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Review on Experimental Study on Effect of Corrosion on Strength of Steel Reinforcement and Concrete Beam

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Abstract: Reinforced concrete structures are more durable as it is capable to withstand the different environmental exposure. But corrosion of its reinforcement is the limitation to concrete's durability even if it of good quality which is cause due to penetration of chloride, moisture, etc. This paper reviews corrosion of the reinforcement embedded in concrete and rebar solely. Accelerated Corrosion Technique is adopted along with different water cement ratio used for evaluating corrosion by various researchers. Some researchers use minerals like fly ash as a replacement of cement to achieve economy. Various tests were conducted on specimen with corroded reinforcement and non-corroded reinforcement to compare loss in strength and its behaviour for different curing period.
It can be observed that corrosion of reinforcement can adversely affect strength, durability and ultimately its design life. The Structural Designer provides an economic design for structures which is adequate for member for its better performance throughout its design life. But a poor workmanship, poor quality material, improper maintenance introduces a corrosion in concrete members. Proper measures should be taken to select repair technique, repairing material, skilled personnel to prevent future corrosion of reinforcement otherwise the structure will collapse resulting in loss of property and users lives.
Keywords: Corrosion, Reinforcement, Strength, Durability, Economic Design.

I. INTRODUCTION

Concrete is a composite material. It consists of fine aggregate, coarse aggregate and binding material. Binding material commonly is cement in addition to water for hydration with or without admixtures. Strength of steel is more than that of concrete but still concrete more popular in construction industry. It is most widely used construction material .The reason of its popularity is its remarkable resistant to water which makes it superior than steel from structural point of view. It can be given any form or shape which satisfies the structural and architectural aspect. Also ingredients are easily available.

Concrete is weak in tension, its tensile strength is 1/10th of compressive strength due to which it fails in tension. To overcome these tensile stresses it is reinforced in the zone of tension by a material of high tensile strength which is steel. So for better performance of reinforced concrete the bond between the steel and the concrete is most important and bond get affected by Corrosion. It can also reduce the tension resisting capacity of the steel. Concrete is a composite material, it consist of fine aggregate, coarse aggregate and binding material. Binding material commonly is cement in addition of water for hydration with or without admixtures. Strength of steel is more than that of concrete but still concrete more popular in construction industry.

It is most widely used construction material .The reason of its popularity is its remarkable resistant to water which makes it superior than steel from structural point of view. It can be given any form or shape which satisfies the structural and architectural aspect. Also ingredients are easily available. Once the corrosion affects bonding and the tensile capacity of the reinforced steel, the performance of the reinforced concrete element in resisting flexure, shear, etc, is thus likely to be affected.

II. LITERATURE REVIEW

Hulusi Ozkul, Unal Anil Dogan, Ali Raif Saglam, Nazmiye Parlak (2008):

Studied Corrosion Resistance of GGBS Concrete. The aim of this research is to study resistance to chloride induced corrosion of reinforcing steel bars embedded in ground granulated blast furnace slag (GGBS) concrete.150mm x150 mm x150 mm size cube were casted for compression tests and lollipop cylinders of 100 mm in diameter and 200 mm in height specimens containing a 10mm diameter steel bar located in the centre for corrosion tests were casted. Two concrete mixes were prepared such as C25 and C35 at two different binder ratios and tested. GGBS was used as a replacement of cement in ratios of 30%, 50% and 70%.Test results showed that for both concrete mix, increasing amount of GGBS cause reduction in 7-day to 28-day compressive strength. The longest corrosion initiation time were obtained for 70% replaced (cement) concrete specimen and

30% and 50% replaced specimens followed it. On the other hand, for C35 grade concrete, the best performance was of 50% GGBS replaced specimen instead of 70% replaced ones, showing optimum GGBS replacement ratio. Also, cracking was reduced as the percentage of GGBS increases. It can be conclude that for high amount of GGBS replacement, reduction in compressive strength was observed as compared to OPC concrete. Time for corrosion onset for GGBS concrete was 1.5 -2.5 times longer than OPC concrete. Crack formation period for GGBS concrete was 2.4 - 5.4 times longer than OPC concrete. So for chloride-induced corrosion, GGBS as cement replacement seems to be a good solution.

