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Analysis of the Resistance of Joints in Reinforced Concrete Strengthened by FRP Sheets against Released Forces of Earthquake

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Abstract

The beam-column joints in reinforced concrete are crucial parts of structures. Earthquake exerts a high shear force on reinforced concrete which can lead to transfiguration of beam-column. As much attention is not usually paid to junctions in implementation of reinforced concrete structures; therefore, reinforcement of joints and increasing their flexibility are important issues studied by different researchers. A limited number of elements are considered in the present study based on analytical prototype for beam-column joints. In this research, the purpose is the reinforcement of resistance and flexibility of joints against lateral forces which exert in diffraction frame, through resistance of reinforced concrete by using FRP layers. Each of these samples is strengthened by using FRP layers which are made of carbon. A sample of external junction has been specified with its dimensions and placement of reinforcing bars. This method is based upon using leaflets in joint zone, along different directions. The mentioned joints have been modeled three dimensionally and analyzed under nonlinear static load using finite element method by ABAQUS software. Nonlinear materials related to concrete are also considered. Communication bending in connection system between strong beams and columns has been taken into consideration as well. Comparison of results between strengthened and non-strengthened samples for all three joints shows by the reinforcement implemented in this research the inflexibility, porter age capacity and also final flexibility of connections have been improved much.

Key words: Making resistant, Reinforced concrete joints, FRP layer, ABAQUS

1. Introduction

Beam-column joints are typically considered the weakest connection in resistance mechanism in LRC structures against earthquake. In recent years, frequent breakage of joints has caused worries about efficiency of structures. The Beam-column joints are put under extreme shear forces by a severe earthquake, so increasing the resistance of this structures is essential. As a result, joints of the beams and columns experience the worst change in shear shape which can lead to cracks in buildings. Furthermore, shear capacity of joints can decrease the degree of shear breakage and be effective on all structures and buildings and their degree of resistance. The joints have great portion in the frame action in flexible bending system. Reduction of toughness and resistance in joints has extreme influence on frame reaction against lateral loads. Accordingly due to the mentioned issues, the joints are known as a weakness point in flexible bending systems. Laboratory studies have demonstrated that in connections the condition is undesirable under final load which results in swinging of the beams and columns. This rotation causes change in the final shape of beams and columns to 50 percent and changes the shape of structure. So it is essential to have non-tensile change of the shape in concrete joint as the result of connection lapse. The cutting forces which are results of tensions and pressures can lead to refraction in joint nucleus. These are shown in Fig. 1.

To absorb energy and control relative change in formation of the floors during earthquake, the standard of designing weak pole and strong column is observed in flexible bending reinforced concrete structural. This standard designs the frame in a way that column and joint act almost in elastic range. In recent years, with progress in FRP production methods which go along with reduction of price, use of composite layers in reshuffling of components increases the implementation speed and is an effective and economic way. The studies carried out to reinforce concrete joints by FRP are not as much as those performed to reinforce other parts of components.

Laboratory studies have done by Pessiki et al. (1990). They performed research on reinforced concrete joints with firm underneath columns both in joint zone and in tensionless zone. Their studies showed that, the main fraction of constructions is confined to joints network. These joints indicated that cutting resistance is about, where the complete concrete resistance in is joints network in MPa. The final malleability and frightens has sharpened.

The earliest laboratory researches were done by Otany et al. (1985). The sample used by them was previously used by Pantazopolod and Bonachi (1994) for examining steady loads. This condition gives us a suitable opportunity to compare the results of proposed model with the analytical model which they presented.

Concerning the reinforcement of exterior joints, studies accomplished by Pervin and Granta can be mentioned (2000, 2001). Their researches were experimental and numeral modelling. They dealt with L form in reinforcing the samples and indicated the rise of bending resistance and reduction in flexibility. Also Pantidlis et al. (2000) dealt with reinforcement of exterior joints in laboratory research the most important result of which was the increase in shear resistance of the joint and enhancement in load capacity of column.

Regarding the reinforcement of interior joints, Moslem (2000) in University of California put cracked joints under cyclic loading after mending them by using complete composite covering. Increase in bending resistance and flexibility was the result of their research/ Also Samali et al. (2002) in University of Sidney aimed to reinforce interior joints. The important result of their experiment was the enhancement in load capacity.

Another effort for modeling these components was made by Hafman et al. (1992). Their findings relied on easy goingness about this problem in order to model these joints.

They also decreased the amount of components' capacity against the exerted load. In their analysis, the capacity of joint was calculated by using ACI_ASCE 352R (1976). A further effort was made by Bracci et al. (1992) to model the joints which are under loading pressure and stress. Their studies were consistent in decrease of stiffness of beams and columns and showing the degree of reduction in resistance.

