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Fire Evaluation of RC Frames Strengthened with FRPs Using Finite Element Method

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Abstract: Reinforced Concrete (RC) structures may confront with extreme loading conditions. Sometimes, structures are not only under extreme loading such as earthquakes but also, they may be subjected to fire. Therefore, investigation of reinforced concrete structures which are the most common ones is essential. In this study, experimental RC frame is considered to validate in ABAQUS finite element software. RC frame is subjected to both earthquake and fire loading condition to assess the seismic behavior of structure under extreme conditions. FRP techniques is also consider evaluating the seismic behavior such as load capacity, ductility, energy absorption and stiffness. In this regard, two different approaches including reinforcing and wrapping are employed. In this research, the pattern of retrofitting and reinforcing are the novelty of this work. In fact, the effect of using steel bars, BFRP bars and sheets are evaluated. The new method for combination of steel-BFRP bars and different BFRP sheet's angle as divergence and convergence are investigated. After carrying out the load-displacement diagrams, the seismic parameters of RC frames are compared and the optimized method and model is presented.

Keywords: Reinforced Concrete (RC) Frame, Fire, FRP Bars and Sheets, Finite Element Method

Introduction

Reinforced Concrete (RC) structures are one of the most common infrastructures in the world. However, it has always been confronting with internal or external deterioration due to natural disaster like earthquake, flooding or even environmental problems (Asmari *et al*., 2017; Kodur and Agrawal, 2016; Lim *et al*., 2014; Sayyar Roudsari *et al*., 2020a; 2019b; 2019c; Tang and Saadatmanesh, 2003). Therefore, investigation of these structural members is vital (Fallahi *et al*., 2019; Sayyar Roudsari *et al*., 2019a; Yi *et al*., 2008). These evaluations have been done by so many researchers to find out the seismic effects on strength the structural capability (Bracci *et al*., 1997; Chandrasekaran *et al*., 2016; Crisafulli, 1997; Fanaie *et al*., 2015; Sayyar Roudsari *et al*., 2018). However, the reinforced concrete structures are also come across to extreme loading conditions like fire, impact loadings, explosion and so on (Huo *et al*., 2018; Lenwari *et al*., 2016; Li *et al*., 2015; Liu *et al*., 2018; Mistri *et al*., 2016; Soleimani *et al*., 2019; Soleimani and Sayyar Roudsari, 2015; Soroushnia *et al*., 2011). These artificial or natural phenomena cause devastating consequences because the deficiency of RC structures. Using Fiber Reinforced Polymer (FRP) is one of the most common methods of retrofitting RC members (Gong *et al*., 2019; Qin *et al*., 2019; Soleimani and Sayyar Roudsari, 2019). It can be used to enhance not only capability of RC structure for seismic loads but also, employing FRP material is suitable for extreme loading conditions. Kodur *et al*. (2019) studied to find out the effect of high temperature properties on FRP material. His results indicated that the properties of temperature can have influence on FRP's performance. Fallahi *et al*. (2018) did analytical study to retrofit the RC frames using finite element software. The results showed that CFRP can enhance the load capacity of RC frames. Li *et al*. (2019a) experimentally evaluated the performance of post-fire on reinforced concrete frames. He tested four specimens under various loading conditions like in furnace chamber and quasi-static, respectively. The results presented that the fire exposure decreased the load capacity, stiffness and ductility. Hamoush *et al*. (2020) performed the experimental and numerical investigation on steel frame embedded with gypsum board wall. He tested the specimen under lateral cyclic loading condition and carried out the load0displacement results. In order to enhance the load capacity, he employed the grommet damping system. The results indicated that the frame and wall have better performances when the specimen was strengthen with dampers. Shah and Sharma (2017) investigated the effect of fire and spalling on the performance of RC columns. His results indicated that the confinement of RC column has an indispensable role in resistance of column. Sayyar Roudsari *et al*. (2020b) did numerical study on RC column to find out the effect of time on load capacity and stiffness of RC column during the fire load. He used ABAQUS software to define specific criteria for material properties and simultaneous fire and axial loading on RC column. The 600°C as fire load was applied on the column's surfaces for 10,15 and 20 min. The validation of his work shows very good agreement with experimental results. Moreover, the time duration of fire caused a significant reduction of stiffness. On the other side, some researchers focused on the material properties behavior under fire conditions and evaluate the effect of water-cement ration, aggregate size and type, using the fiber cementitious, material from renewable source and so on (Ahn *et al*., 2016; Hamoush *et al*., 2019; Khaliq and Kodur, 2017; Ma *et al*., 2015; Zhang *et al*., 2016). Zhou and Wang (2019) evaluated the repairing of fire damaged RC members. He did some studies to find out the effect of both fire and axial load on the existing structures. His results showed that using FRP jacket is the most efficient method in improving RC member's behavior than Near Surface Method (NSM) or steel wrapping method. Based upon above, it is obvious that there are many researches on the area of RC members, fire and retrofitting. However, most of them are experimental works concentrating about the effect of only fire temperature or retrofitting with FRPs (Jiang *et al*., 2018; Kodur *et al*., 2012; Li *et al*., 2019b; 2019c; Raouffard and Nishiyama, 2016; Sasmal *et al*., 2011; Wang *et al*., 2007).

In this study, RC frame is modeled by ABAQUS software. The RC frame is loaded under concurrent pressure and fire loads for five different fire temperature and time. These frames firstly tested as steel reinforcement and load-capacity diagram are carried out. Then, two strengthening methods as reinforcing with basalt (BFRP) bars and wrapping with basalt sheets are deployed to evaluate the RC frame behavior. Eventually, the seismic behavior of each model is discussed and the optimized model is presented.

Materials and Methods

The base of this research is the experimental works of (Hemmati *et al*., 2016). The RC frame of his research is a combination of 24 MPa concrete compressive strength High-Performance Fiber Reinforced Cementitious Composite (HPFRCC) for beam-column connection and 48 MPa for other regions. In Fig. 1, the geometry, reinforcement and different concrete compressive area are shown. Also, Fig. 2 displays the actual loading condition in the laboratory.

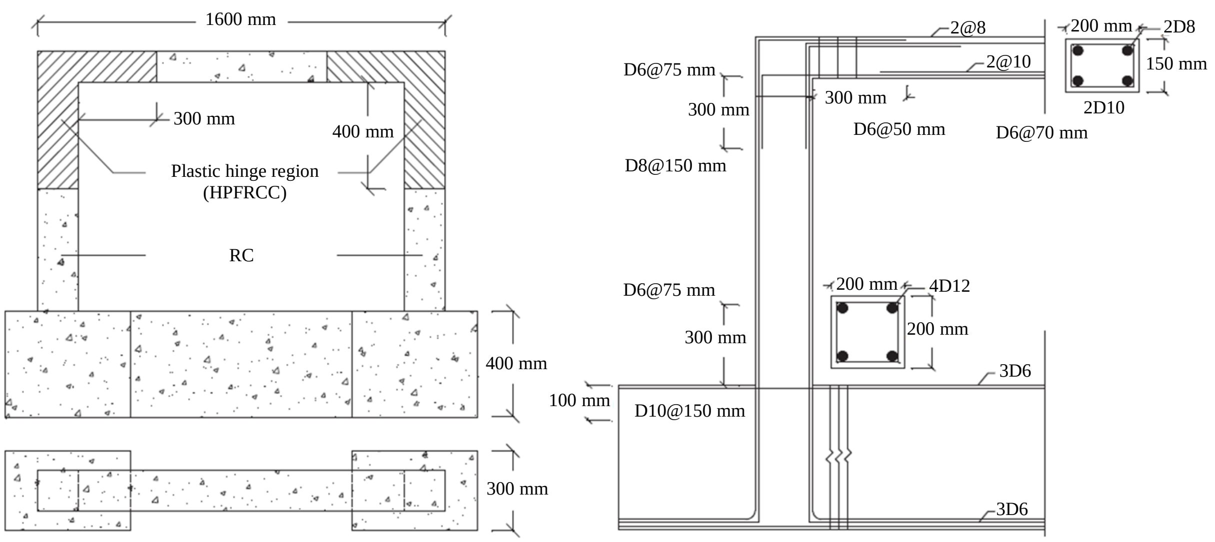


Fig. 1: Reinforcement details of RC frame

Fig. 2: Actual loading conditions of experimental tests (Hemmati *et al*., 2016)