Anand Kuber Parande, B. Ramesh Babu, M. Aswin Karthik, Deepak Kumaar K.K,Palaniswamy N. (2008):

Conduct study on strength and corrosion performance for steel embedded in metakaolin blended concrete/mortar. The aim of this research is to study effect on mechanical property and corrosion behaviour of steel using metakaolin (5–20%) as partial replacement in ordinary portland cement (OPC). Concrete (of proportion 1:3.3:6.9 with a w/c ratio of 0.45)and Mortar (of proportion 1:3 with a w/c ratio of 0.40) cube specimens of size 10cm x 10cm x10 cm were casted using OPC with replacement of metakaolin (MK) by the weight of cement at 5%, 10%,15% and 20% and tested. Best results were obtained for the addition of 15% of MK when compared to other replacement levels and further increase in percentage of MK reduces compressive strength. Minimum chloride penetration was at addition of 5% and 10% MK into the mortar specimen. Corrosion rate was less for 5% 10% and 15% metakaolin replacement than control. But at 20% metakaolin, corrosion rate was high. For mortar specimens with 5% - 15% metakaolin, it have good soundness properties when compared to control system and vice versa for 20% metakaolin. Also, lesser values of the coefficient of water absorption for 5%, 10%, and 15% of metakaolin replacement were observed and vice versa for 20% metakaolin. Time of initiation of crack was higher for 15% MK replacement than other systems studied and after it time decreases. It was concluded that good corrosion resistance property were observed at 15% of metakaolin replacement with cement.

S.Muralidharan, A.K.Parande, V.Saraswathy, K.Kumar, And N.Palaniswamy (2008):

Studied effect of silica fume on the corrosion performance of reinforcements in concrete. The effect of silica fume on the strength of concrete and corrosion of reinforcement in mortar and concrete was investigated.100 mm × 100 mm ×100 mm concrete cubes were casted using 1:3.3:6.9 mix proportion with water/cement ratio of 0.50. Specimens of only OPC and OPC with various percentage of silica fume were casted and tested. Steel rods were embedded in cylindrical mortar (1:3) specimens of size 58 mm in diameter and 60 mm in height using W/C ratio of 0.45. The mortar specimens containing ordinary Portland cement (plain) and OPC with various silica fume percentage of 2%, 4%, 6%, 8% and 10% were subjected to anodic polarization studies. The result shows slightly higher compressive strength in specimens than control system. At 8% silica fume level better corrosion resistance was observed. At 10% silica fume level when current was doubled showed lesser corrosion resistance. It can be conclude that at 8% addition of silica fume satisfactory corrosion resistance was observed and beyond this it loses it corrosion resistance property.

Dr. Faiza E. Gharib, Ahmed Abdulhaq and Ali Abd (2012):

Performed Experimental Study of Reinforcing Steel Bars Behaviour Under Corrosive Conditions. In this study, corrosion behaviour of steel reinforcing bars was investigated. Eight concrete mix groups were established and concrete mix was designed for test. Different sulphuric acid ratio was used for corrosion test. The steel bars with and without coating were used. Specimen corrosion was studied by using corrosion rate and hardness test and results were compared between coated and uncoated steel rebar. It is observed that the fatigue life of steel bar is reduced with increase in corrosion level. It gets affected by environment, loading conditions, steel bar type, steel bar coating and so on. The Corrosion effect on coated bars was less as compared to steel bars without coating. The strength loss of steel and bond slip (between steel bar and concrete) was high in case corroded steel as compared to un-corroded steel.