In the current research, after an introduction to connection, we study the reinforcement of external connections. We deal with all three kinds of joints, and then the three dimensional finite elements modeled by ABAQUS software are analyzed in nonlinear manner. The analysis results for reinforced samples and base are compared with each other.

2. Research Methodology

In the present study, the components 12 nods for joints network were used.

This component has the advantage of cube displacement. Using single cube displacement which is shown in joint lattice has special advantage in reinforced column which will be explained later.

Fig. 2 illustrates the proposed beam-column connection model, and it is shown that the joints network of beam and column is limited by transmittal components with proximity of other beams and columns. Transmittal components in non-tensional network have 10 nods.

Each component consists of different forces on itself and different transmitting forces to other components. In this range, most of common linear materials show the same behaviour. The presented forms are more realistic than computer programs which use simple calculations and indeed ignore most effective factors. The remained length of beam and column is modeled using existing linear components. The point that we have not made a comparison among components pertains to degree of freedom. Krishnan’s and Desayi’s proposed curve (1964) is used for introducing stress-strain curve. Compressive resistance of concrete is considered 36.4 MPa and its tensional resistance is considered 25 MPa. Characteristics of CFRP used in this research are shown in Table 1.

In all cases, three layers of FRP are used for reinforcement of samples. These layers which are introduced as linear elastic in software have elastic module of 230 GPa and Poisson ratio of 0.3.

To model bar anchor, nonlinear springs were used in external connections (Hoffmann et al., 1992; ACI-ASCE Committee 352, 1976). Fig. 3 demonstrated base connection studied in the present research.

Fig. 4 depicts the reinforced connection sample as well as direction of fibers utilized in reinforcement.

In reinforced sample joint, FRP layers used in lateral beam are used to reinforce beam Bending and delay crack in beam and also to make the critical cross-section in beam away from edge of column.

Since beam is weak and column is strong, so the highest strain in column's longitudinal reinforcement occurs on the edge of column; therefore, we decrease the intensity of taunt in the zone of armature’s resignation to the nucleus join and delay the breakage of joint by decreasing strain in column’s linear armature and transmission of critical cross-section.

The used sheets along the column are to reinforce the column and delay cracking in the column and make strong, and maintain the mentioned strong-weak standard so it does not lose its joint. In exterior joints as is observed in Fig. 5, in addition to the sheet used in column’s lateral part, FRP sheet are used behind the joint which are along parallel fibers of column axis. Reinforcement of joint is achieved in three different lengths. In Fig. 3, support conditions and static loading used in this study are shown. The load is exerted gradually on the joints during loading. To obtain better convergence, smaller steps are considered during initiation of cracking and also at time of armature resignation.

4. Results and Analysis

Behavior of the existing connection was tested regarding its flexibility, and sample responses indicate an improvement in plasticity behavior of the sample reinforced by FRP. Furthermore, increase in stiffness of the reinforced sample occurs. Comparison of the reinforced and non-reinforced samples reveals that FRP sheets are capable of tolerating connection shear strength and sustain the connection concerning plasticity; hence, technique of connection's reinforcement with the aim of improving the shear capacity of connection has been successful in removal or delaying failure shear mode. Subsequent to nonlinear analysis of the sample in ABAQUS software, results of analysis for Von Misses stress in concrete and composites together with equivalent plastic strain in reinforcing bars and concrete at critical region of connection were calculated which are shown in figures 6-9, respectively. Finally, as is observed in Fig. 10, hysteresis graph obtained by analysis using ABAQUS finite elements software yielded results similar to those of experimental model (ACI-ASCE Committee 352, 1976).

As can be seen in Fig. 11, the displacement and transformation caused by loadings exerted to the connection are obviously observed.

5. Conclusions

a) For this type of connection, stiffness of reinforced samples has increased compared to base samples (up to 33% for external connection)

b) In external connection, loading capacity of reinforced samples compared to base samples had a considerable increase (up to 42% for external connection)

c) Final plasticity has increased in external connection (up to 28% for external connection)

d) The trends of increasing stiffness, loading capacity and flexibility are intensified by increasing reinforcement in samples.

