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RESTRENGTHENING OF RCC BEAM BY BEAM JACKETING

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Abstract: The partial damage of structural components cause failure of serviceability and safety requirement of structures and economical losses of owner. Re-strengthening of structures during its life cycle management became major issue for civil engineers. The purpose of this paper is to assess the structural performance and strength behavior for a partially damaged flexural member and also the ultimate load capacity of cracked reinforced concrete beam re-strenghtened by RCC beam jacketing. Structural components taken into consideration are flexural cracked and un-cracked reinforced concrete beam. The numerical analysis is conducted by using the finite element software ANSYS to evaluate the behavior of cracked and un-cracked beam under different loading conditions. A further numerical analysis is done for the same beam after re-strengthening by 'beam jacketing' technique. It is observed that beam jacketing technique reduces the stress at crack tip to a value less than that of uncrack beam stress . It reduces not only the stress at crack tip but also increases the load carrying capacity and stiffness of the beam.

Keywords: *Crack and un-cracked beam, restrengthening, RCC beam jacketing, FEM*

1.0 Introduction

Reinforced concrete beams need strengthening when the flexural capacities of the beam exceed the allowable limiting value. During life cycle of structures such accident may occur because the assumed design load conditions in design step may be not coinciding during design life of structures. Again during service life, structural performance degrades because of material deterioration, corrosion, carbonation, alcali-silica reaction (ASR) etc. This environmental deterioration factors also accelerate the process of reduction of flexural capacity of beam togther with mechanical loadings and causing crack in beam. Also a structure designed by old practice like for gravity loads are unable to withstand seismic forces and caused wide spread damage. In early stage, research on re-strengthening of concrete structures done by addition of beam, post tensioning or propping and supporting (Saadatmanesh *et al*.,1989; Klaiber *et al*., 1982). At present, significant improvement of high performance materials like steel and fiber reinforced plastic (FRP) composites and epoxy or adhesive materials, the external plate bonding technique found to be more effective method (Zattar and Mutsuyoshi, 2004; Jummat and Alam, 2007). The effectiveness of these methods depend on proper bonding between concrete and steel plate. The premature deboning of adhesively bonded plate may arise flexural, axial and shear peeling failure which are major problems in plate bonding technique (Jummat and Alam, 2006; Jummat *et al*.2011). Bolting of FRP or steel plate with concrete may overcome the above failure, but bolt slipping and ductile failure (Deric and Oehlers,2001) make this method ineffective. As a result, selection of appropriate re-strengthening technique based on structural response under loading condition needs higher priority. For overcoming this problem associates with current practice, the reinforced concrete jacketing can play an effective role in re-strengthening cracked beam.

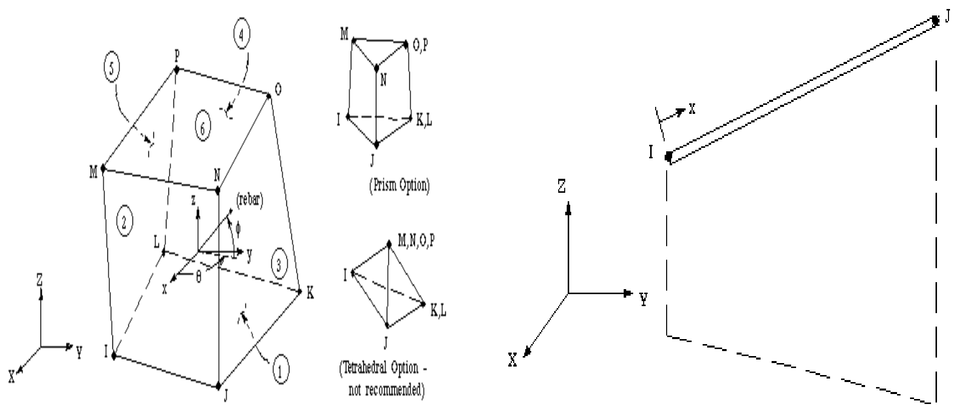
This paper describes the load carrying behavior of cracked and RCC jacketed beam under various loading conditions. RCC jacketing increases the member size significantly, but it is advantageous because, increase the member size also increase the stiffness which is more useful where deformations are need to be controlled (Losanne, 2003). Design for strengthening work is based on composite action between the old and new materials. Strain compatibility calculations may have to be carried out carefully to account for factors such as creep. As the new jacket behave compositely with the parent member, the new jacket can take additional loads and reduce the stresses and strain in the old one.