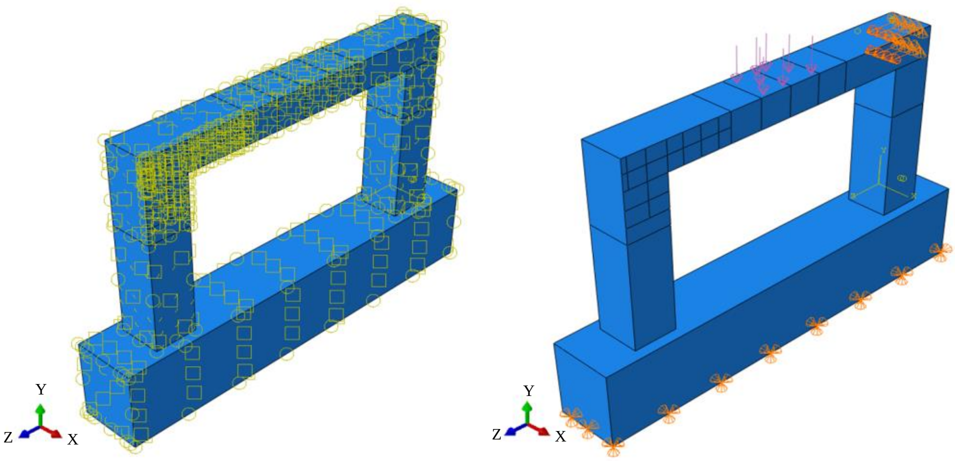


Fig. 3: Interaction and boundary condition modeling in ABAQUS

Table 1: Mechanical Properties of BFRP Sheets (Kheyroddin and Naderpour, 2008)

Tensile Strength-Parallel of Layer Direction (MPa)	Compressive Strength-Parallel of Layer Direction (MPa)	Tensile Strength-Perpendicular of Layer Direction (MPa)	Compressive Strength-Perpendicular of Layer Direction (MPa)	Longitudinal Shear Strength (MPa)	Transvers Shear Strength (MPa)
550	250	133	536	117.4	117.4

Finite Element Modeling and Validations

There are two validations in this research; one for RC frame without fire (Hemmati *et al*., 2016) and other RC column under fire load. In order to validate the experimental, ABAQUS finite element software is employed (Fig. 3). The material properties of concrete are defined by Concrete Damage Plasticity Model (CDPM). Computing CDPM parameters as compressive and tensile strain-stress as well as its damages is done using (Roudsari *et al*., 2019). He did the state-of-the-art method for finding CDP parameters with higher accuracy using theoretical methodology and MATLAB toolbox. The module of elasticity for steel is 200 GPa and yield stress is 400 MPa. The Basalt Fiber Reinforced Polymer (BFRP) is defined using Table. 1. Also, the module of elasticity for BFRP is 50 GPa and ultimate stress and failure strain are considered 1095 and 2.19%, in order. The Non-Linear Static Analysis is defined to apply appropriate boundary conditions. Moreover, the longitudinal and transvers bars are interacted with concrete using Embedded Region. The dead load above the beam is applied as pressure while the lateral load is subjected by Displacement Control. 8-node element using reduced integration (C3D8R) is used for solid concrete members and T3D2 is used as truss element for reinforcement. Also, the shell element is deployed for modeling CFRP sheets and the tie interaction is considered between concrete surface and CFRP. It should be noted that the CFRP sheet has 150 mm width and 2 mm thickness (one layer).

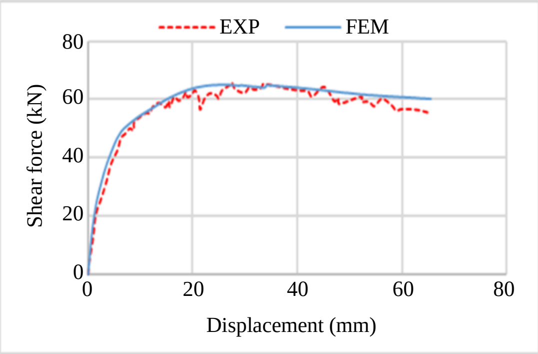


Fig. 4: Validation of experimental versus ABAQUS Software; without fire load

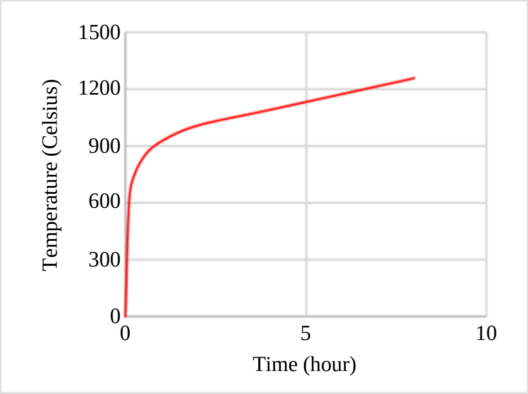


Fig. 5: Time-temperature diagram (ISO, 2019)

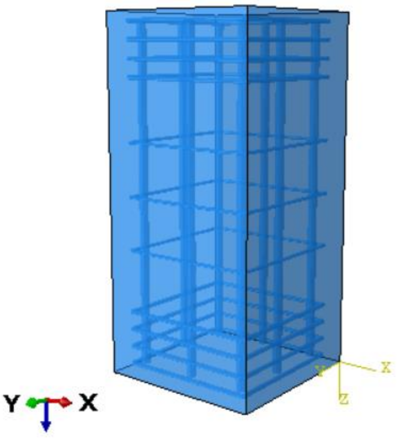


Fig. 6: RC column modeling under both fire and lateral load

In Fig. 4, the validation of RC frame without fire load is shown. Comparison of Finite Element Method (FEM) and experimental result indicates that the difference of load capacity is less than 2%. After the accurate validation of RC frame, the fire should be validated, too. In order to validate the fire modeling, the experimental research of (Zhang *et al*., 2017). The column cross-section is reported 350×350 mm and eight of 20 mm longitudinal bars and 10 mm as transvers bar diameter are used. The RC column is applied under lateral and fire loads. The maximum fire temperature is subjected to reach up to 900°C. The fire is considered based on ISO-843 Standard which is displayed in Fig. 5 (ISO, 2019). It has to be mentioned that the modeling criteria is done like the RC frame validation. Also, the fire parameters which are done by (Roudsari and Abu-Lebdeh, 2019) is used for this numerical research. He used the conductivity and specific heat criteria for fire temperature. In the fire validation model, the Coupled-Temp Displacement (Transient) type of analysis is used. The RC column model is shown in Fig. 6.