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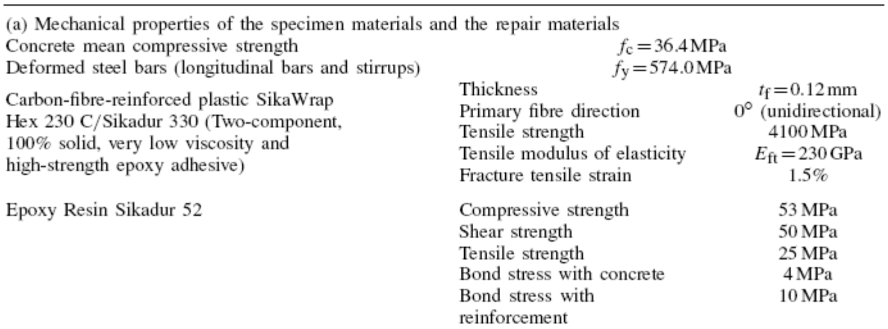
Table 1. Characteristic of used CFRP in reinforcing joints (Samali et al., 2002).



(a) Mechanical properties of the specimen materials and the repair materials		
Concrete mean compressive strength		$f_c = 36.4$ MPa
Deformed steel bars (longitudinal bars and stirrups)		$f_y = 574.0$ MPa
Carbon-fibre-reinforced plastic SikaWrap Hex 230 C/Sikadur 330 (Two-component, 100% solid, very low viscosity and high-strength epoxy adhesive)	Thickness	$t_f = 0.12$ mm
	Primary fibre direction	0° (unidirectional)
	Tensile strength	4100 MPa
	Tensile modulus of elasticity	$E_{ft} = 230$ GPa
	Fracture tensile strain	1.5%
Epoxy Resin Sikadur 52	Compressive strength	53 MPa
	Shear strength	50 MPa
	Tensile strength	25 MPa
	Bond stress with concrete	4 MPa
	Bond stress with reinforcement	10 MPa

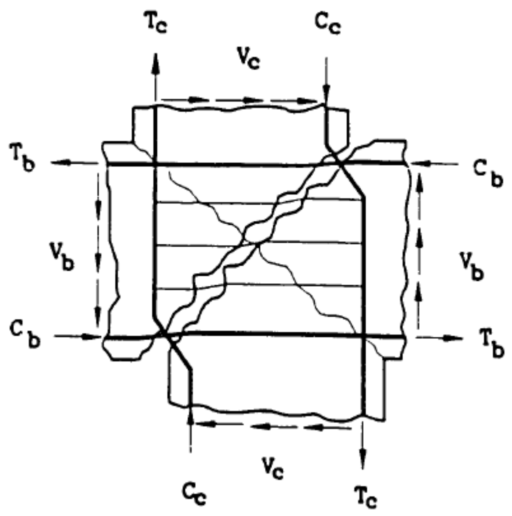
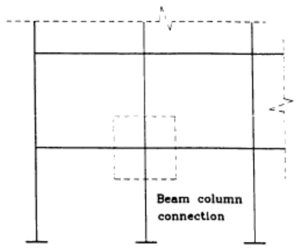
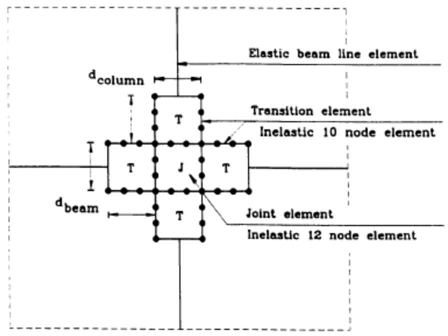


Fig 1: Cutting crack in joint nucleus, internal horizontal tension (Tb), pressure (Cb), and tension forces and vertical (Vb), internal vertical tension (Tc), pressure (Cc), horizontal cutting force (Vc).



(a) Part of a typical R.C. frame



(b) Proposed element

Fig 2: Proposed particles provide gradual transmittal in lattice displacement.

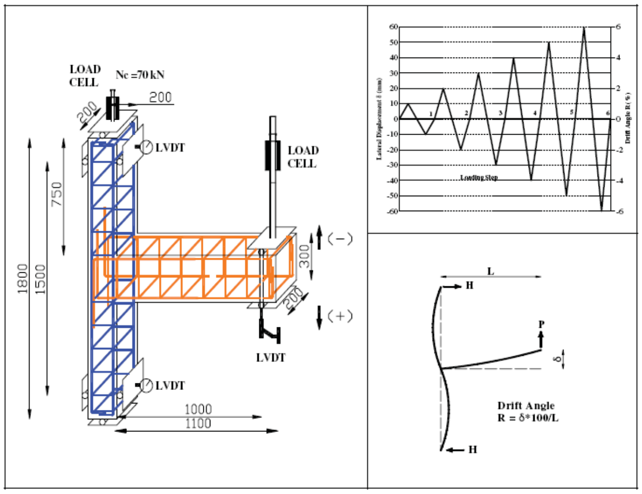


Fig 3: Sample of connection and loading.