2.0 Finite Elemet Modeling of RC Beam

Reinforced concrete is a composite material consists of concrete and rebar. Modeling of reinforced structure is quite complex because it requires perfect bonding at concrete and reinforcement interface. For modeling of reinforce concrete beam *Solid 65* and *Link 8* element are used to model concrete and reinforcement respectively as shown in Figure 1. Solid 65 is a 3-dimensional solid element which is capable of cracking in tension and crushing in compression, plastic deformation and creep. The element is defined by 8 nodes having three degrees of freedom at each node. Link 8 3-D spar is a link element with three degree of freedom at each node can take uniaxial tension and compression having plasticity, creep, swelling, stress stiffness properties (ANSYS). The reference model is a 12 feet span beam having flexural reinforcement with 4 no. 6 reinforcing bar is considered. The beam is assumed to have a crack of depth 2 inch at the bottom of the mid span and also subjected to a concentrated load of 4500 lb at mid span and unifromly distributed load of 10 lb/in^2. The geometry and boundary conditions for beam are shown in Table 1.

Table 1: Geometry and Boundary conditions for beam

Property	Amount/condition
Span length (feet)	12
Depth (inch)	10
Width (inch)	10
Crack depth (inch)	2
Crack opening (inch)	0.1
Support condition	Simply suport
Concentrated load	4500 lb
A distributed load	10 lb/in^2



(a) (b)

Figure1: (a) Solid 65 3-D reinforced concrete, (b) Solid element LINK 8 3-D spar

3.0 Finite Element Analysis of Cracked and Un-cracked Beam

Finite element model of the reference beam has carried out using ANSYS software. The concrete was modeled by 8 noded solid 65 element and the reinforcing bars were modeled by link 8 3-D spar which is a 2 noded truss element. The finite element meshing of un-cracked beam and stress condition are shown in Figure 2(a) and 2(b). The target node for uncrack beam stress is same as that of the crack tip of cracked beam. The crack beam has modeled such that it has crack of depth 2 inch with crack opening 0.1 inch. The crack tip has modeled with very fine mesh to represent proper stress concentration at crack tip as shown in Figure 2(c) and 2(d). It is found that the maximum stress at the crack tip after crack generation is 800.779 psi which is 4.4 times of uncrak stress of value 180.46 psi as shown in Figure 2(b) and 2(e).

