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Crack Width Reduction in Cover Zone Using Fibre Reinforcement and Crystalline Admixture

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ABSTRACT

Concrete structural elements are prone to cracking due to the low tensile strength of concrete, and while it cannot be completely eliminated, efforts are being made to reduce its development, propagation, and increase in crack width. Reinforced concrete beams are typically provided with higher cover to reinforcement for long-term serviceability and durability, but this practice may actually increase cracking and reduce serviceability over time. This study aims to investigate the effectiveness of adding fibers to the concrete mix in reducing the onset of cracks and crack widths in reinforced concrete beams with higher covers. The study involved testing smaller beams with normal cover containing fibers, followed by reinforced concrete beams with higher cover containing different proportions of fibers.

1. Introduction

Concrete is the most important construction material in the world. It is a mixture of sand, gravel, cement and water. Concrete is good in compression but weak in tension. Since it is weak in tension, tensile crack formation is common in concrete buildings and structures. Cracks on roof and walls of bathrooms, swimming pool areas are most common and serious issue facing nowadays. Even the newly constructed buildings face this problem. When these cracks are formed on concrete, concrete become more permeable to water. This create damping effect and degrades the properties of concrete.

In order to tackle this problem, tendons are added in cover zoneto reduce the formation of crack. Also, Crystalline admixtures are added in various proportions which acts as permeability reducing agents. Crystalline admixtures (CA) have a two-fold effect: permeability reduction and self- healing of cracks. The chemical composition of these admixtures is kept confidential by the company, but the main constituents are silicates, pozzolans, slags and fillers. CA will react with cement to form complex compounds, among which one acts as pore blocker and other have self-healing property of cracks. The combined action of crystalline admixtures and fibres help in crack reduction due to entry of water through bathroom floors, swimming pool etc.

2. Crystalline admixtures

Crystalline admixtures are substances which are capable of reducing the permeability of concrete and self-healing of cracks. CA are composed of silicates,pozzolans,slags and fillers.The majority of CA are commercial products and their chemical composition is kept confidential. The leading companies using CA are Xypex,Penetron and Sika.CA on exposure to water form insoluble crystals which fills up the cracks. The active component of CA is denoted as $M_xR_x$and the chemical reaction taking place is:

$$3CaO\text{-}SiO_2 + M_xR_x + H_2O \longrightarrow Ca_xSi_xO_xR\text{-}(H_2O)_x + M_xCaR_x\text{-}(H_2O)_x$$

The effect of CAs may cause the blockage of the pores and the formation of hydrophobic layer in the capillaries.The product $M_xCaR_x\text{-}(H_2O)_x$ acts as a pore blocker in the micro-cracks and capillaries resulting in resistance to penetration of water.The primary mechanisms for an external closure of the crack is the formation of calcium carbonate ($CaCO_3$)

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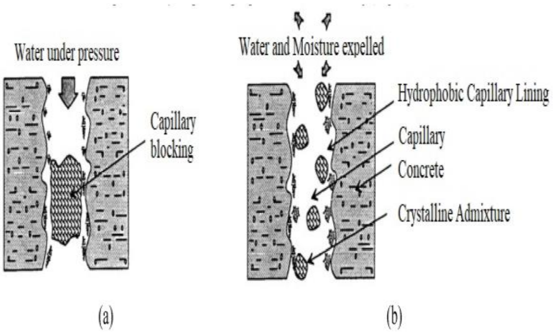
stimulated by the presence of CA, which in turn promotes the dissolution of Ca^{2+} ions from the matrix. Thus, the external crack surface has optimal concentrations of Ca^{2+}, carbonate (CO_3^{2-}), and bicarbonate (HCO_3^-) ions dissolved in water. Consequently, this interaction leads to the $CaCO_3$ precipitation that is hugely related to the increase of the material's durability.



Crystalline admixture action on blocking and hydrophobic coating in the cracks

(a) Under pressure and (b) water and moisture expelled (Source:A. de Souza Oliveira et al. 2021)

3. Tests

3.1 Compressive strength test(IS456:2000)

Compressive strength can be defined as the capacity of concrete to withstand loads before failure. Compressive strength test is conducted by casting cube specimens of size 150mm×150mm×150mm. It is generally conducted after 7, 28 and 56 days of curing. This test shows how the material will react when it is being compressed.Mazen J. et al., studied the effect of crystalline admixture on compressive strength of M30 concrete at 3,7, 14 and 28 days.They concluded that 28 days strength of cubes with admixture is slightly higher than 30MPa.

3.2 Flexural strength test

Flexural strength test is conducted using beams of dimension 500mm×100mm×100mm. Beams are casted and tested using Universal Testing Machine after 7 and 28 days of curing. Woosuk Kim. et al. studied the effect of steel fibres on flexural strength of concrete. When fibre volume increased from 0 to 0.75%, flexural strength increased by 15%. When the volume of fibres increased from 0.75 to 1.5%, flexural strength drops.