Naga Chaitanya and Vamsi Krishna (2014):

Studied Flexural Strength of Reinforced Concrete Beam Due To Corrosion. The focus of this study is to analyze the strength experimentally of beams with corroded steel reinforcement using Ordinary Portland cement. Accelerated corrosion technique was used to corrode the beam for test. Total 17 reinforced concrete cantilever beams with OPC of grade M20, with cross sectional dimension of 300mm x 400mm and 2150mm in length were casted. Beams were tested as vertical cantilever beam in specially prepared loading setup and load deflection behaviour is studied. The behaviour of reinforced concrete beams with 2.5%, 5.0%, and 7.5% amount corrosion of steel bars is studied, out of which 5 were control beam. The control beams failed in flexure at an ultimate load, 92.09 kN. The 2.5% corroded beams failed at an ultimate load 87.83 k N and remaining 5%, 7.5% corroded beams failed at 86.17 k N, 72.14 kN. As compared to the controlled beam, 2.5%, 5% and 7.5% corroded beam specimen takes 7% and 25% less load. The author found that, in aspect strength the control beam is more efficient than that of corroded beam and deflection of control beam was less as compared to corroded beam. Increase in the corrosion rate, above 5%, cause reduction in ductile property of beam. The

number of crack that developed in control beam is more than corroded beam but as corrosion increases the width of cracks increases in corroded beam as compared to control beam.

K. Venkateswara Rao,B. Devi Pravallika and K. Phani Krishna (2016):

Studied Flexural Strength and Corrosion Properties of Reinforced Concrete Beams. The focus of this study is to investigate and compare the flexural strength and theoretically estimated loss of steel of corroded and un-corroded reinforced concrete beams with cement replaced by 0%, 10%, 20%, 30% fly ash. Accelerated corrosion technique was used with 5%Nacl and impressed current were adopted to corrode the beam experimentally. Total 24 beams are tested after complete curing for 28 days, under UTM with a loading rate varying from 1.2 N / (mm2/min) to 2.4 N/ (mm2/min) and loss in steel was also calculated. It can be concluded that increase in fly ash percentage increases flexural strength and a considerable decrease in steel loss. At 10% replacement with fly ash steel loss was greatly decreased and a little change in flexural strength.

Xiaolin Zhang, Xuebing Liang, Zeqiang Wang, Hancheng Huang, and Haijun Zhou (2016):

Studied the effect of Steel Corrosion on the Bond–Slip Performance of Reinforced Concrete. In this paper the effects of reinforcement corrosion on bond performance between high yield strength deformed bar and concrete is studied. Total 20 specimens were casted, out of which 10 were of M20 grade and 10 were of M40 grade with varying percentage of steel corrosion. Specimen was a concrete prism with rebar set with two stirrups to prevent confinement. Two PVC pipe were used to limit bond length. The accelerated corrosion technique was used for corroding rebar and pull out test was also performed to check bond stress. The author observed that increase in corrosion cause decrease in bond strength for both grade of concrete. Also, as the corrosion rates increase, the energy dissipation of the specimen has also increased firstly and then decreased, and it is highest for a reinforcement corrosion ratio of about 4%.

Rizwan Azam, Ahmed K. El-Sayed, Khaled Soudki (2016):

Studied Behaviour of Reinforced Concrete Beams without Stirrups subjected to Steel Reinforcement Corrosion. The effect of corrosion on the behaviour of reinforced concrete beams without stirrups was experimentally investigated. Total 7 reinforced concrete beams of size 150mm X 250mm X 1700mm without stirrups were constructed. Three different longitudinal reinforcement ratios (0.91%, 1.21%, and 1.82%) and two different corrosion levels (3% and 10%) were selected for test. Three point bending test was used with 1400mm span. For low corrosion level, maximum crack width was 0.6mm and for medium level corrosion crack width was 1mm - 1.25mm.The cracks was along reinforcement for 2 bars as main reinforcement and for 3 bars, irregular cracks developed at support and bottom of mid-span. It was observed that beam with less spacing were having horizontal crack which are bad for bond. The process of corrosion was slow in beam with higher percentage of steel than beams with lower percentage of steel. The load carrying capacity of beams with higher percentage of steel was more than beams with lower percentage of steel (for 10% corrosion, the load carrying was 55% of un-corroded beam). The failure of beam was due to bond failure instead shear failure.