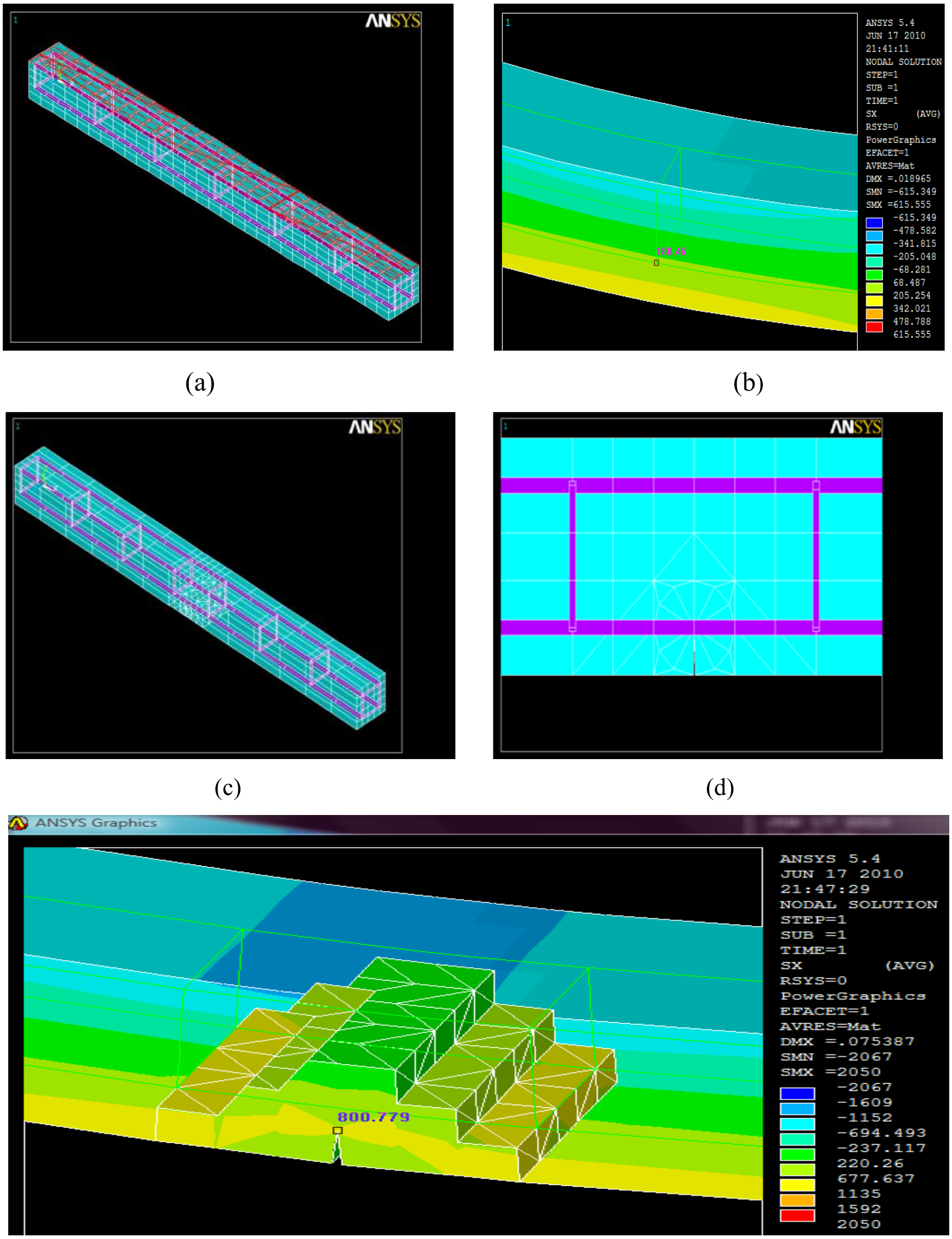
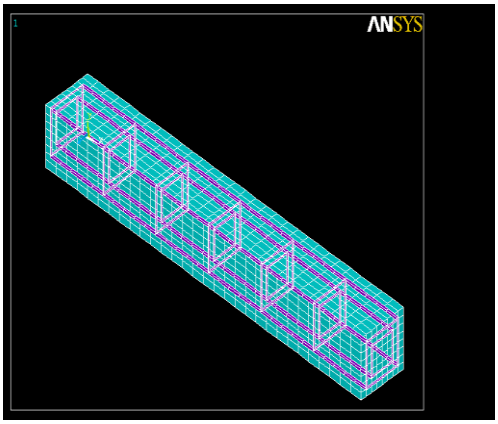
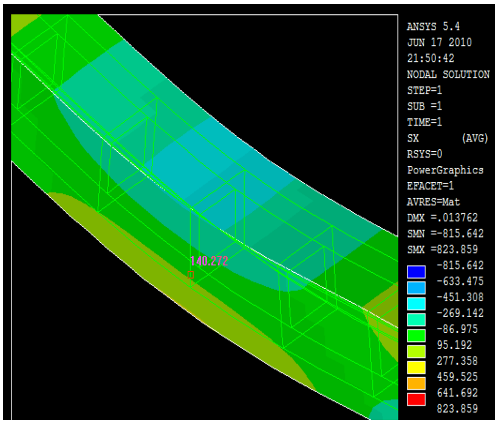


Figure 2: (a) Un-cracked beam model, (b) Un-cracked stress of the beam of target node (c) Cracked beam model, (d) Cross view of crack, (e) Cracked beam stress at crack tip





(a) (b)

Figure 3: (a) Modeled beam after jacketig (b) Crack tip stress after jacketing

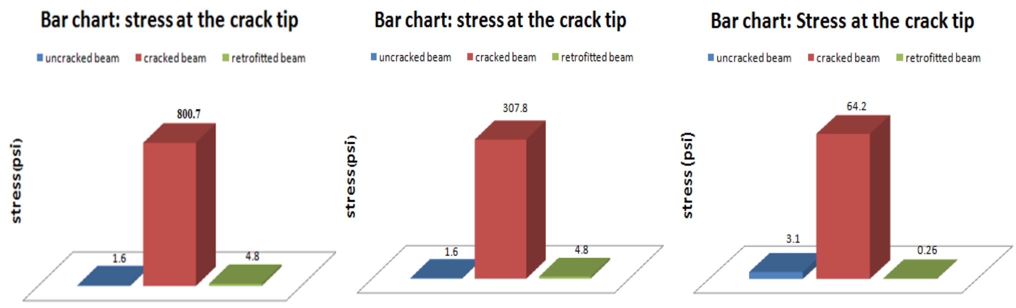
4.0 Finite Element Analysis of Re-strengthening Beam

