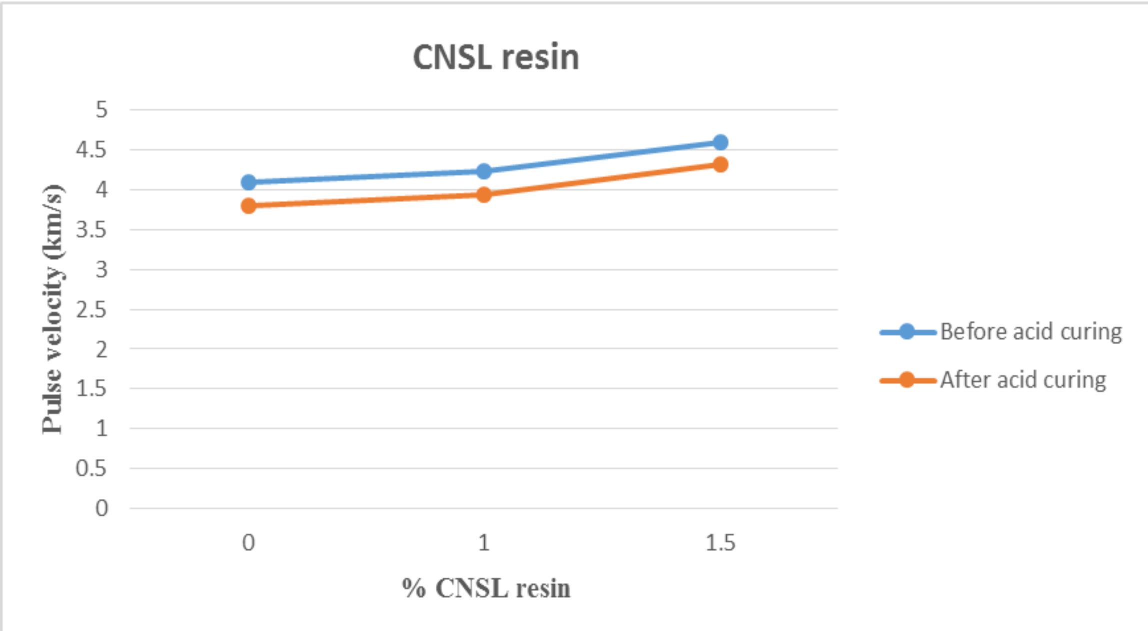

Figure 6:- Pulse velocity of different proportions of cnsl resin

For cnsl resin, 1.5% has the highest compressive and flexural strength amongst the various proportions.Reduction in Compressive strength is least in the composite mix containing 1.5% cnsl while strength reduction ranges from 15%-22% for different mixes. Reduction in flexural strength is least in 1.5% cnsl amongst its various proportions. For cnsl resin, 1.5% cnsl gives the best resistance to corrosion of concrete (acid attack).

5. CONCLUSION

Based on limited experimental investigation concerning the corrosion resistance of reinforced steel in concrete the following observations are made regarding the resistance of cnsl resin which is added as an admixture for M25 grade concrete: For overall mixes, it is concluded that the mix having 1.5% cnsl gives the best resistance to corrosion as compared to different individual mixes.

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