In Fig. 7, the load-displacement diagram of second validation indicates the significant agreement of fire modeling by FEM as 214 kN for FE output and 210 kN for experimental. It is obvious that the accuracy is about 2%.

Parametrical Study

In this research, the RC frame is developed for analyzing under 200, 400, 600, 800 and 1000°C. There are three categories including:

- RC frame reinforcing with steel bars
- RC frame reinforcing with BFRP bars
- RC frame wrapped with BFRP sheets

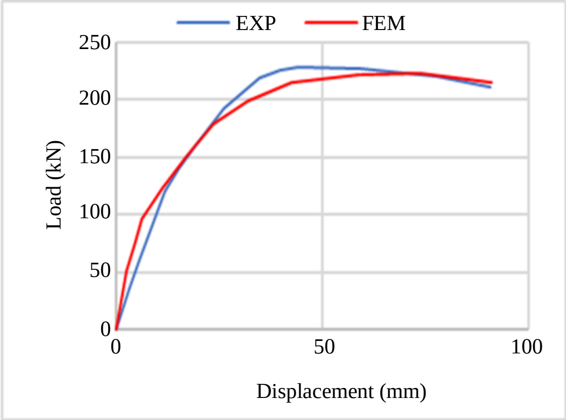


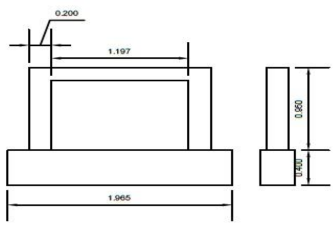
Fig. 7: Validation of experimental test; RC Column - versus ABAQUS under fire

In fact, after validations, the behavior of RC frame under five different fire loads is investigated. The bottom line is the pattern of reinforcement. In BFRP bars modeling, in one model, the longitudinal bars of the beam are BFRP and steel bars are used for columns and slab. Another pattern is indicated that all longitudinal bars in both beam and column are reinforced by BFRP bars. In Table 2 and 3, the model's description of retrofitting patterns is shown. Also, Fig. 8 presents the assembly and interaction of RC frame. The initial fire temperature is zero and the maximum target one depends upon the fire temperature, for instance for 200°C, it should be 200. Also, the Specific Heat is considered 5700 for bars, 6000 for BFRP sheets and 1000 for concrete using Constant Volume criteria. The range of conductivity for FRP bars and layout are 0.003-0.0057 and 0.035-0.006, respectively. The conductivity for steel bars is 0.04-0.0518 and the specific heat is 5255. The conductivity parameters for concrete is 0.0005-0.00114. The Hashin Damage parameters are used to define the tensile and compressive behavior of FRP layout (the longitudinal tensile strength is 1278 MPa and its elasticity modulus is 46000 MPa). Also, the Max Allowable Temperature Change Per Increment is applied 10°C. In the interaction module, the Surface Film Condition as the Film Coefficient and Sink Temperature are considered 0.01 and 25, respectively. The lateral and pressure loading are considered as the same as validation model. In the loading module also, the Predefined Field is created to make environment temperature of Concrete Frame by applying 25°C. The fire load is utilized by choosing Other/Temperature from Boundary Condition, applying at the inside surface of frame. Each temperature has its own amplitude using Fig. 5. Also, the Heat Flux is applied "10" for all elements. Figure 9 demonstrates the temperature, pressure and lateral displacement loading conditions of RC frame. Eventually, in the term of meshing criteria, the mesh study is used to verify the mesh seed size. Also, the family type of element's mesh is Coupled-Temperature-Displacement (Fig. 10).

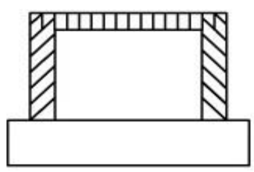
Table 2: Models description details and names

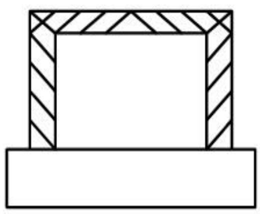
Names	Description
M-0	Reinforced by Steel bars without Temperature Loading
M-200	Reinforced by Steel bars under 200 Celsius Degree Loading
M-400	Reinforced by Steel bars under 400 Celsius Degree Loading
M-600	Reinforced by Steel bars under 600 Celsius Degree Loading
M-800	Reinforced by Steel bars under 800 Celsius Degree Loading
M-1000	Reinforced by Steel bars under 1000 Celsius Degree Loading
FB-C45B90	Strengthening with BFRP, Column 45-degree, Beam 90 degree
FB-C45B45	Strengthening with BFRP, Column 45-degree, Beam 45 degree
FB-C0B45	Strengthening with BFRP, Column 0-degree, Beam 90 degree
F-BB-Total	Reinforcing by BFRP bars in both Beam and Column
F-BB-Beam	Reinforcing by BFRP bars in the Beam
F-CB-Beam-Bot	Reinforcing by CFRP bars in the Tensile zone of the Beam

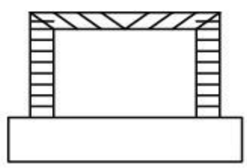
Table 3. Geometry details of retrofitting pattern of rc frames



Original RC Frame


Model 1: The layout direction for column and beam is 45 and 90 degree, respectively.


Model 2: The layout direction for column and beam is 45 degrees.


Model 3: The layout direction for column and beam is 0 and 45 degree, respectively.

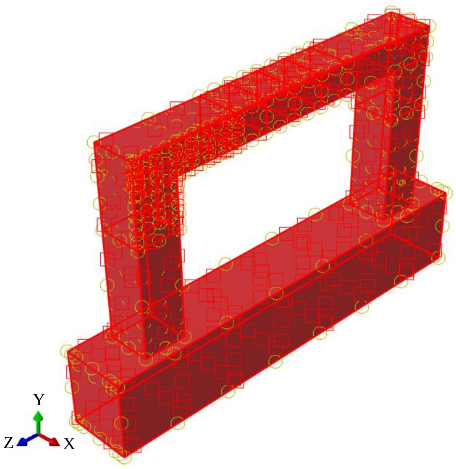


Fig. 8: Assembly and Interaction of RC frame in ABAQUS

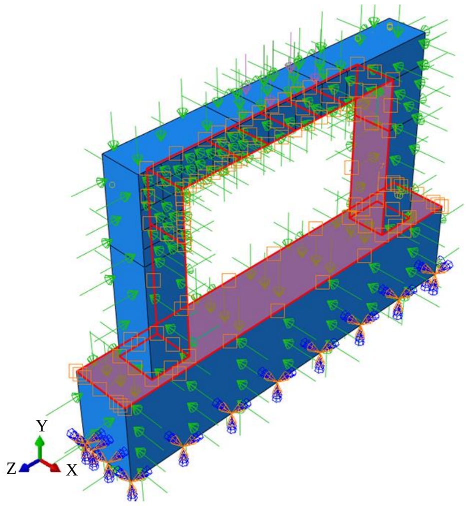


Fig. 9: Temperature, pressure and lateral displacement loading conditions in ABAQUS