The cracked-beam is re-strengthened by beam jacketing method. The beam is retrofitted with addition of 4 no.6 longitudinal bars and no.3 transverse steel just outside of the original concrete section and the original concrete section is covered by 2 inch thick new concrete as shown in Figure 3(a). The re-strengthening beam is analyzed under the same loading and boundary condition that was used for un-cracked and cracked beam. By analysis of RCC jacketed beam, it is found that the stress at same position of cracked tip is 140.3 psi which is 5.7 times less than that of cracked beam stress as shown in Figure 3(b).

5.0 Result and Discussion

The load carrying capacity of cracked, uncracked and retrofitted beam has checked under three loading conditions like I) Distributed loading II) Third point loading III) Concentrated loading at the middle of the beam. It is found that after crack generation the normal stress along X direction increase about 2 to 4.5 times, along Y direction about100 times and along Z about 20 times on average. Significant stress variation is found along Y plane than other plane. The shear stresses also significantly increase along YZ plane. After application of beam jacketing normal stress along all directions are found within allowable limit and also below than that of uncrack beam stress. In every case the normal stresses along X,Y,Z at the crack tip of un-cracked, cracked & re-strengthened beam is shown in Figures 4, 5, 6 and Figures 7, 8, 9 for different loading conditions.

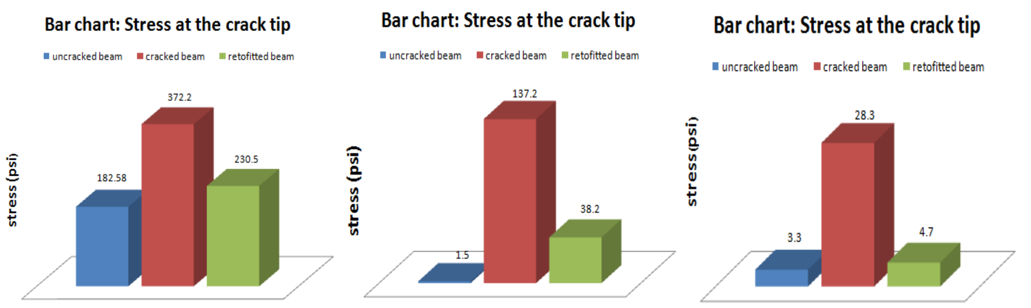
Loading condition I: Uniformly Distributed Load



(a) (b) (c)

Figure 4: (a) Stress along X direction, (b) Stress along Y direction, (c) Stress along Z direction

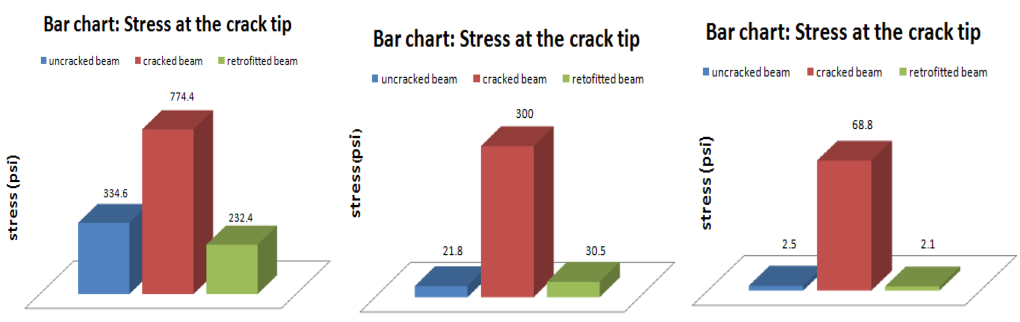
Loading condition II: 3rd Point Loading



(a) (b) (c)

Figure 5: (a) Stress along X direction, (b) Stress along Y direction, (c) Stress along Z direction

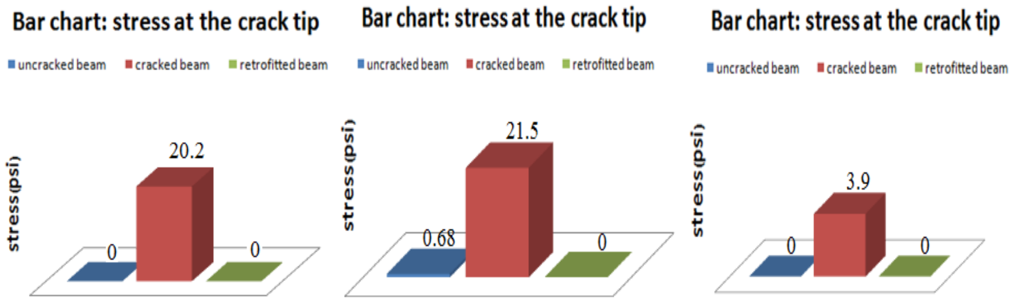
Loading condition III: Concentrated Load at Mid span



