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Numerical modeling of FRP reinforcements in concrete frames under dynamic loading

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ABSTRACT

Special concrete frames are designed to withstand the bending loads caused by earthquakes, and how to reinforce them is debatable. In this study, the effect of a type of these frames that are reinforced with FRP composite reinforcements was discussed. The research was conducted by finite element method and after validation with a real sample and checking the convergence of the results, permission to use this method was issued. The result was that the loads caused by earthquakes, which affect the structures in the form of bending and shear, despite the need for proper resistance to repel the effect, need a little flexibility in movement so that such loads do not cause material fatigue. FRP reinforcements, due to their good flexibility, provide limited movement of the frame, so fewer loads is applied to it and proper connection between the members also eliminates danger. Thus, structures with a suitable safety factor and bending and shear loads will not be able to pose a hazard. A comparison was made between the effects of metal reinforcement and composite reinforcement, which proved to be positive. Special concrete type also showed good resistance to severe seismicity and was considered suitable for construction in seismic areas.

1. Introduction

Composite reinforced with high performance fibers is a material with a combination of cement paste and short reinforcement fibers that are formed under tensile stress in several cracks and due to its high bond strength, it has been used as a repair material (Choi et al., 2014). One of the prominent characteristics of these fibers is high tensile strength compared to ordinary concretes and the tensile strength of these materials is about ten times that of ordinary concrete. These materials have many applications due to their energy absorption properties, high hardness and high durability. These materials have been used for the purpose of reinforcing building components such as concrete (Zafar and Andrawes, 2015). Also, the main weakness of reinforced concrete flexural frames is the lack of ductility and confinement, especially in the joints, so that failure in these joints causes the destruction of the whole structure (Song et al., 2021). Beam-to-column joints are still one of the main components of force transmission in the structure. Their type and behavior in the frame is of particular importance. By applying an earthquake to the joints, a tensile and compressive force is created at the top and bottom of the beams, and the concrete inside the joint cracks and collapses due to the reciprocating movement during the earthquake. Proper operation of joints in reinforced concrete flexural frames is essential to maintain the stability of these structures in the event of severe earthquakes or dynamic loading (Choi et al., 2014).

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Engineered cement composites in concrete, commonly abbreviated to latten, unique type of cementitious composite that has high properties and damage tolerance to heavy loads (including tensile and shear loads) is one of its features. These materials are designed for elastic and paste applications (Zafar and Andrawes, 2015). Fiber is used in concrete to increase tensile strength and prevent the spread of cracks, and especially to increase softness. The fibers increase the strength of the concrete; however, if the concrete is under high pressure and cracks, the fibers prevent the spread of cracking. The main difference between polymer fibers and other methods of concrete reinforcement is that the fibers are not just placed in a specific area, but are part of the concrete mortar and turn it into a reinforced composite material (Saqan et al., 2018).

In the case of reinforcements, a new type of composite material is introduced, which is known as ‘FRP’. This type of composite reinforcement can be placed inside the concrete and provide a basis for its reinforcement. With the passage of time and the increase of world population, the need for progress in the field of construction, maintenance and strengthening of existing structures and the use of new technologies is increasingly felt. In addition, the need to build earthquake-resistant structures is felt more due to the increased seismicity of countries around the world. Among the new technologies that have a special place in construction, concrete additives, reinforcement and reinforcing fibers in the form of special concrete frames. The use of composite additives improves the desired properties of concrete, such as its strength, and in some cases, by reducing the weight of concrete; puts very light materials in the way of building engineers (Esfandiari and Latifi, 2019).

Composite reinforcement is actually a type of composite in concrete that increases the tensile strength by using reinforcing fibers inside the volume. This composite compound has good integrity and cohesion and allows the use of composite reinforcement as a formable material to produce strong curved surfaces. Composite reinforcement is also capable of absorbing high energy and does not break down easily under impact loads. In fact, composite reinforcement is an advanced type of technology in which new natural and synthetic fibers have replaced single-material steel. Composite reinforcement has suitable properties such as high ductility, excellent strength, energy absorption and cracking stability, which can be used for many applications (Esfandiari and Latifi, 2019). Extremely high compressive strength is obtained from FRP using suitable granulation that is homogeneously mixed. On the other hand, the increase in tensile/flexural forces, fracture and damage control is mainly due to the random splitting of the reinforcing fibers in the mix. As a result, many studies on this type of composite show that FRP has extraordinary damage control properties compared to other types of reinforcement in terms of dynamic loading (Parghi and Alam, 2017).

This type of reinforcement is one of the best materials used in the construction of impact-resistant buildings, such as shelter structures and explosives storage facilities, and concrete-shaped buildings have an extraordinary ability to absorb impact energy. This type of combination can also be used well in the construction of airport runways. Other uses for this structure include the construction of prefabricated building components such as panels or the spraying of concrete on the curved surface of a structure. In addition to the above, you can also take advantage of advantages such as sound insulation of the structure and high speed of execution (Song et al., 2021).

2. FRP Armature Reinforcement

FRP reinforcement is a composite product that replaces steel reinforcement and significantly prevents corrosion damage from reinforcement in corrosive and acidic environments. The use of FRP is the best option for reinforcing concrete in places where there is no need for problems with contact with electric and magnetic fields. This product has been widely used due to its good resistance to sulfates and chlorides and also its good resistance to corrosion and rust. Therefore, to reduce the cost of repairing offshore structures that are exposed to the corrosive environment of the sea and are destroyed due to the gradual loss of concrete coating of steel rebars, the use of FRP rebars along with existing coping methods such as cathodic protection and The use of epoxy coatings has been relatively successful (Parghi and Alam, 2017). FRP reinforcement can also be used to design and build new buildings. These materials with their properties reduce the diameter and increase the distance of reinforcement in reinforced concrete members such as slabs, tunnels, foundations. These reinforcements are classified according to the fibers used in their polymer (Saqan et al., 2018):

- FRP glass reinforcement,
- Carbon FRP reinforcement,
- FRP armature reinforcement.

