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

Meisam Safari Gorji [1], Mohammad Zeynali Moghaddam [2]

[1.] Department of Civil Engineering, University of Tehran, Tehran, Iran
[2.] Department of Civil Engineering, Islamic Azad University, Zahedan Branch, Zahedan, Iran
m.zeynali1389@gmail.com

Abstract: The joints of columnar poles in reinforced concrete are crucial parts of constructions. Earthquake exerts a high shear force on reinforced concrete which can lead to transfiguration of columnar poles. These joints do not receive much attention in implementation of reinforced concrete structures; therefore, reinforcement of joints and increasing their malleability are important issues studied by different researchers. A limited number of elements are considered in the present study based on analytical prototype for connectors of columnar poles. In this research, the purpose is the reinforcement of resistance and malleability 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. This method is based upon using leaflets in joint zone, along different directions. The mentioned joints have been modelled three dimensionally and analysed under static burden using finite element method by ANSYS software. Nonlinear materials related to concrete are also considered. Diffraction connection in joint system between stable poles and pillar has been taken into consideration as well. Comparison of results between strengthened and non-strengthened samples for all three joints shows that the toughness, porterage capacity and also final malleability of joints have been improved much by the reinforcement implemented in this research.

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1. Introduction

Pole and columnar joints are typically considered the weakest junctions in resistance mechanism in LRC structures against earthquake. In recent years, frequent breakage of joints has caused worries about efficiency of structures. The joints of the poles and columns are put under extreme shear forces by a severe earthquake, so increasing the resistance of these structures is essential. As a result, joints of the poles and columns experience the worst change in shear shape which can lead to cracks in buildings. Furthermore, cutting capacity of joints can decrease the degree of cutting breakage and be effective on all structures and buildings and their degree of resistance. The joints have great portion in the frame action in malleable diffraction 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 malleable diffraction systems. Laboratory studies have demonstrated that the condition is undesirable under final load which results in swinging of the poles and columns. This rotation causes change in the final shape of poles and columns to 50 percent and changes the shape of structure. So it is essential to have non-tensible 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.

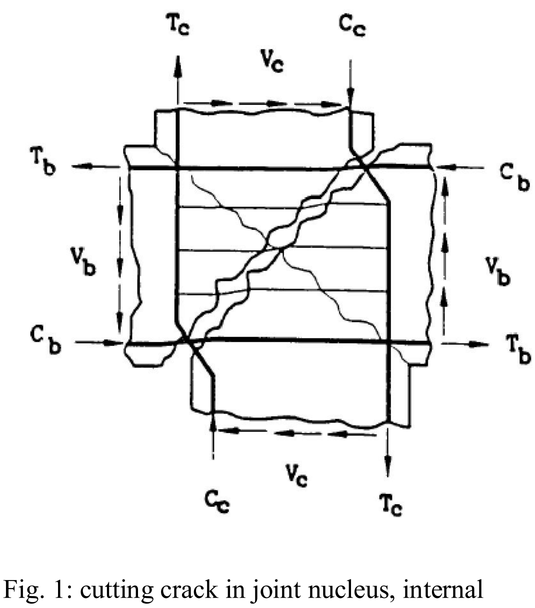

Fig. 1: cutting crack in joint nucleus, internal horizontal tension (Tb), pressure (Cb), and tension forces and vertical (Vb), internal vertical tension (Tc), pressure (Cc), horizontal cutting force (Vc)

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 malleable diffraction components or reinforced concrete. 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 Passiki and co-workers [1]. 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 joint lattice. These joints indicated that cutting resistance is about , where is the complete concrete resistance in joint lattice in MPa. The final malleability and frightens has sharpened.

The earliest laboratory researches were done by Otany and co-workers [2]. The sample used by them was previously used by Pantazopolod and Bonachi [3] 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 [4-5]. Their researches were experimental and numeral modelling. They dealt with L form in reinforcing the samples and indicated the rise of diffraction resistance and reduction in malleability. Also Pantidlis and coworkers [6] dealt with reinforcement of exterior joints in laboratory research the most important result of which was the increase in cutting resistance of the joint and enhancement in load capacity of column.