3.3 Rapid chloride penetration test (ASTM C 1202)

This test is conducted to evaluate the resistance of concrete to chloride ion ingression. RCPT mould is a cylinder of diameter 100mm and thickness 50mm.Mohd Nasim. et al. conducted RCPT test and concluded that the charge decreased significantly for 28 days but there was no significant change for 56 days upon the addition of crystalline admixtures. According to them this improvement in chloride penetration resistance in concrete with crystalline admixtures is due to reduction in capillary action and volume and its microstructural characteristics.

3.4 Splitting tensile strength test

The splitting tensile strength will be determined by dividing the maximum applied load by the appropriate geometrical factors. ASTM C496 (Ref. 7.1) formed the basis for the development of this procedure.According to Emdad et al., the inclusion of steel fibers has been found to have a considerable effect on the split tensile strength of HSC. It appears that the split tensile strength increases as the volume content of steel fibers increases. The improvement in split tensile strength can range from 55 to 100% when compared to reference specimens. This finding is significant and can be utilized to enhance the strength and longevity of HSC in different construction applications.

4. Crack width(IS 456:2000)

Vandawalle et al. Carried out both theoretical and experimental investigation on the cracking behaviour of reinforced concrete beams containing steel fibres and also looked into the effect of aspect ratio of the fibres. It was found out that fibres of greater aspect ratio (l/d) added to the concrete resulted in lesser crack spacing and crack width. To study this he conducted four point bending test on

The theoretical crack width computation is done using IS 456:200.The ANNEX F of the code deals with the calculation of crack width. Design surface crack width

$$W_{cr} = \frac{3a_{cr}\varepsilon_m}{1 + (2(a_{cr} - C_{min})/h\text{-}x)}$$

where

a_{cr} = distance from the point considered to the surface of the nearest longitudinal bar.

C_{min} = minimum cover to the longitudinal bar

ε_m = average steel strain at the level considered

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beams.

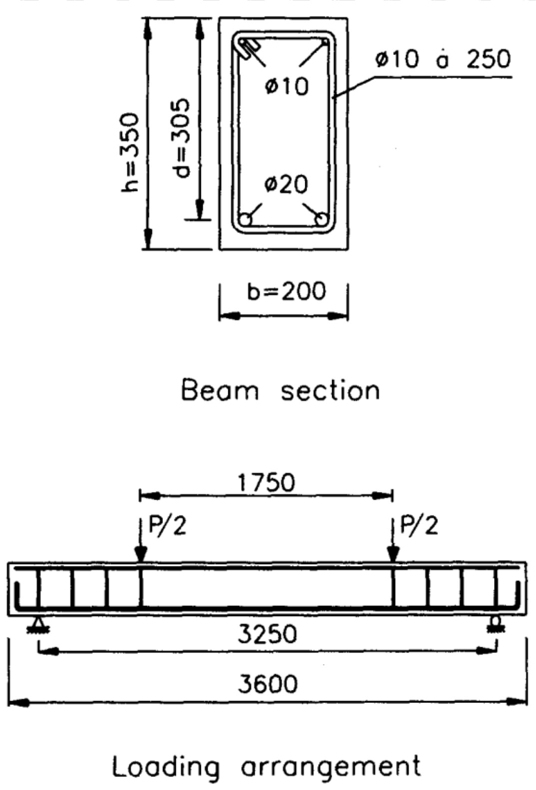

Fig 2:Test setup(Source:Vandawalle et al.)

h = overall depth of the member

x = depth of the neutral axis

$$\varepsilon_m = \varepsilon_1 - \frac{b(h-x)(a-x)}{3E_s A_s (d-x)}$$

where

A_s = area of tension reinforcement

b= width of section at the centriod of the tension steel

ε_1= strain at the level considered, calculated ignoring the stiffening of the concrete in the tension zone

a= distance from the compression face to the point at which the crack width is being calculated

d= effective depth

5.Conclusion

According to Mujeeb M Rahman et .al the optimum amount of CA while considering permeability is 2% it reduced water absorption nearly to 0.Aline De Souza Olivera et .al revealed that CA has an influence on healing capacity. It will perform as a healing stimulator depending on the mix design and CA dosage. According to Shaang et .al strengthening using half width CFRP sheets improved the stiffness of LWRC beams and reduced the deflection without a corresponding increase in ultimate load capacity , whereas the beams strengthened using full width CFRP sheets showed a significant increase in ultimate load capacity and reduced deflection.According to Jubum Kim et .al the coefficient of variation of flexural strength with respect to variation in volume of steel fibres is 0.14.

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