2.1. Application of FRP reinforcement

FRP reinforcement or FRP composite reinforcement is a suitable alternative to steel reinforcement in high corrosion environments. These reinforcements are made by combining FRP fibers and a resin coating. For this reason, they are also called FRP composite reinforcement. The price of FRP composite reinforcements is very low compared to steel reinforcements and the properties that the user receives from them. Because if the user is wants to get the same properties from steel reinforcement, it has to be pay attention several times more than the price of FRP reinforcement (Fahmy and Ibrahim, 2020). These reinforcements significantly prevent corrosion damage to steel rebar in corrosive and acidic environments. The use of FRP reinforcement FRP is the best option for reinforcing concrete in places where there is no need for problems with contact with electric and magnetic fields. FRP reinforcement can also be used to design and build new buildings. Also, RRP increases the damping created in the structure against vibrations caused by earthquakes or industrial equipment and is the best option to increase the resistance of the structure against earthquakes or vibrations (Ali et al., 2018).

2.2. Types of FRP reinforcement

FRP composite reinforcements consist of two polymer parts, FRP and resin. The behavior of both FRP and resin polymer fibers is effective in the final behavior of FRP composite reinforcement. Depending on the type of resin, which can be one of the types of polyester, epoxy, vanilla ester or PVC, or the type of FRP polymer fiber, which can be one of the types of carbon, glass or optical fiber which is available in the market as follows (Fahmy and Ibrahim, 2020):

- Glass reinforcement or G-FRP,
- Carbon reinforcement or C-FRP,
- Aramid Armature reinforcement or A-FRP.

Among the above reinforcements, fiberglass or G-FRP is the cheapest reinforcement (Fahmy and Ibrahim, 2020).

2.3. Behavior of FRP composite reinforcements

The behavior of FRP composite reinforcements is quite elastic. This elastic behavior continues until the moment of rupture. As mentioned, the strength of FRP composite reinforcements is much higher than that of steel. Due to this, their elastic strain is much higher than steel. This makes all the deformations that occur in FRP composite reinforcements reversible FRP composite reinforcements vary depending on the type of polymer and its resin (Ibrahim et al., 2017).

2.4. Practical purposes of FRP reinforcement

Before reinforcing a concrete structure with reinforcement, it is necessary to carefully consider and evaluate the properties of the reinforcement component in order to provide usability suitable for the final use and compatible with the designer's opinion. Natural corrosion resistance for concrete structures reinforced with FRP reinforcement is a great benefit for structures that are highly susceptible to corrosion, such as offshore structures, bridge decks, as well as structures in exposed to environments containing antifreeze salts. In parts of MRI or other equipment sensitive to electromagnetic fields, the non-magnetic nature of FRP has many advantages (Zhang and Xu, 2019).

The lack of ductility of FRP reinforcements, despite their non-magnetic properties, makes this type of reinforcing rod more widely used in applications that are highly vulnerable to problems such as corrosion or electromagnetic effects. A noteworthy point in using FRP reinforcement is that it should not rely on data on its compressive strength. The present data show that the compressive modulus of FRP reinforcements is less than their tensile modulus (Ali et al., 2018). The combined effect of mechanical behavior in relation to FRP and their low modulus compared to steel causes the highest share of compressive stress calculated for FRP in the case of failure of concrete structures. Under loading, it is relatively small, so FRP reinforcements should not be used as reinforcement for columns or other members under pressure. Also, these parts should not be used as compression reinforcement in strengthening the members that are affected by bending forces (Aliasghar-Mamaghani and Khaloo, 2021). It should be noted that the use of FRP reinforcement, due to the possibility of changes in the way of loading and displacement of the bending anchor during loading, can provide acceptable performance, especially against compressive forces. Although the compressive strength of FRP reinforcement should be discarded, more research is still needed (Ferrotto et al., 2018).

2.5. Fatigue life in concrete

One of the parameters related to the research topic is the fatigue life due to seismic load. Consecutive shocks cause the reinforcement or concrete to fail at loads below its resistance. The definition of fatigue is that due to the application of alternating load, even if this load is less than the failure load, the part will break, which is called the fatigue phenomenon. The main reason that fatigue failure is dangerous is that it occurs without prior awareness and empowerment. Fatigue results in a brittle-looking fracture without any gross deformity. The fracture surface at the macroscopic scale is usually perpendicular to the principal tensile stress. Fatigue failure surface is usually identified by the appearance of the failure surface, which consists of a smooth area resulting from abrasion with the propagation of cracks in the section and an uneven area that is softly broken in the piece when the load is not borne by the section. Failure progress is often indicated by a set of loops, which progress inward from the failure point (Aliasghar-Mamaghani and Khaloo, 2021).

The relative share of each stage of the total failure cycles depends on the test conditions and the material. But it is well established that a fatigue crack can form before 10% of the sample life expires. Of course, there is a lot of ambiguity in deciding when a deepened slip can be called a crack. In general, a larger share of the total failure cycles is due to the propagation of stage 2 cracks in low-cycle fatigue than in high-cycle fatigue, while the growth of cracks in stage 1 is higher for high-cycle fatigue and less stress. If the tensile stress is high, such as fatigue in sharp-grooved specimens, the growth of stage 1 cracks is not noticeable at all. Careful structural examination of fatigue shows the fact that fatigue cracks usually start at a free level. In rare cases where fatigue cracks start from the inside, there is always a boundary, such as the boundary between the carbonized surface layer and the base metal (Ferrotto et al., 2018).