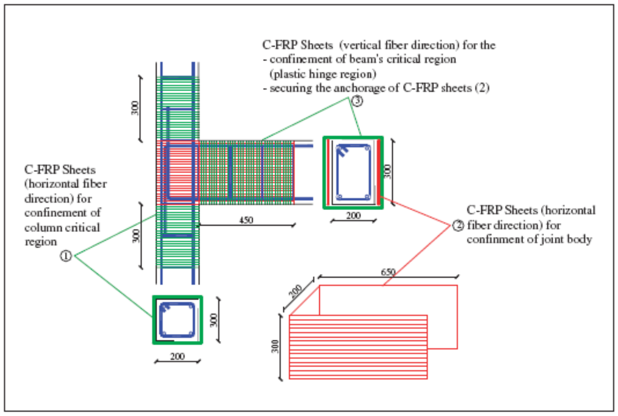


Fig 4: Sample reinforced by layers FRP.

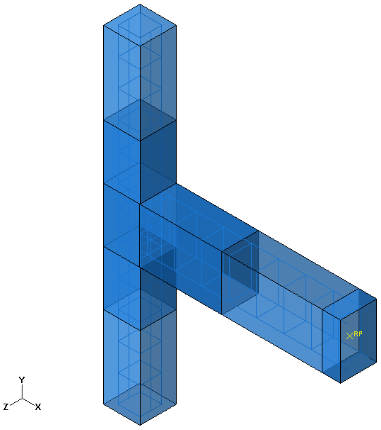


Fig 5: Final assembly of connection model.

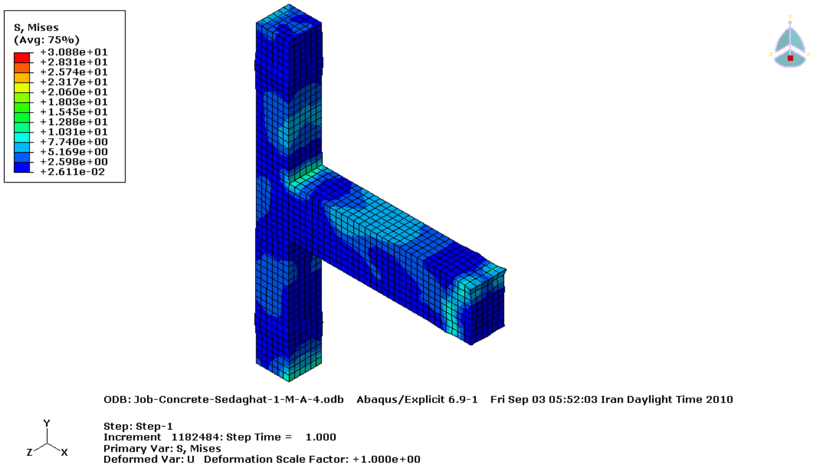


Fig 6: Von Misses stress created in concrete.

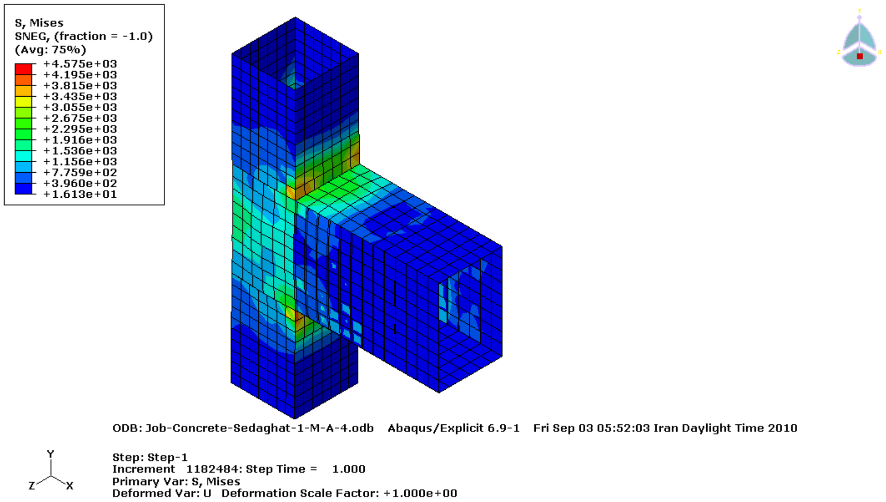


Fig 7: Von Misses stress created in composites.