Regarding the reinforcement of interior joints, Moslem [7] in University of California put cracked joints under cyclic loading after mending them by using complete composite covering. Increase in diffraction resistance and malleability was the result of their research/ Also Samali and co-workers [8] in University of Sidney aimed to reinforce median joints. The important result of their experiment was the enhancement in load capacity.

Another effort for modelling these components was made by Hafman and colleagues [9]. 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) [10]. A further effort was made by Bracci and co-workers [11] to model the joints which are under loading pressure and stress. Their studies were consistent in decrease of toughness of poles and columns and showing the degree of reduction in resistance.

In the current research, after introducing angle joints, as well as exterior and interior joints, we deal with all three kinds of joints, and then the three dimensional finite elements modelled by ANSYS software are analysed in nonlinear manner. The analysis results for reinforced samples and range are afterwards compared with each other.

2. Finite Elements Model

In the present study, the 12-knot components were used for joint lattice.

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.

Figure 2 illustrates the proposed pole and column joint model, and it is shown that the lattice joint of pole and column is limited by transmittal components with proximity of other poles and columns. Transmittal components in non-tensional lattice have 10 knots.

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 pole and column is modelled using existing linear components. The point that we have not made a comparison among components pertains to degree of freedom. Krishnan's proposed curve [12] is used for introducing stress-strain curve. Compressive resistance of concrete is considered 25 MPa and its tensional resistance is considered 3.15 MPa. Characteristics of CFRP used in this research are shown in Table 1.

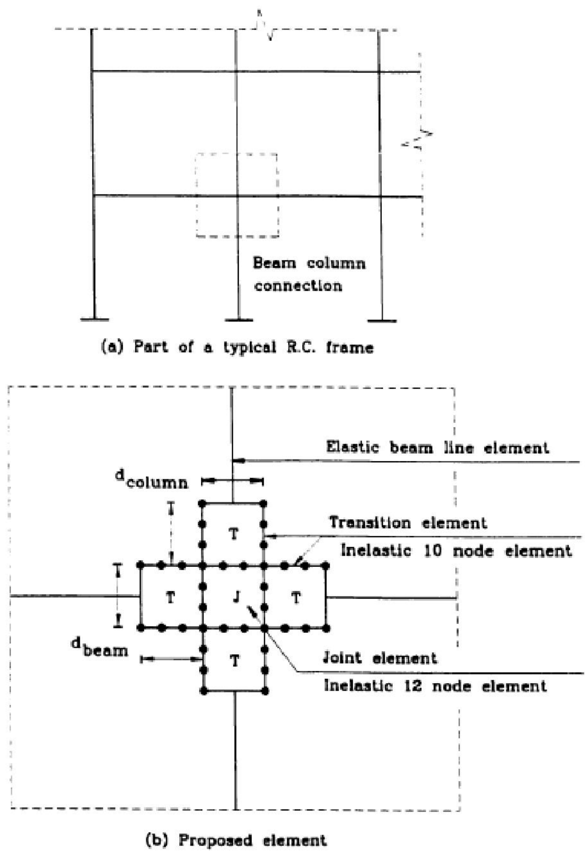

Fig. 2: proposed particles provide gradual transmittal in lattice displacement

Table1: characteristic of used CFRP in reinforcing joints [13]

Layer thickness (mm)	Compressing Yield (MPa)	Tensile Yield (MPa)	Shearing Yield (MPa)	Young Module (MPa)	Poison Ratio
1.067	σ_{c1}=12 σ_{c2}=599 σ_{c3}=227.972	σ_{t1}=958 σ_{t2}=28 σ_{t3}=19	G_{12}=3266 G_{13}=3266 G_{23}=1862	E_1=62050 E_2=4826 E_3=4826	ν_{12}=0.216 ν_{13}=0.216 ν_{23}=0.3

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 200 GPa and Poisson ratio of 0.3.

For modelling inhibitory lapse of exterior and angle joint, nonlinear springs are used [9, 11]. Figure 3 illustrates three kinds of joints studied in this research.