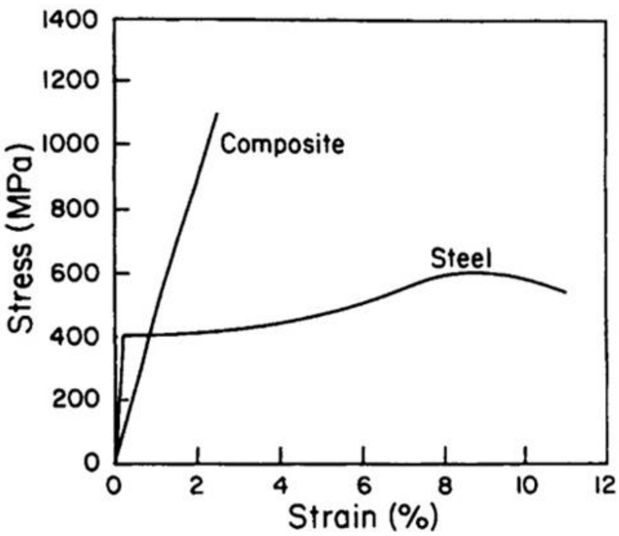

Figure 1. Stress-Strain curve of composite vs. steel reinforcements (Shin et al., 2020)

3. Materials and Methods

The research method here is finite components with the help of ABAQUS software. Finite elements in simple language means dividing the problem into smaller parts and solving them part by part and providing the final answer. Much finite element software has been developed that has been extensively calculated and has been able to simulate the problem graphically, in a way that is more understandable to users.

Drawing parts: The parts of a concrete were drawn as shown in the plan. In ABAQUS software, there is a section called Part where parts can be drawn. Drawing software such as Katia and AutoCAD are commonly used to draw complex parts which are four pieces (Ram et al., 2020):

- Concrete frame that holds the blocks (concrete without composite reinforcements),
- The blocks that are inside the embedded place (are cubic),
- Supports that are drawn as a rigid and immutable body. For a rigid body, the reference point is defined,
- Composite reinforcements with the aim of reinforcing concrete, which were drawn in the form of solid cylinders with a relatively long length relative to the diameter. This piece was deformed and drawn in three dimensions.

Properties of parts: In this section, the rupture criterion must be determined. Loss of the bridge's load-bearing capacity causes it to fail. In materials science, the loss of bearing capacity of a material is defined as the failure of that material. According to this definition, the failure of a substance can be evaluated in different scales (microscopic to macroscopic). In matters related to structures, it is also possible for the structure to react after the onset of nonlinear behavior. Therefore, material failure plays a very important role in determining the integrity and safety of the structure. On the other hand, the lack of approved rupture criteria (for all conditions) has led to more research on structural damage assessment with respect to the issue of material failure. Failure of materials can be divided into two general categories, microscopic and macroscopic failure according to their evaluation scale. Microscopic failure of materials is defined by the onset and growth of cracks within them. Investigating this type of failure is a good way to better understand how cracks form in laboratory specimens and structures that are subject to certain global load distributions. Failure criteria in this case are related to the microscopic rupture of the material. Micromechanical failure models are the most popular failure models at the microscopic scale. Micromechanical models take advantage of the advantages of both continuous media mechanics and classical failure mechanics (Pan et al., 2018).

The process of microscopic failure is such that initially, the plastic deformation begins to cause micro-cavities and their expansion into the material. This process continues until an area of plastic narrowing or rupture of the space between the cavities. Finally, adjacent holes are connected. This process is the basis for the development of micro-mechanical models. Macroscopic failure of materials is defined according to their load-bearing capacity or energy storage capacity. Macroscopic failure criteria fall into one of four groups (Ram et al., 2020):

- Tension or strain failure,
- Energy failure (S and T criterion),
- Damage failure,
- Experimental failure.

In general, there are five different levels for defining failure and deformation which are (Ram et al., 2020):

- Scale of structural components,
- Macroscopic scale (definition of stress and strain),
- Medium or Microscopic scale (an empty space),
- Atomic scale.

The behavior of the materials at each of these levels is considered as a set of behaviors at its subsurface. Efficient failure and deformation criteria are compatible with all of these levels. Fragile material failure is investigated through the following approaches (Ram et al., 2020):

- Experimental failure criteria,
- Linear elastic fracture mechanics,
- Elastic-plastic fracture mechanics,
- Energy-based methods,
- Adhesive area methods.

Predicting ultimate fracture toughness is another important aspect of yield in malleable materials. So far, several different models have been proposed and used by engineers to predict the ultimate strength of formable materials. The degree of success of each of these models is different. For metals, these failure criteria are usually based on a combination of porosity and strain relative to failure or a parameter of damage. In this study, the criterion of experimental rupture has been used. This means that the criteria that were obtained experimentally based on the software were entered and simulated. The rigid part does not need to define the properties and only the mass is determined for it. But concrete is definable. Concrete components have the property that the properties under tension under pressure are different. In the initial part, only two properties of elastic and plastic are defined, which are shown in Table 1.

Step: The defined step can be static or dynamic. In civil engineering issues, the static step has a special place. The output of the problem was also determined as time dependent.

Call: All surfaces in contact with each other can be placed as a contact characteristic of concrete components to maintain the desired connection. Sometimes friction is the cause of the connection between the parts and sometimes chemically, the connection occurs, which can determine the type of connection between the components.