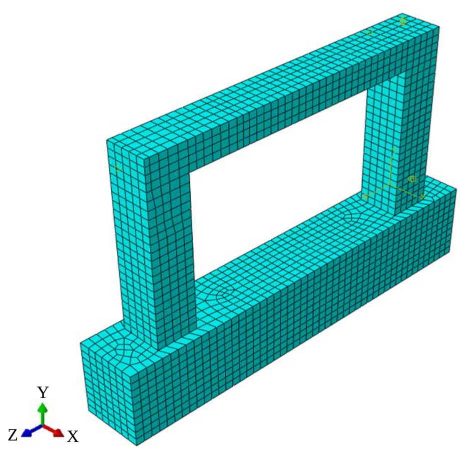


Fig. 10: Meshing in ABAQUS

Results and Discussion

In this section, the load-displacement diagrams of parametrical studies are shown. In Fig. 11, the load-displacement of frame reinforced with steel bars under different fire load is shown. As it can be seen, M-0 which is not under fire load, has the maximum load capacity and by increasing the temperature, the load capacity is reduced. Figure 12 to 16 present the effect of using Basal Fiber Reinforced Polymer (BFRP) bars in frame. In Fig. 12 and 13, it is seen that models reinforced with steel bars have as the same capability as BFRP bars. However, due to the fact that module of elasticity for steel is four time bigger than BFRP, the M-200 and M-400 have better performance in elastic area. Comparison of Fig. 14 to 16 shows by increasing the temperature from 600 to 1000 Celsius Degree, the steel bars tend to lose the stiffness. In fact, M-600, M-800 and M-1000 smoothly reduced the strength and at the 1000°C, it completely failed. Moreover, looking at model F-BB-Total and F-BB-Beam (Table 2), presents that using

BFRP totally has higher load capacity than using it only on beam area. The results of retrofitting by BFRP sheets (Table 3) shows the good performance of BFRP wraps in increasing load capacity of models under extreme fire (Fig. 17 to 21). In fact, the BFRP sheets avoid the collapsing issue even in 1000°C. In this regard, the unique method of wrapping in this research is discussed, here. As it can be seen in the angle of sheets has a vital effect in seismic parameters of RC frame. As a case, FB-C45B90 model (column 45 and beam 90 degree) has the highest capability among all wrapping methods. In Fig. 17 to 19, when column of RC frame retrofitted by 45 degree (FB-C45B90 and FB-C45B45) is better than third pattern (FB-C0B45). Comparison of FB-C0B45 and FB-C45B45 which the difference is column's wrapping angle shows that 45-degree angle for BFRP sheets also has higher performance. In Fig. 20 and 21, the load capacity of retrofitted models compared with model with only steel bars (M-800 and M-1000) declared that not only this system avoid collapsing of structure which is clear in M-1000 but also, it increase the maximum load capacity in 800 and 1000°C, too.

Discussion of Parametrical Study

In this section, the seismic behavior like ductility, stiffness, load capacity and seismic factor (*R*) have been presented. The ductility factor is computed by dividing the maximum displacement (Δ_{ult}) on the displacement corresponding to yield force (Δ_y). Equation (1.) explains the ductility formulation (Sayyar Roudsari *et al*., 2020b):

$$\mu = \Delta_{ult} / \Delta_y \quad (1)$$

Also, the stiffness is calculated using load-displacement diagram as the division of yield load

(Sayyar Roudsari *et al.*) by yield displacement (Δ_y), Equation (2):

$$E = V_y / \Delta_y \quad (2)$$

Eventually, the seismic factor (*R*) is defined by multiplication of strength reduction factor (R_u) by strength enhancement factor (R_s) Equation (3):

$$R = R_u \times R_s \quad (3)$$

In the Equation 3. the strength reduction factor (R_u) is regarding the maximum load if the structure's behavior remains in elastic zone; ((V_{el}) over the yield load (Sayyar Roudsari *et al.*)) Equation (4):

$$R_u = V_{el} / V_y \quad (4)$$

And, strength enhancement factor (R_s) is computed by the yield load (Sayyar Roudsari *et al.*) divides by the load at the first plastic hinge (V_s):

$$R_s = V_y / V_s \quad (5)$$

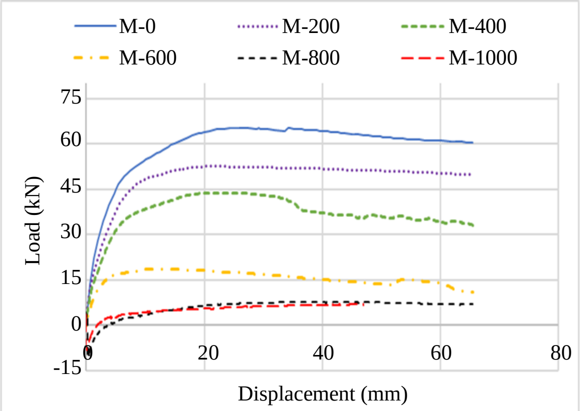


Fig. 11: Load displacement diagram for model with steel bars under different temperature Loading