Ahmed K. El-Sayed, Raja R. Hussain, Ahmed B. Shuraim (2016):

Studied the effect of stirrup corrosion on the shear strength of the reinforced concrete short beams. The effect of corrosion of stirrups on the shear strength and behaviour of reinforced concrete beams was experimentally investigated. Total fourteen full scale reinforced concrete beams (200mmX350mmX2800mm) were constructed and tested under four-point bending test till failure. They were reinforced with 4-25mm bars at bottom and 2-10mm bars at top along with 8mm stirrups at variable spacing of 100mm, 150mm and 200mm.Four point bending test was used. The diagonal cracking load was more for 30% mass loss of steel of specimen than 10% mass loss of steel specimen. The corrosion cracks and stains were observed on beam after the test completion. These cracks were measure of corrosion of stirrups and its width increased with increase in corrosion. The concrete beams degraded and reduction in the shear strength and stiffness was observed of corroded beam as compare to un-corroded beam. Except beam with least spacing all other beams fail due to failure of stirrups means due corrosion. Shear strength was decreased with increase in crack width, while its reduction was decreased with decrease in spacing of stirrups and shear span to depth ratio.

Syed Sohailuddin, Mirza Affan Baig, Riya Dey, Abdul Mohsin, Simran Goswami, Mohd. Faizan, Mohd. Tanweer Alam (2018):

Studied corrosion behaviour based on flexural strength. The objective of this work was to study the effect of corrosion of reinforcement on the flexural strength of reinforced concrete beams. Accelerated corrosion technique with 5%Nacl solution was adopted to corrode beams. 18 Beam specimens of size 180mm × 230mm × 700mm are prepared of grade M25 for Portland Pozzolana Cement (PPC) and tested. It is observed that strength in conventional beam is gained after 7 days and in corroded beams, the corrosion comes into play after 7 days. The corroded beams had less load carrying capacity and higher deflection then the conventional beams. Number of cracks developed, were more in conventional beams as compared to Corroded Beams, but as the rate of corrosion increases the width of crack was increased in Corroded Beams than in Conventional Beams. Poor workmanship leads to failure but corrosion is long going process and is deadly and its failure is mostly uncertain.

Shrikant R. Kale and Sudhir Patil (2019):

Executed Experimental Investigation Of Effect of Corrosion on Reinforced Concrete Beam. The aim of the study is to investigate the effect of corrosion on torsional strength, shear strength and flexural strength of reinforced concrete beams. A beam of 150mmX150mmX700mm with 2 bars of 10mm diameter are provided at top and bottom with 8mm diameter stirrups and concrete cube of 150mmX150mm of M20 grade were casted. Universal testing machine (UTM) is used for flexural and shear strength evaluation and load and deflection behaviour is analyzed. A special setup was prepared for finding torsional strength. The study shows that 26.18% reduction in ultimate load carrying capacity at 9% of corrosion. The shear and torsion resisting capacity was also reduced. Width of crack were less for 0% - 6% of corrosion but width increases rapidly for 6% - 9% of corrosion.

III. CONCLUSION

From the study, we can conclude that corrosion is big problem, need due attention. Corrosion reduces strength of steel firstly and then of concrete member. The reinforced concrete structure gets corroded due to expose of reinforcement to atmosphere. The environmental condition vary from place to place so, does the corrosion rate Also, as per different environmental condition different measures are taken to reduce corrosion effect and its occurrence. This will increase strength and design life of structure.

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