Boundary conditions: The boundary condition includes the amount of displacements, forces, or constraints. In this study, the boundary conditions are determined as follows:

- All mobility of the lower supports (six degrees of freedom) was restricted.
- High rigid objects were given the desired force or displacement at a frequency of 0.1 Hz.

Mesh: Meshing has a significant effect on responses. Coarse mesh causes error. But as the meshes become smaller than a certain value, there is no change in the responses, and in fact the results tend to converge. Therefore, a reasonable amount of mesh has been done and then the issue of independence from mesh has been investigated.

Table 1. Technical specifications of FRP

No.	Parameter	Unit	Value
1	Number of layers	-	Depending on RTP diameter
2	Elastic modulus	MPa	$E_x = 25579$ $E_y = E_z = 2136$
3	Poisson's ratio	-	$\upsilon_{xy} = \upsilon_{xz} = 0.2$ $\upsilon_{xz} = 0.3$
4	Shear modulus	MPa	$G_{xy} = G_{xz} = 1450$ $G_{yz} = 825$
5	Tensile strength	MPa	552
6	FRP thickness	mm	1

4. Results and Discussions

4.1. Simulation of concrete frame

Regarding the design, it should be noted that the design part has been done in Katia software. In Abacus software, there is a section called Part where parts can be drawn. Drawing software such as Katia and AutoCAD are commonly used to draw complex parts. In this research, there are complex parts that can be easily drawn and assembled in Katia software, and after completion, the desired file can be transferred to Abacus software. In Abacus software, the simulation steps can be continued. In simulation stages; first, the necessary explanations are given about the simulation of the concrete frame. First, the frame structure was modeled in three dimensions and solid with a total height of 1000 and a length of 2700 mm. Column cross-section with dimensions of 250×250 mm and frame cross-section with dimensions of 150×250 mm were modeled. The model geometry is presents in Fig. 2. Also, FRP sheet with a length of 2400 mm and a width of 50 mm was modeled as a shell. Secondary, the material properties were recorded according to what was described in the Table 1 and the type of explicit dynamics analysis was determined for it (Fig. 3). The loading was also applied as a seismic acceleration instruction for 8 seconds on the floor of the foundations in the longitudinal direction (Figs. 4 and 5). A force of 17,250 N was applied as a total force.

Due to the state of independence from the mesh, which was previously proved, the reinforcement piece with a size of 100 mm and the type of truss element of the truss T3D2 was elemental. This type of element has the ability to withstand tensile force and is suitable for the design of concrete reinforcing materials.