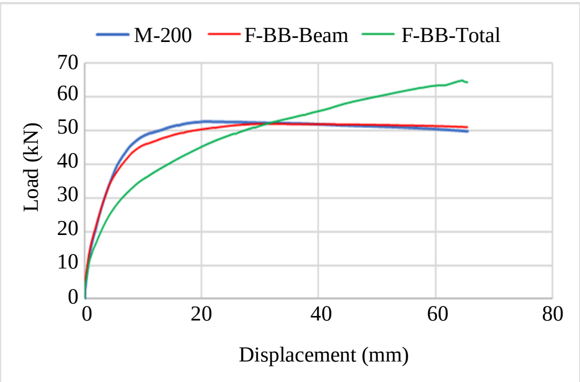


Fig. 12: Load displacement diagram BFRP bars - model under 200 Celsius degree

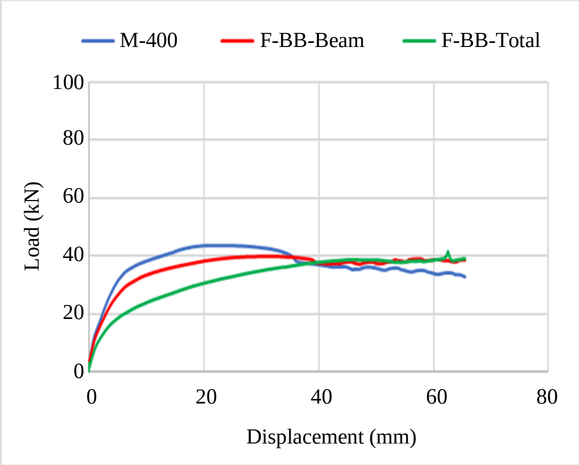


Fig. 13: Load displacement diagram BFRP bars - model under 400 Celsius degree

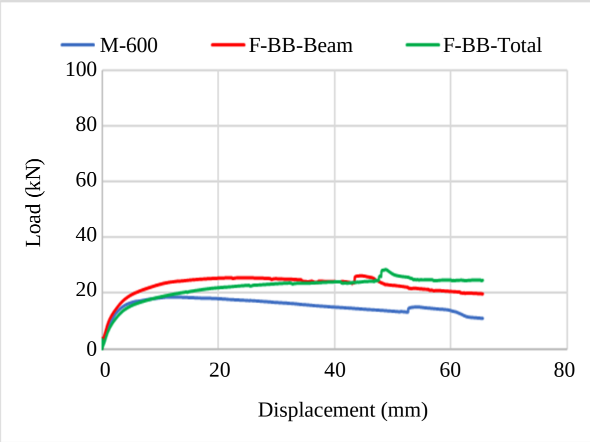


Fig. 14: Load displacement diagram BFRP bars - model under 600 Celsius degree

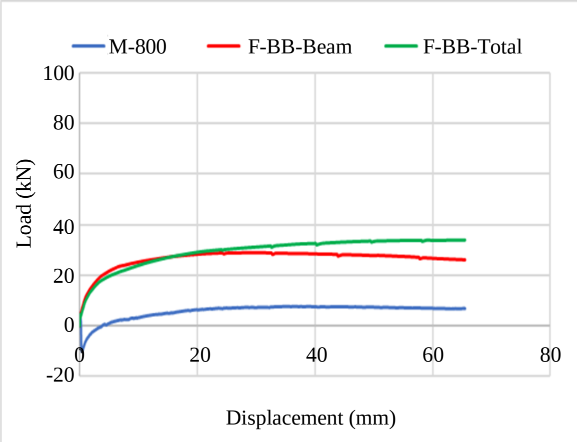


Fig. 15: Load displacement diagram BFRP Bars - model under 800 Celsius degree

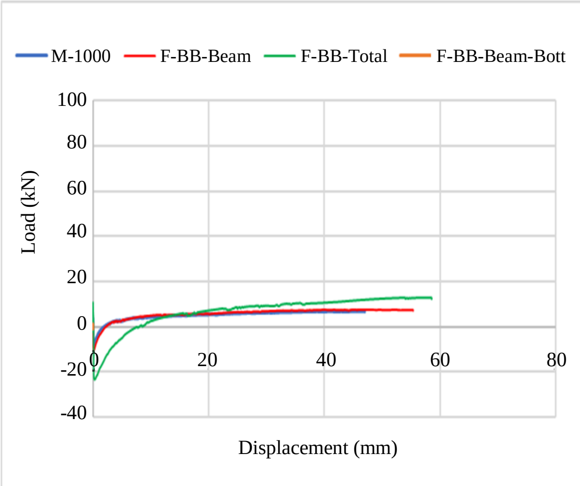


Fig. 16: Load displacement diagram BFRP bars - model under 1000 Celsius degree

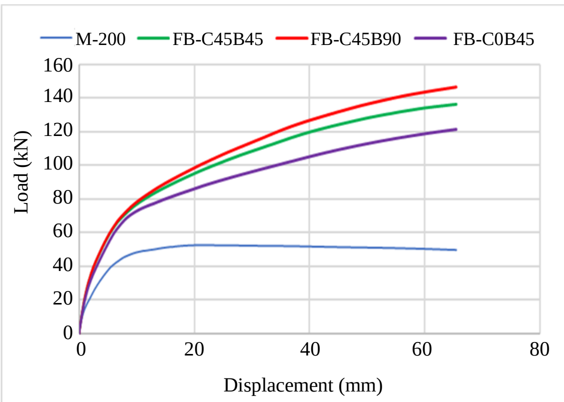


Fig. 17: Load displacement diagram retrofitted by BFRP Sheet, models under 200 Celsius degree

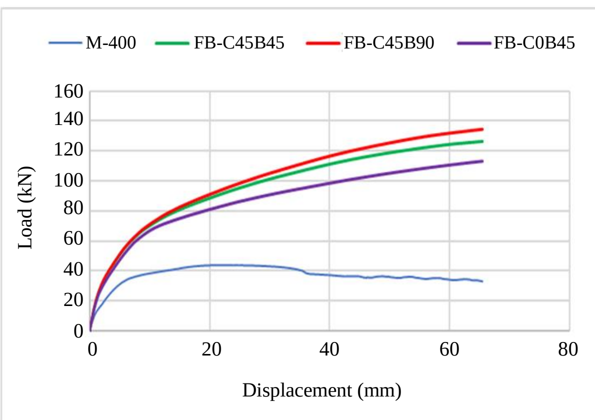


Fig. 18: Load displacement diagram retrofitted by BFRP sheet, models under 400 Celsius degree

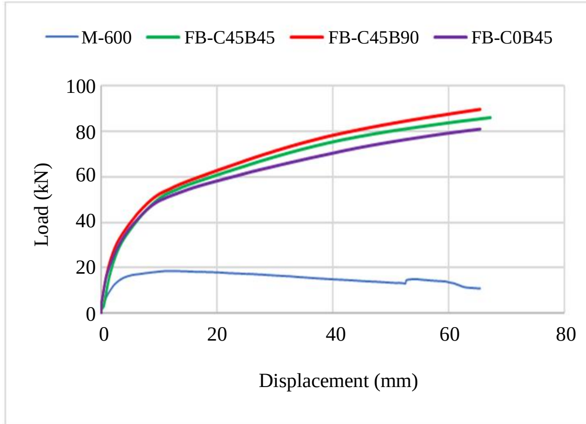


Fig. 19: Load displacement diagram retrofitted by BFRP sheet, models under 600 Celsius degree

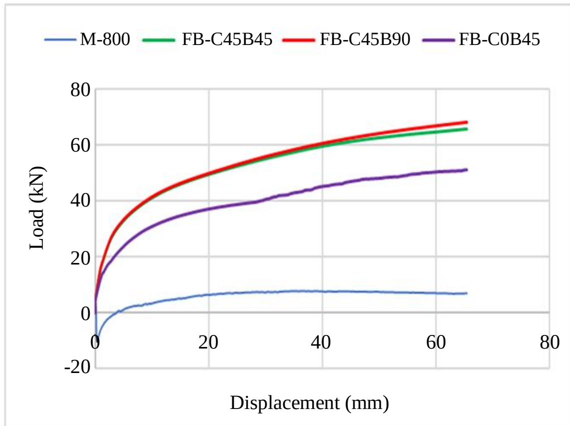


Fig. 20: Load displacement diagram retrofitted by BFRP sheet, models under 800 Celsius degree

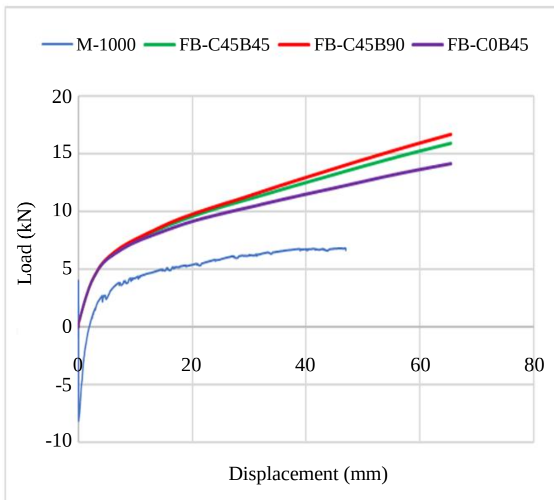


Fig. 21: Load displacement diagram retrofitted by BFRP sheet, models under 1000 Celsius degree