In figure 4, reinforced examples of three joints and the used yarn for reinforcement are shown. For naming reinforced interior, exterior and angle joints, letters C, E, and K are used.

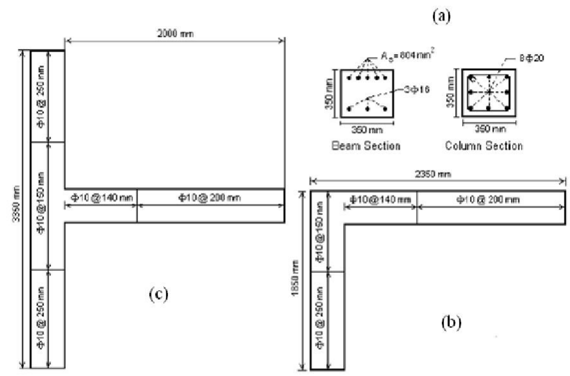

Fig. 3: Example of range joint

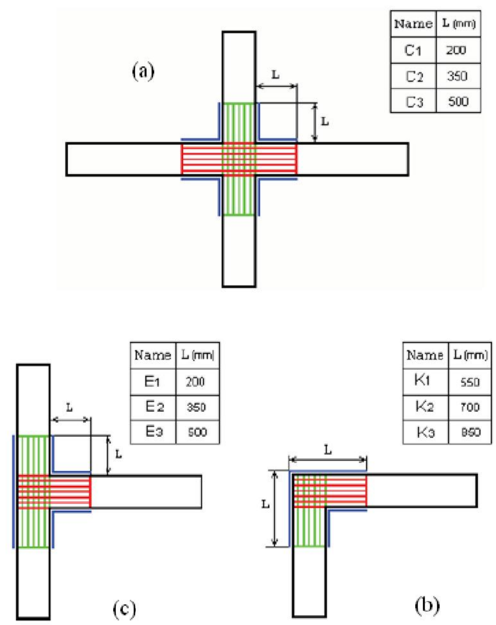

Fig. 4: Examples of reinforced samples

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

Since pole is weak and column is strong, so the highest strain in column's linear armatures 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 shown in figure 2, in addition to the sheet used in column's lateral part, FRP sheet are used behind the joint which are along parallel fibres of columnar axis. Reinforcement of joint is achieved in three different lengths. Figure 5 shows support condition and also the static loading used in this research.

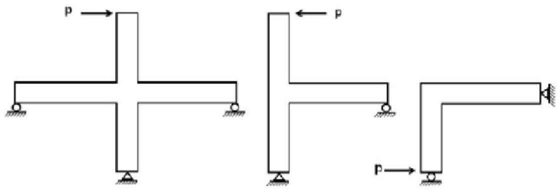

Fig. 5: Condition of backing and the considered sample loading in this research

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.

3. Nonlinear Analytic Results

The analytical results for all three joints after making nonlinear analysis in software are described in the form of load curve versus displacement. As can be observed in Figs. 6, 7 and 8, the curves for reinforced samples in three different lengths were drawn for each kind of joint as well as its control curve.