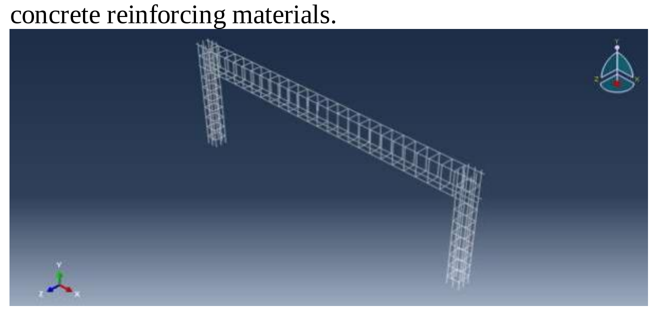

Figure 2. The geometry of reinforced concrete with FRP

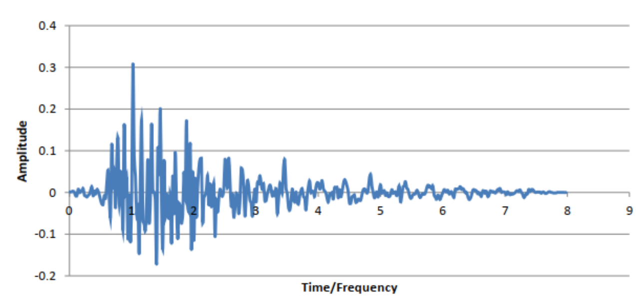

Figure 3. Earthquake load profile applied to the structure

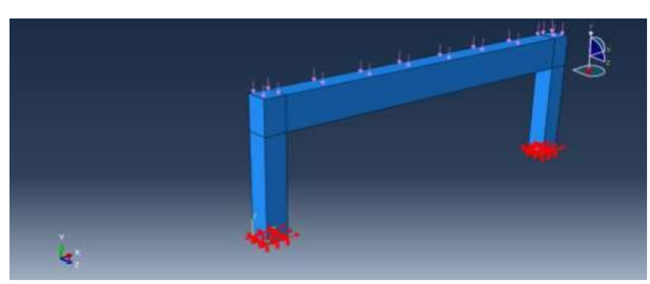

Figure 4. Loading condition on simulated concrete-structure

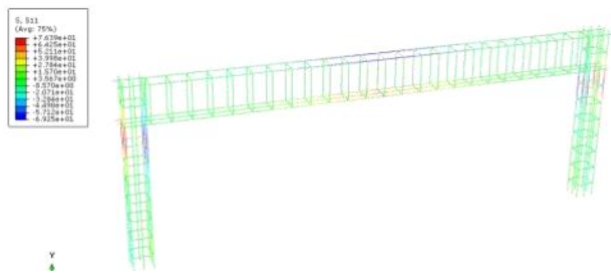

Figure 5. Stress distribution in composite reinforcements

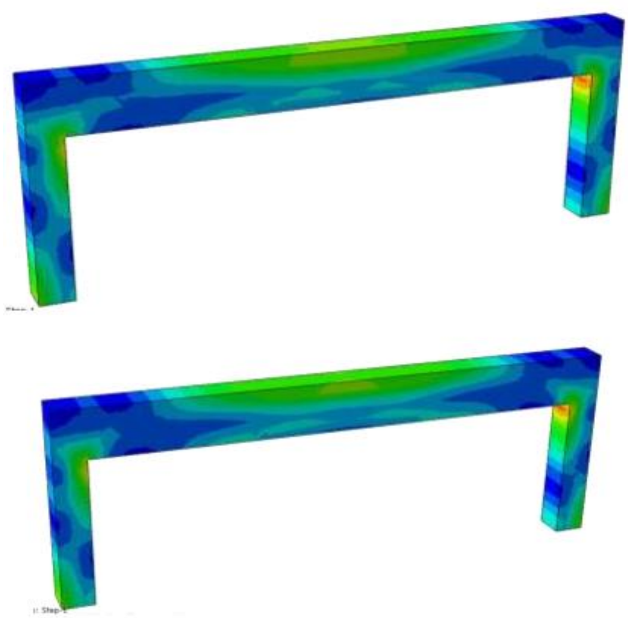

Figure 6. Stress distribution in the concrete frame

4.2. Cracks created in concrete due to dynamic load

The importance of the crack issue is very important in civil engineering discussions due to its role in the expansion of the concrete crack line, and the dangers posed by its existence. In this section, the role of the type of reinforcement and its connection on the cracking method is discussed. Naturally, the size and other characteristics of the cracks predict the behavior of the material under seismic loading, and therefore it is necessary to analyze and interpret the desired results by careful study in this area.

Fig. 7 shows the ratio of minimum and maximum Van-Meiss stresses over the analysis time. Due to the use of the stress ratio parameter, the vertical axis does not have a unit of scale. As it is known, in the initial moments, this specific ratio between the maximum and minimum stress is small, but after 2 seconds, the value suddenly changes and this ratio changes. But the remarkable thing is that in the specified time of 7 seconds, this reaches its maximum limit which is around 70. It can be interpreted that this large amount is due to the growth of cracks, which leads to a sudden increase in stress in the crack depth. However, the wider area of the concrete is subjected to a constant load due to the increase in length due to the application of the load, as well as a lower amount of stress, and the maximum to minimum ratio changes suddenly. It is almost impossible to pinpoint a definite reason for its fluctuations over this period. In cracks, such changes in the stress ratio, especially at the crack edge, are almost normal, as the crack is easily subjected to loading. The average of the numbers in the chart indicates that the values are normal, but a sudden change that is evident in the maximum part can lead to a sudden break. However, there is a theory that it is possible to prevent undesirable deformation by strengthening the cracks with different actions and to keep the maximum and minimum stress ratios within a certain range. Sudden failures are avoided if you are able to control this ratio. Composite reinforcement, in this case, has shown its flexibility. The ratio mentioned in Fig. 8 in the FRP type is lower and more regular than in the other type of armature type. However, both types of reinforcement performed well. Fig. 9 shows the size of the crack opening in relation to its length, and usually due to the strong pressure applied to it from the middle of the body, the stress is applied from the axis and shows its effects. However, the effect of the axial load can increase the crack depth. It is clear that this value has a certain ratio because the diameter of the opening is almost directly related to the amount of crack length.

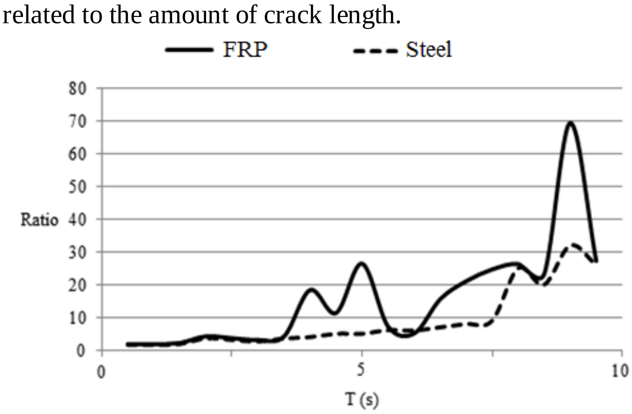

Figure 7. Van-Meiss tension ratio at the crack edge in two types of reinforcement

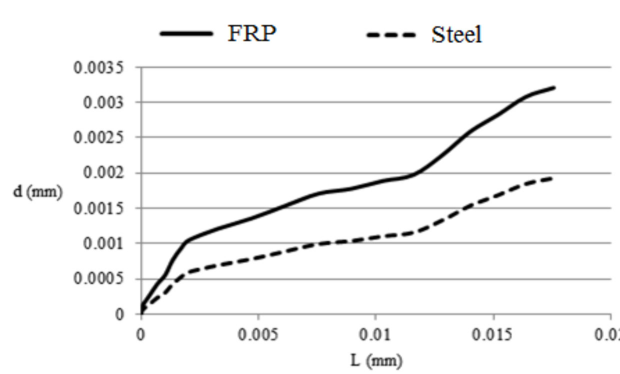

Figure 8. Increasing the diameter of the crack opening in terms of the ratio of crack length in concrete

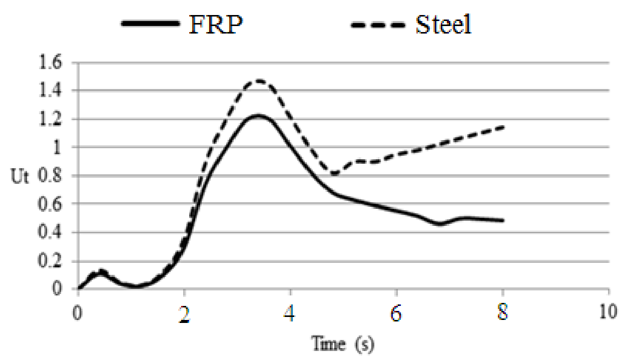

Figure 9. Ratio of crack edge displacement to seismic load displacement in concrete