In Fig. 22 to 26, the load capacity of all models is shown. In Fig. 22 comparing M-0 with M-200 shows that the RC frame has a reduction of load capacity from 65.25 to 52.58 kN. In models reinforced with BFRP bars (F-BB-Total), it is obvious that when BFRP bars are employed for all longitudinal bars, it has almost the same capacity as M-0 (without fire load). Comparison Fig. 23 and 24 indicates that the retrofitting method by BFRP sheets can enhance the load capacity of RC frame. On the other side, the comparison of each model with specific loading condition has still higher value than the original (M series). In other word, model like FB-C45B90 under 400°C has load capacity value about 134kN while the same model capacity under 600°C is about 90 kN. In Fig. 24 and 25, in 1000°C cause the collapsing of RC frame which the highest value is belong to retrofitted model busing FB-C45B90 pattern. In Fig. 27 to 31, one of the most important seismic parameters as stiffness are shown. In the Fig. 27 to 29 and comparing BFRP bars specimens show that using BFRP bars only in beam has better performance of stiffness. In this regard, F-BB-Beam model under 200, 400 and 600°C has the stiffness value about 19.8, 17.5 and 12 GPa, respectively. When F-BB-Total models are compared, although stiffness is even less than using the steel bars. The reason of this issue goes back to the lower module of BFRP bars. On the other side, it can be presented now, when the combination of BFRP (in beam) and steel bars (columns) are used, the stiffness is higher than other reinforcing technique. The reason is that when steel or BFRP bars embedded in both beam and columns, the strong-weak beam and column phenomena happens. This issue causes the RC columns failed before beam's failure. Therefore, using BFRP bars with lower elasticity modulus and higher ultimate stress improved the stiffness of RC frame. Moreover, comparing Fig. 30 and 31 show that there is a significant reduction of stiffness after 800°C. Models under 1000°C in Fig. 31 approves this issue when the M-0 (20.76 GPa) compared with M-1000 (1.7 GPa), F-BB-Beam (2.6 GPa), FB-C45B90 (1.8 GPa) and F-BB-Beam-Bott (3.75 GPa). Now, the important aspect is that when using steel bars on compressive side of beam and BFRP on the tensile ones has the best performance of strengthening models under 1000°C. In Fig. 32 to 36, the ductility factor is shown. Based on these results, the models reinforced with only steel bars have more ductility than others up to 400°C. Since then, the combination of steel and BFRP bars have higher value either in reinforcing or wrapping models. In this case, F-BB-Beam has a ductility factor on about 21.8, 29.77, 32.7, 43.67 and 18.45 under 200, 400, 600, 800 and 1000°C. An interesting point is for F-BB-Beam-Bott model under 1000°C which has the ductility value more than 20. Comparing Fig. 35 and 36 shows that the most critical part of RC frame under extreme fire load (800 and 1000°C) is the tensile part of the beam due to weakness of the beam. So, adding BFRP bars only on the tensile area of beam can increase the ductility of whole system. In Fig. 37 to 41, the seismic factor of RC frame is shown. As it can be seen, the seismic factor of models retrofitted with BFRP sheets is higher than reinforcing method. For instance, the seismic factor of FB-C45B90 compared with F-BB-Beam (optimized method) is about 5.6 and 4.21 under 200°C, while this value for 600°C is 4.17 and 2.37. On the other side, it can be seen that there is a sequence in retrofitting models indicates that FB-C45B90, FB-C45B45 and FB-C0B45 have the highest to the lowest seismic value, in order. Furthermore, FB-C45B90 has the best performance of improving the seismic factor during the fire load.

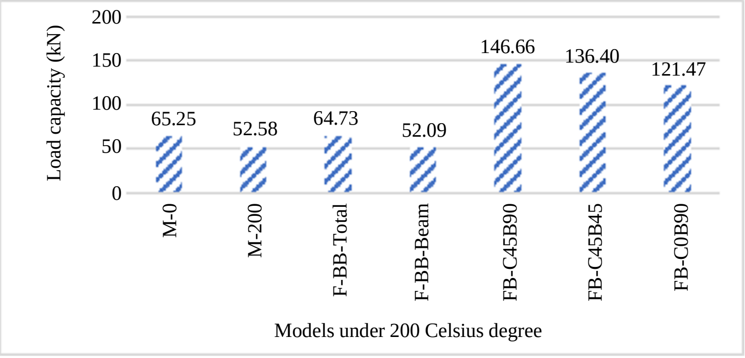


Fig. 22: Comparison of load-capacity - 200 Celsius degree

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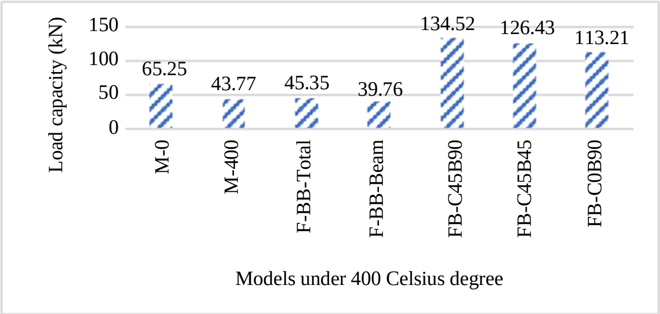