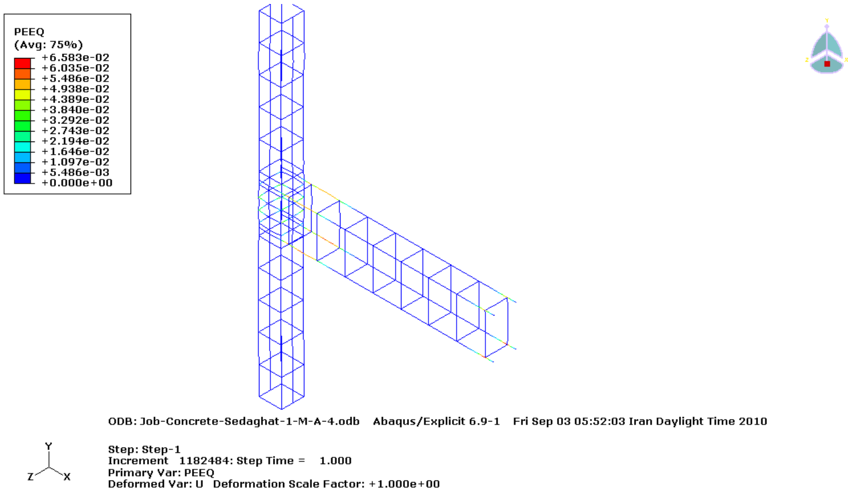


Fig 8: Equivalent plastic strain in reinforcing bars.

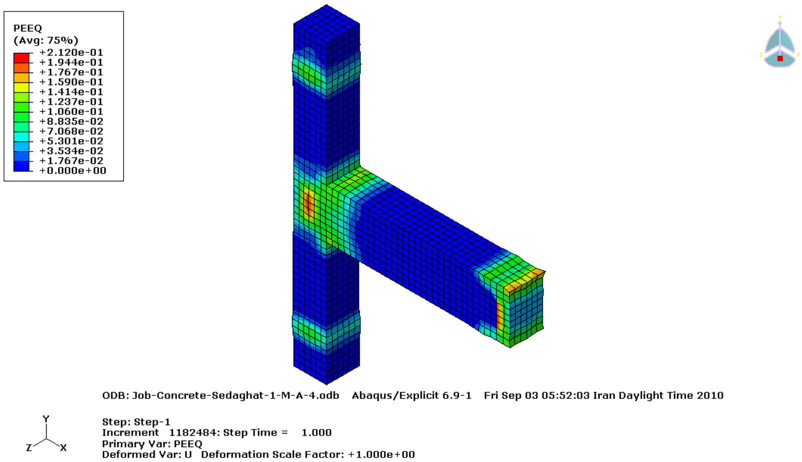


Fig 9: Equivalent plastic strain in concrete.

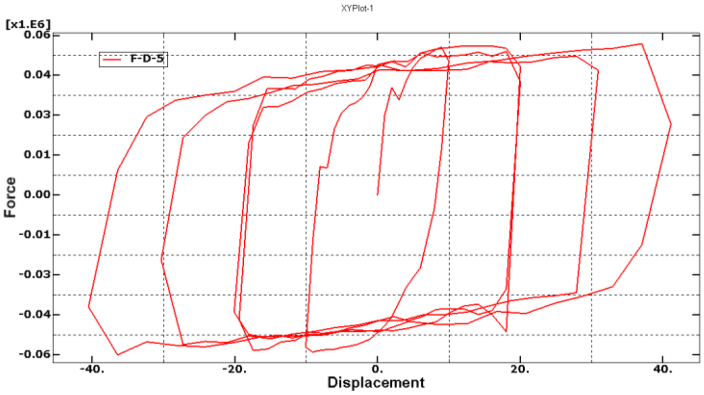


Fig 10: Hysteresis diagram.

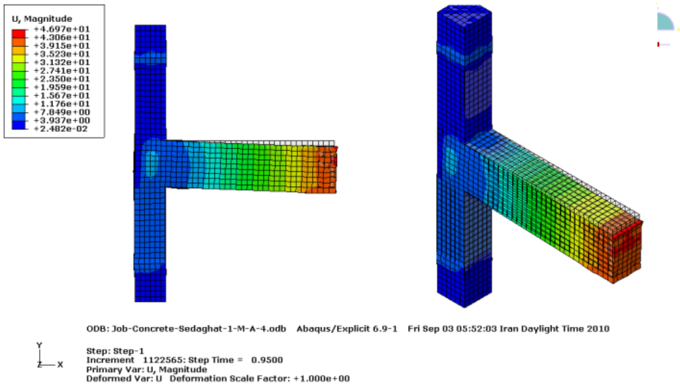


Fig 11: Displacement of the part and comparison with initial state.