As a result, the increase in crack size can be proportional to the amount of crack length. The result is that the size of the opening is directly related to the length. Of course, this result is not desirable. This feature is the nature of special concrete that has been studied in this study. Engineers can prevent the failure of the part by closing the crack opening and preventing the increase of the opening length, and by controlling the increase of the crack opening, its length can also be prevented. Fig. 10 shows the ratio of the vertical displacement of the crack edge to the displacement of the seismic load site. Thus, the values of the vertical displacement of the seismic load in terms of time are taken into account and the same behavior is measured again at the end of the crack edge. Then the ratio of this value was calculated and its graph was drawn in terms of time. At the beginning and end of this graph, values less than one are observed. This means that the amount of crack displacement is less than the displacement of the force-injecting object. It is interpreted that due to the seismic load, first the strain is present at the junction of the force-injecting body and the applied force is applied to the small deformation in that area and has little effect on the whole frame. At the end of the strain, the joint is suddenly deformed throughout the concrete, and the amount of cracks, the amount of deformation of which is very high, after a while, this ratio returns to the previous state. According to researchers, this special type of concrete can prevent its expansion after increasing cracks. A special feature of composite reinforcement is the change of properties at different points. Because its effects can be time dependent. This type of reinforcement is not like FRP reinforcement, whose properties are constant throughout the process as well as at all points, but it can behave differently as the crack displacement increases. The characteristic of this different behavior is that by increasing the length of the tear to a certain extent, it then counteracts the growth of cracks. In other words, a kind of self-resistance is evident in this type of frame because in the final moments, there is no longer a specific strain between the connections with the body entering the force. This decrease in ratio can be due to the self-resistance of the frame with the mentioned specifications.

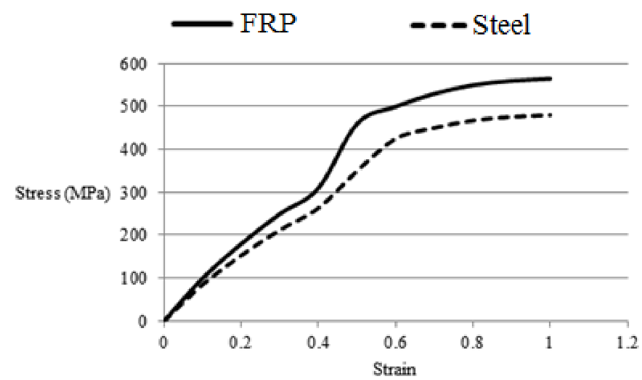

Figure 10. Crack stress-strain curve in two types of reinforcement in seismic loading

In the typical type of reinforcement, the crack can be moved more than FRP. Of course, both types of reinforcement have a good performance in this category. But the FRP type has shown better resistance than the other type.

4.3. Effective parameters of concrete frame

While changing the parameters of reinforcement percentage, reinforcement current stress and height to width ratio, their effect on frame values, stress and strain and crack depth have been calculated and discussed separately.

Number of reinforcements and connection: the effect of the number and method of connecting the reinforcements is investigated. For this purpose, the cross sections are reinforced in four specimens as shown in Fig. 11. The bolts are placed in 10, 12, 16 and 20 lengths along the length of the grip and in the first stage; the frame rise is measured in two conventional reinforcements and FRP which are detailed has been shown in Fig. 11. What can be deduced from Fig. 11 is that the behavior of both types of concrete due to the increase in the density of reinforcement is a decrease in the frame. This means that by increasing the reinforcement in the cross section of the frames, the frame can be reduced.

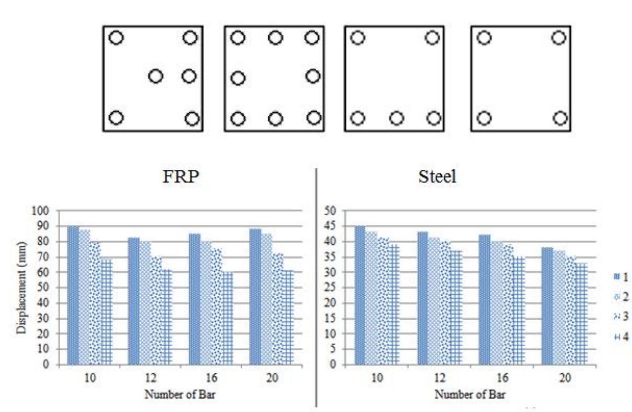

Figure 11. Number of reinforcements and frame rise in two examples of FRP vs. steel