Fig. 23: Comparison of load-capacity - 400 Celsius degree

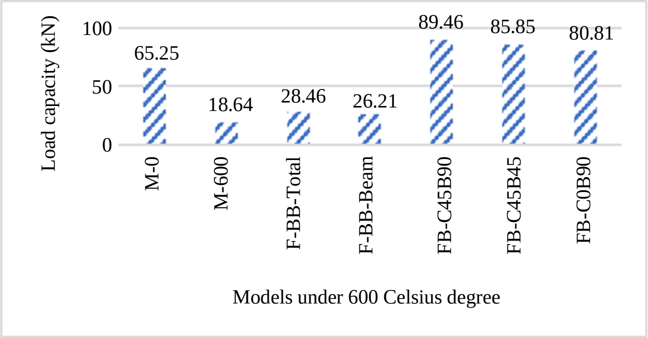

Fig. 24: Comparison of load-capacity - 600 Celsius degree

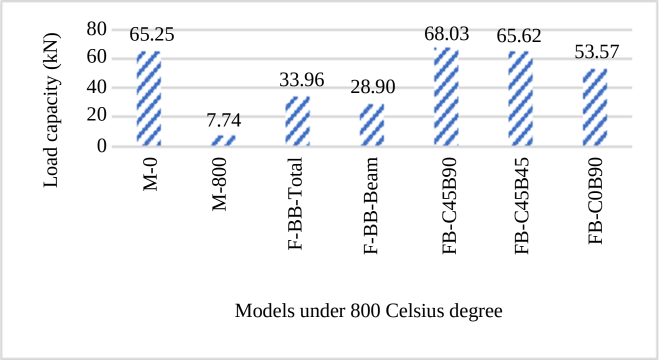

Fig. 25: Comparison of load-capacity - 800 Celsius degree

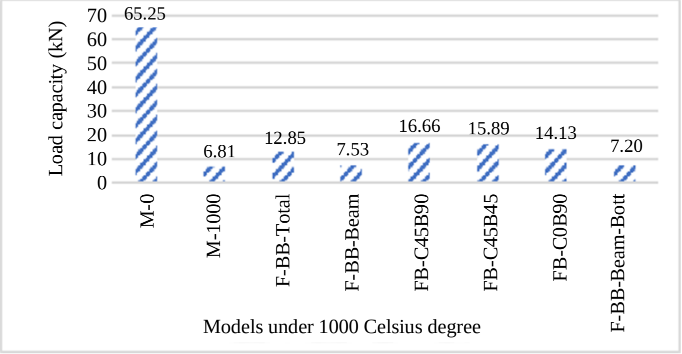

Fig. 26: Comparison of load-capacity -1000 Celsius degree

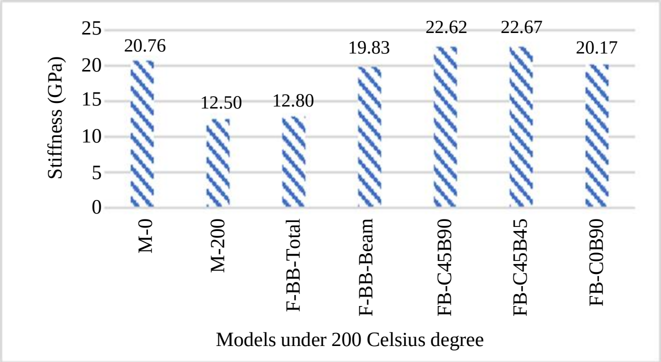

Fig. 27: Comparison of Stiffness-200 Celsius Degree

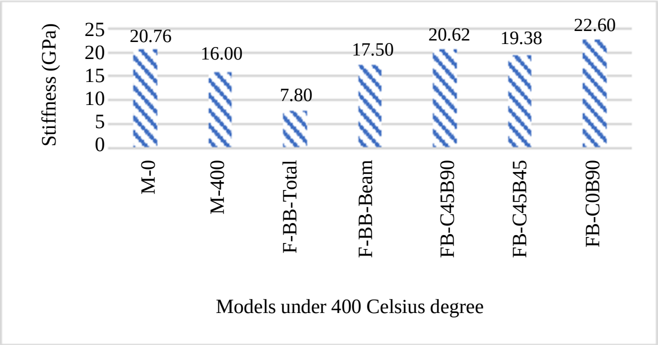

Fig. 28: Comparison of stiffness -400 Celsius degree

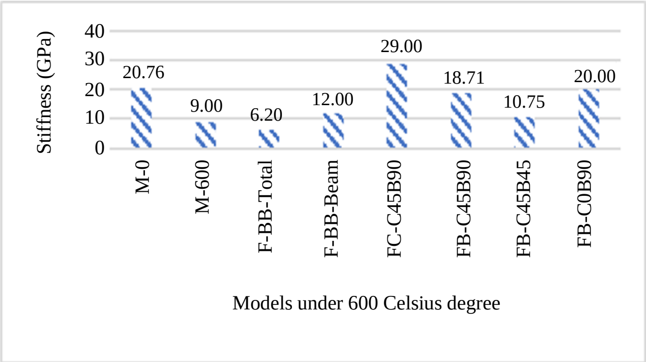

Fig. 29: Comparison of stiffness -600 Celsius degree

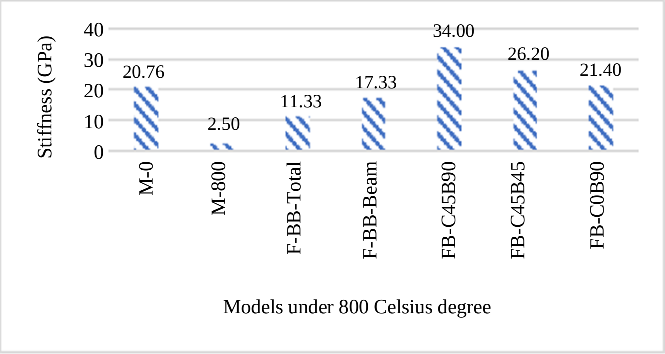

Fig. 30: Comparison of stiffness -800 Celsius degree

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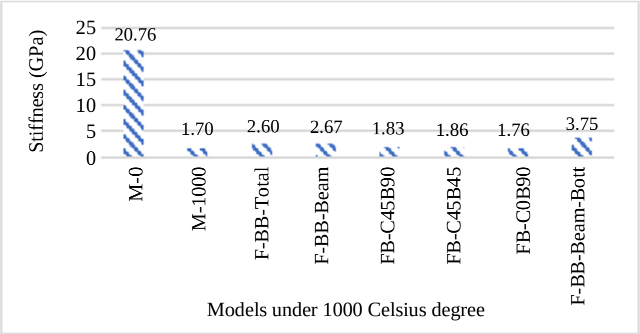