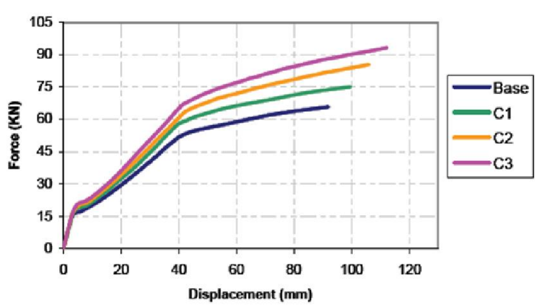

Fig. 6: Load curve- movement of interior joints

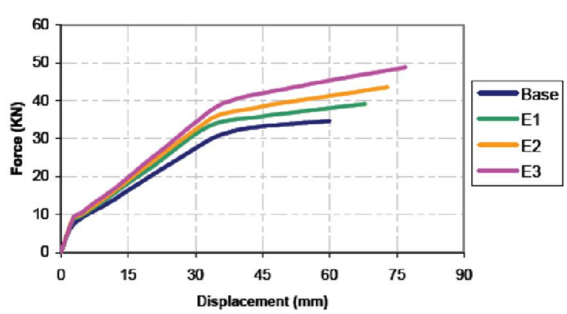

Fig. 7: Load curve- movement of exterior joint

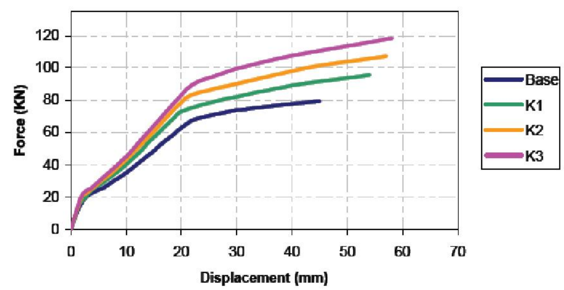

Fig. 8: Load curve-movement of angle joint

The general shape of these curves is similar for all interior, exterior and angle joints. According to the shapes, all curves consisted of three different parts: the first part of curve which is linear is related to recessive behavior of samples before initiation of cracking. At the end of this part, a horizontal jump is observed which is related to start of cracking. In the second part, curves have steady slope to the beginning of armature's resignation and it is the result of cracking in joints. In the third part, the slope changes considerably, and the curve gradually becomes horizontal due to resignation of tensional armature in joints. Using the drawn curves for all three interior, exterior and angel joints, we will discuss three problems. The first problem is the increase in strength of reinforced samples in comparison with control samples. Since the slope was approximately steady in second part of the curve, we discuss this phenomenon for all kinds of joints in loads where tensional armature in control case starts to resignation and the curves start to change in slope. The second problem is analysis of final load at moment of joints breakage. The third case which we deal with is the final displacement caused by the final load. The obtained results for all three joints, i.e. exterior, interior, and angle joints, are presented in Tables 2 to 4.

Table 2: Analysis result for interior joint

Joint Name	Hardness/base hardness in 50 KN (Yield force of base sample)	Final force (KN)	Final force/final force of base sample	Final deformation (mm)	Final deformation/final deformation of base sample
Base	1	66	1	92	1
C1	1.15	75.9	1.15	99	1.08
C2	1.22	84.5	1.28	106	1.15
C3	1.30	92.5	1.40	113	1.23

Table 3: Analysis result for exterior joint

Joint Name	Hardness/base hardness in 30 KN (Yield force of base sample)	Final force (KN)	Final force/final force of base sample	Final deformation (mm)	Final deformation/final deformation of base sample
Base	1	34.7	1	60	1
E1	1.18	39.2	1.13	68	1.13
E2	1.24	43.7	1.26	73	1.22
E3	1.33	49	1.42	77	1.28

Table 4: Analysis result for angle joint

Joint Name	Hardness/base hardness in 67.5 KN (Yield force of base sample)	Final force (KN)	Final force/final force of base sample	Final deformation (mm)	Final deformation/final deformation of base sample
Base	1	79.5	1	45	1
K1	1.22	95.5	1.2	54	1.2
K2	1.31	107.1	1.35	57	1.27
K3	1.39	118.3	1.49	59	1.31

4. Conclusion

According to results presented in the tables, the following findings were yielded:

a) Inflexibility values of reinforced samples in comparison with that of control samples for all three joints have increased (for interior joint up to 30%, for exterior joint up to 33%, and for angle joint up to 39%).

b) Loading capacity of reinforced samples compared to control samples has noticeable increase in three joints (to 40% in interior joints, to 42% in exterior joints, and to 49% in angle joints).

c) Final malleability has increased in all three joints: interior, exterior and angle (to 23% in interior joint, to 28% in exterior joint, and to 31% in angle joint).

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

Corresponding Author:
M. Zeynali Moghaddam
Department of Civil Engineering
Islamic Azad University, Zahedan Branch
Zahedan, Iran
E-mail: m.zeynali1389@gmail.com

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