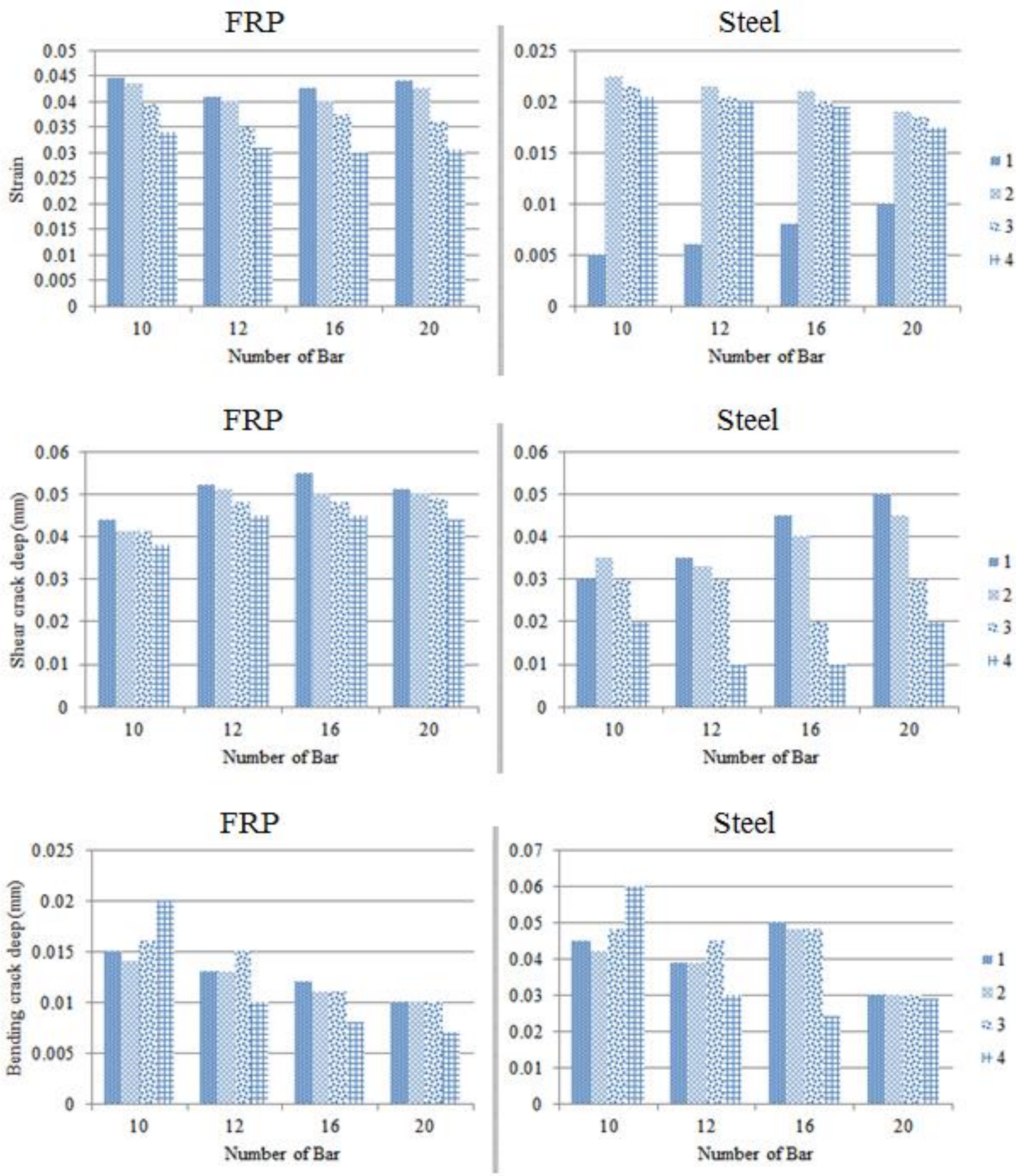

Figure 12. Changes in the number of reinforcements and the shear crack depth of the frame in two samples (FRP/Steel)

In the case of braces, it was also concluded that FRP type reinforcement is ineffective from changing this number, and only ordinary type reinforcement is affected by this increase, as there is an inverse relationship between frame rise and reinforcement density in this type of reinforcement. The result is that increasing the transverse density of the reinforcement has a much better effect on the rise of the frames. This effect is greater in FRP reinforcement. However, it had less effect on the type of conventional reinforcement, and at the same time, the longitudinal density, which had no effect on the type of composite reinforcement, had a significant effect on reducing the rate of rise in conventional reinforcement. The general idea is that by increasing the number of reinforcements in the cross section of the beam, due to the presence of a strong object, the strength of the beam can be increased. But the truth is that in addition to increasing the yield strength, the layout must take into account the flexibility of the beam. In fact, the spring coefficient of the beam should be considered along with its resistance. It is clear that type 4 layout had the lowest rise among all 4 layouts. If you look at the number of reinforcements, the type 3 arrangement has the largest number of reinforcements, but the fact is that the type 4 arrangement gives the rod good flexibility and at the same time increases the strength, which is recommended to use this type of arrangement. It is clear that the stress concentration in the Type 4 layout is higher than in other layouts. In the case of steel reinforcement, this stress concentration can reach dangerous levels. However, in the composite type, this stress is still in the safe range, and it is recommended that the arrangement of steel reinforcements be performed in the same way. In fact, the stress concentration created in layout 4 again creates a safe range in the type of composite reinforcement, and in the steel type, it may jeopardize the safety of the concrete.

As shown in Fig. 12, the cross-sectional increase of the reinforcement is effective in reducing the strain of the FRP reinforcement in the concrete. But in other types of reinforcement, it does not have a definite effect. The longitudinal density of the bolts does not have a significant effect on the strain of both types of reinforcement. The only result obtained in this section is the inverse relationship of the number of transverse reinforcements on the rise of the FRP reinforcement frame. However, in the case of stresses, Fig. 12 shows that increasing the density in each section increases the stresses in the reinforcements. Although there are minor exceptions to the conventional type of reinforcement, the effect of the number of reinforcements on the stress can be confirmed. Steel testers have low flexibility and the type of load distribution in the first type of arrangement has caused the strain in this type of arrangement to be significantly reduced. Such a reduction in strain is significant, as it can mechanically increase the life of the structure. But in the type of FRP connection, due to the nature of the material, the strain is not only not reduced, but also increased.