Fig. 31: Comparison of stiffness -1000 Celsius degree

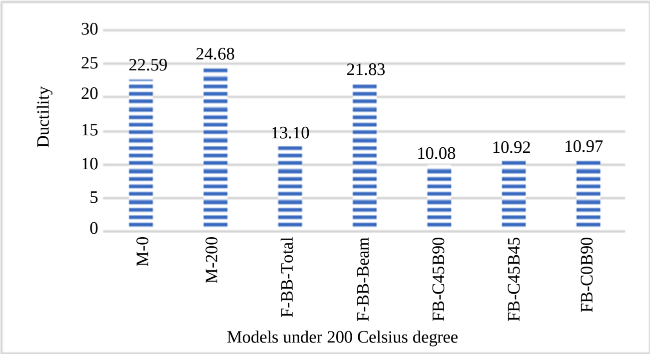

Fig. 32: Comparison of ductility -200 Celsius degree

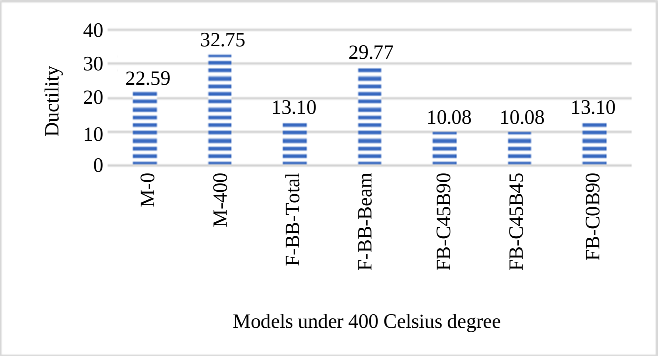

Fig. 33: Comparison of ductility 400 Celsius degree

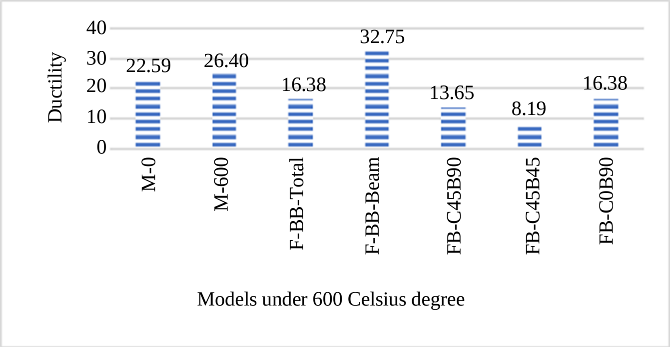

Fig. 34: Comparison of ductility 600 Celsius degree

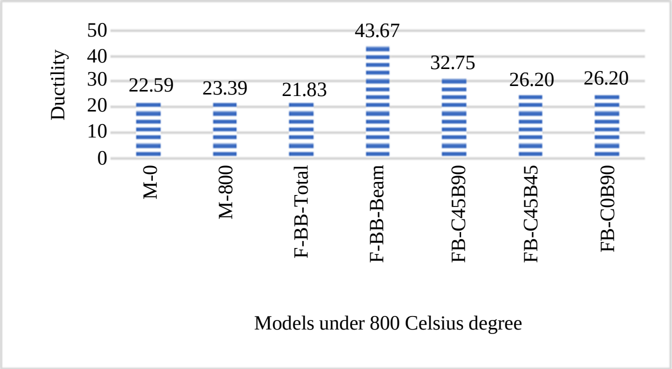

Fig. 35: Comparison of ductility 800 Celsius degree

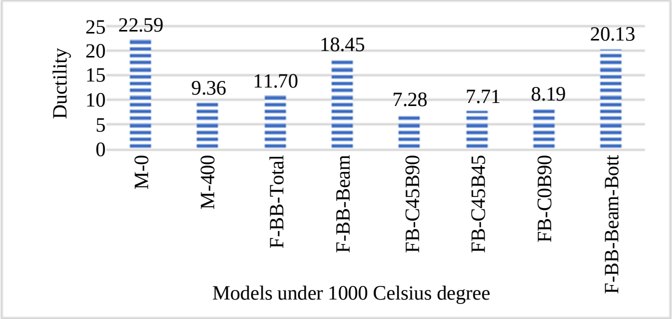

Fig. 36: Comparison of ductility 1000 Celsius degree

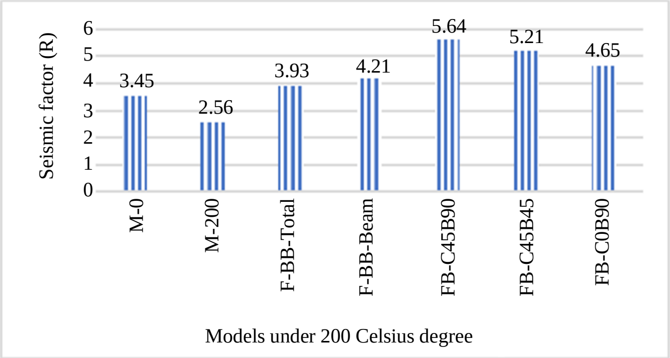

Fig. 37: Comparison of seismic factor- 200 Celsius degree

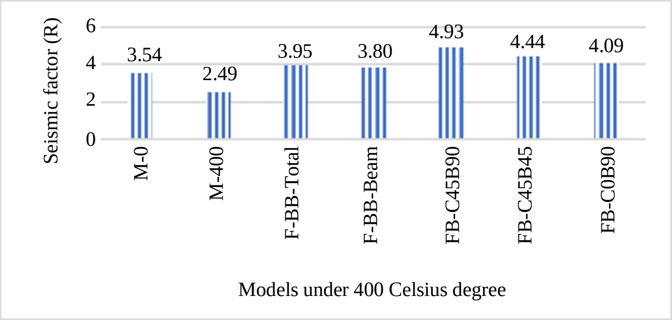

Fig. 38: Comparison of seismic factor- 400 Celsius degree

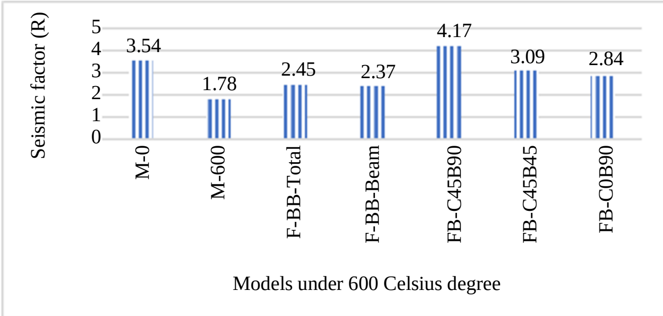

Fig. 39: Comparison of seismic factor- 600 Celsius degree

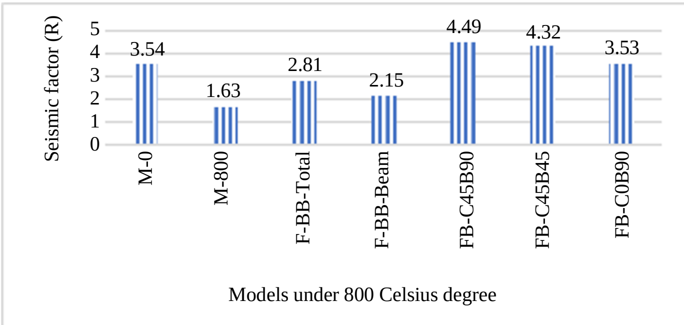

Fig. 40: Comparison of seismic factor- 800 Celsius degree

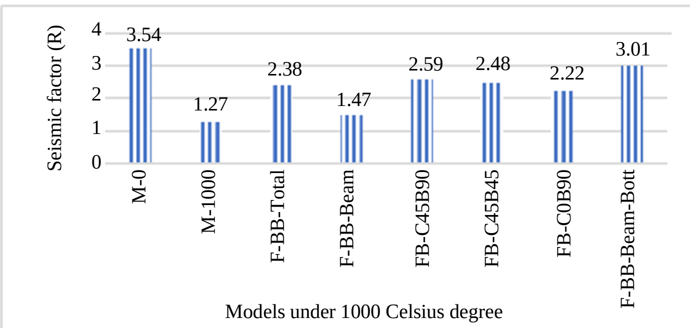

Fig. 41: Comparison of seismic factor- 1000 Celsius degree

Conclusion

Based on the finite element simulation parametrical studies, the following results are made:

- The retrofitting method with BFRP sheets has better performance in increasing load capacity and FB-C45B90 is the best and optimized technique among all other methods.
- Increasing the fire temperature cause reducing of stiffness. However, wrapping with BFRP sheets performs better than reinforcing method. On the other side, using the combination of BFRP and steel can enhance the stiffness in comparison with model with only steel bars.
- Models reinforced with only steel bars has the higher ductility under 200, 400 and 600°C, but after that it has a reducing trend.
- The reinforcing combination which is called now as optimized model (F-BB-Beam) has the highest ductility than other specimens (except model with steel like M-200, M-400, M-600 and M-800) up to 800°C. Since then (on 1000°C), the F-BB-Beam-Bott model show the highest ductility factor. It can be concluded that using BFRP bars in tensile are of beam combined with steel in compressive side can significantly improve the ductility of RC frame.
- In seismic factor results, the FB-C45B90 is the best method of retrofitting up to 800°C and model with

only steel bars reduces the seismic factor by increasing the fire load.

- The RC frame tolerates the fire loading conditions up to 600°C. Up to this temperature, the retrofitting and reinforcing technique can have positive effect on enhancing the performance of RC frame's behavior. Granted, these techniques still can improve the behavior but, the improvement is too small

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The Authors also declare that there is no conflict of interest.

Author's Contributions

Reza Salehi: Performed modeling with FEM software and data analysis. Also, participated in writing the manuscript.

Abbas Akbarpour: Provided the research topic and guided the research development, experimental plan and data analysis. Also, participated in writing the manuscript.

Armaghan Shalbaftabar: Performed modeling with FEM software and data analysis. Also, participated in writing the manuscript.

Ethics

This article is original and contains unpublished material. Authors declare that are not ethical issues.

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