(a) (b) (c)

Figure 6: (a) Stress along X direction. (b) Stress along Y direction, (c) Stress along Z direction

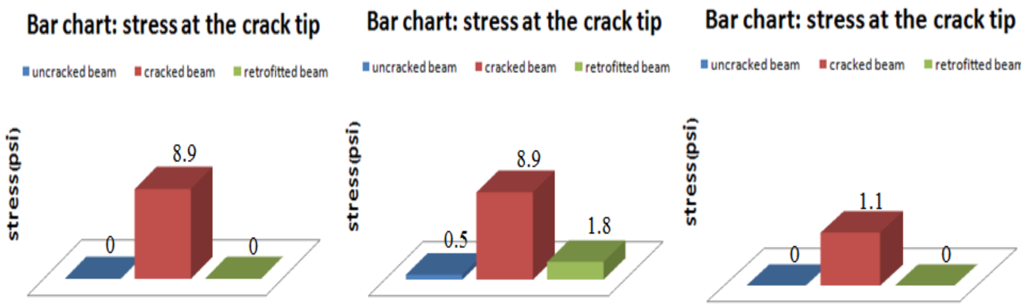
Loading condition I: Uniformly Distributed Load



(a) (b) (c)

Figure 7: (a) Stress along XY direction, (b) Stress along YZ direction, (c) Stress along YZ direction

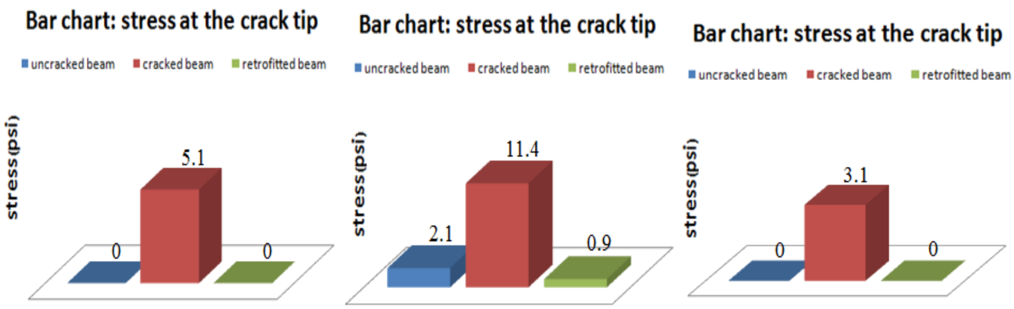
Loading condition II: 3rd Point Loading



(a) (b) (c)

Figure 8: (a) Stress along XY direction, (b) Stress along YZ direction, (c) Stress along YZ direction

Loading condition III: Concentrated Load at Mid span



(a) (b) (c)

Figure 9: (a) Stress along XY direction, (b) Stress along YZ direction, (c) Stress along YZ direction

6.0 Conclusion

The analytical study on restrengthening of RCC beam by beam jacketing has done using fully 3D computerized beam model using ANSYS program. It is found that the stresses condition at crack tip of cracked beam is significant compared with the stresses of uncrack beam. Application of RCC jacketing not only reduce the stress value than that of uncrack beam stress, also increase the stiffness and load carrying capacity of beam because of larger cross section. Perfect bonding between old and new concrete and addition of extra longitudinal reinforcement helps to transfer stress from old concrete which result is reduction of crack tip stress. From analysis result the following conclusion can be drawn.

1. Beam jacketing method reduces the stress at crack tip to a value less than the stress at that position before cracking.
2. Re-strengthening work by enlargement of the section of the beam increasing the stress capacity at the location other than the crack location.
3. As beam jacketing increasing the size of the beam, stiffness of the beam also increases as well as the beam can take additional accidental load.
4. For beam jacketing over old concrete, a perfect bonding between the old and the new concrete must be ensured first. Otherwise load cannot be transferred effectively.
5. As steel can take much more tension than concrete, steel size can be reduced.

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