Reinforcing concrete in any condition can increase its strength in relation to compressive and tensile seismic loads, especially flexural. Of course, the necessary proportion in the placement of reinforcement in concrete must be observed, and if there is a mismatch between these two categories in terms of area, weight and properties, it can cause damage to the building. For example, the excessive weight gain of reinforced concrete is due to the lack of proper coordination in this area. None of the previous research has shown any results regarding the advantage of non-reinforced concrete over reinforced concrete. One of the important parameters affecting the performance of reinforced concrete is the proper interaction between the reinforcement and concrete. It is concluded that metal reinforcement with the specifications mentioned in this study, has a better interaction with the reinforcement. Of course, the unique properties of metal reinforcement are also significant, including low weight, self-recoil properties, better strength, the ability to increase the length and generally better performance against various types of seismic loads. Examining the condition of the reinforcements as well as the reinforcements placed inside the concretes, it was concluded that the condition of the reinforcement inside the composite concretes is much better than FRP concretes. This refers to the better interaction of this type of concrete with reinforcement, and reinforced concrete of this type is called more effective than FRP concrete in this case. Such properties are better suited between metal reinforcement and concrete and regulate the behavior of the building structure. Examining the diagrams, it was found that the behavior of metal reinforcement, apart from better performance, is much more regular. This is related to the better interaction of concrete with reinforcement and the type of reinforcement. Regarding the behavior of concretes against changing parameters, it can be inferred that FRP composite reinforcement, although in some parameters, has a more unfavorable behavior, but its flexibility has given it considerable behavior. But the impact of this concrete is less than the normal type of reinforcement. In fact, changing the parameters has a strong effect on ordinary reinforcement. This can be dangerous. Because if for any reason a change of position occurs, the probability of adverse behavior of ordinary concrete is high and may even lead to destruction and damage. This impact is less in FRP composite reinforcement and in certain conditions; its safe condition can be hoped for. It can be said that sudden change in condition has less effect on this type of concrete and the possibility of sudden failure. It's less.

The purpose of reinforcing concrete in cross section is to strengthen the strength of concrete in several aspects, including bending, shear, and tensional. In terms of torsion, usually any type of arrangement can easily eliminate the tensional effect, because the torsion of the reinforcement can be neutralized in any way. Therefore, the layout must be intelligently designed to have both the necessary flexibility in strain and increase the strength of the structure. Therefore, the material of the reinforcement is very effective in determining the effect of the type of arrangement. In steel reinforcements with low flexibility, an arrangement that does not require much flexibility can be used. Among the 4 types of layouts studied, the most important was the type 4 layout in steel reinforcement. However, it is not possible to determine an absolute rule about layouts, and therefore it is necessary to test the effects of the layout type in relation to the problem, examine its effects and choose the best type expected.

5. Conclusion

According to the numerical modeling, the following results are obtained:

A) As the diameter of the braces increases, the amount of stress applied to the frame and column structures has decreased by about 0.5%. Also, with increasing the thickness of the frame and column connection, the amount of stress on the connection has decreased by about 7%. Also, when the diameter of the reinforcements increases, the amount of possible von stress in the connection should be reduced by about 6%.

B) With increasing the diameter of the braces, the amount of stress applied to the reinforcements decreases by about 1.2% and also with increasing the connection thickness, the amount of stress applied to the reinforcements decreases by about 16% and with increasing the diameter of the column reinforcements, the amount of tension They are reduced by 28%, which can be seen that the best thing to do to reduce stress in the reinforcement is to increase their diameter.

C) In FRP reinforcement, the concentration of frame tension at the crack edges is greater than in the case of conventional reinforcement. Also, FRP, the increase can be controlled by increasing the size of the crack opening, but this effect is not observed in ordinary reinforcement and the crack size increases upwards and continues until the concrete breaks down.

D) In FRP reinforcement, the stress applied to it is higher than ordinary reinforcement and in fact it withstands more vibration load due to the flexibility of the reinforcement. Also, in FRP reinforcement, due to the higher flexibility properties, the seismic displacement is usually more than the same as in conventional reinforcement.

E) The share of stress applied to the reinforcements in the FRP type is less than the normal type, which means that the FRP distributes the applied seismic load more appropriately. The cracks created in the FRP reinforcements are less deep than ordinary reinforcements and its length growth is less in similar conditions.

F) The deformation created in FRP reinforcement is much more than ordinary reinforcement. Increasing the number of reinforcements has led to an increase in stress in the concrete, which is less in the FRP composite type than conventional reinforcement in similar conditions. A sudden increase in stress in ordinary concrete can lead to its failure.

G) The presence of reinforcement can control the strain of concrete, but the amount of changes in the condition of concrete in the type of "FRP" is done with a more limited range and this increases the safety of concrete against failure and breakdown.

H) Increasing the reinforcement can prevent the crack from spreading, and this effect is stronger in FRP concrete. The height-to-width ratio is inversely related to the bulk of the frame, and this effect is weaker in FRP concrete than in conventional concrete.

I) The height-to-width ratio is inversely related to the amount of stress applied to the frame, and this effect is slightly weaker in FRP reinforcement than in conventional reinforcement. Also, the height-to-width ratio is inversely related to the amount of strain on the frame, but this effect is unclear for FRP reinforcement. The height-to-width ratio has a great effect on the condition of flexural and shear cracks, and in the case of conventional reinforcement, these effects lead to sudden stress and failure, while the effect of this parameter on FRP reinforcement. It is limited and this increases the safety of this type of reinforcement.

J) The current stress of the reinforcement is effective on increasing the frame rise and this effect is stronger in FRP reinforcement. The current stress of the armature has a direct effect on the stress in the ordinary armature and has no effect on the type of FRP armature. The current stress of the reinforcement affects the size of the shear and flexural cracks of the concrete and this effect is more in ordinary concrete and sometimes manifests itself suddenly.

K) The current stress of the reinforcement has a direct effect on the strain of the concretes and this effect is more severe in FRP reinforcement.

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