Innovative Steel Connections with Composites Steel Bolts/Rubber Subjected to Horizontal/Inclined Cyclic Loads

Suhaib J Ali	extsuperscript{1}, Amer M. Ibrahim	extsuperscript{2}, Sarmad Shafeeq	extsuperscript{3}

	extsuperscript{1,3}Department of Civil Engineering, University Of Technology, Bagdad, Iraq

	extsuperscript{2}Department of Civil Engineering, University Of Diyala, Iraq

ABSTRACT. Shear tab connections are some of the most and simplest connections are used on steel construction. The behavior of shear tabs under conventional loads are studied, but, the behavior of shear tabs become complex under accompanied loads axial and shear forces and moment. The connection should be sufficient ductile rotation to resist the unexpected force when the structures are exposed such as earthquake or wind load. The aim of this study is tested six steel portal frames. Three specimens are tested under horizontal cyclic load-quasi static load and other three specimens are verified under inclined cyclic load – quasi-static load. The connections of specimens are developed by using composites steel bolt/rubber are instead of conventional steel bolts for bolted the shear tab connections at the web of the beam. The composite steel bolts/rubber with different diameters are made of steel bolts covered by rubber taken from the old and wasted tires. Enhanced in the steel connections were cleared by increasing the resistance of these steel frames during the test as well as the tests are investigated that the effect of the inclined cyclic load is more influential than horizontal cyclic load.

1. Introduction

Tectonically Iraq is located in the relatively active seismic zone at the northeastern boundaries of the Arabian plate. North of Iraq is exposed to earthquake M7.3 at November 2017 and other effect M6.3 at November 2018 near of Iraq. More than 150 buildings were damaged on these earthquakes. Therefore, it becomes necessary to study the seismic effect and how to reduce this effect on buildings. The construction of steel structures is designed for earthquake resistance must meet the basic design requirements as follows:

- The steel structure must be rehabilitated after moderate earthquakes occur.
- Side displacement must be controlled to prevent damage to structural elements.
- The structure should be designed so as not to collapse during a major earthquake that may occur only once.

This paper is scoped to study the specimens consist of single-story one bay steel portal frames. Shear tab connections were used to connect the columns with beams for these specimens. Generally, the shear tabs connections are designed as a pinned, this assumption assumes that shear connections are transferred gravity shear to support only, on another word the lateral force is ignored. This project attempts to address the behavior of shear connection under horizontal and inclined cyclic load - quasi-static load.
In case of horizontal cyclic load, the connections are exposed to axial force, moment, and some vertical shear, while in case of inclined cyclic load the connections are exposed to cyclic force axial, moment, and addition vertical shear forces. The shear connections should have sufficient rotation capacity to develop both shear and axial forces in the beam and satisfy the straight requirement for shear and axial load resistance. However, there is no guideline in AISC for design the frame under inclined cyclic load, but the manual of steel construction load resistance factor design AISC-14th (2011), provide examples on combined axial and shear load, such as a beam to column connections. The specimens were investigated and the results compared in between for drift, resistance, strain, and energy dissipation for two angles horizontal and inclined loading effect. Joints of the steel portal frames were developed by used composite steel bolts/rubber instead of the traditional steel bolts where the rubber was used to cover these steel bolts are taken from the old and used tire.

2. Selected Previous Research on Shear Tab Connections

[1], this paper studied the significance of horizontal movements due to vertical loads on the structure. The maximum horizontal displacement of the structure depends on the location of vertical loading and structure form. This study investigated that effect of vertical load on the symmetric, asymmetric, and antisymmetric frame. This study concluded that the vertical loads cause horizontal movement for structure. The structural geometry and the distribution load are the main factors influence at the maximum horizontal movement due to vertical load. The magnitude horizontal movements due to vertical load are affected by structural form. When the dynamic vertical loads are closed the natural frequency of the structure, resonance structural occur horizontal direction.

[2], according to IS 1893-2002, the minimum design specification for story drift due to lateral force shall not exceed 0.004 times of story height. For the determinations of displacement requirements only, and no limit drift for the single-story building. According to the design guide series no. 3: AISC addressed the serviceability limit state for Low-Rise Buildings Design Considerations. The drift limitation dependent on the type of material frame and the acceptance for movement, such as for metal panels framing, the maximum drift is H/60 - H/100 where the H is the height of the building. Per the ACI-318-08 the maximum allowable drift for building due to lateral displacement and including displacement causes by vertical deformation on isolation system must not exceed the subsequent limits:

- The maximum story drift for the structure isolation system obtained by spectrum analysis should not exceed the 0.015h.
- The maximum story drift for the lateral force-resisting system calculated by response history analysis according to load-deflection characteristics should not exceed 0.02h.

Where the (h) is the effective height of the story.

Energy dissipation was founded by [3], from tested full-scale specimens. The energy dissipation calculated from experimental cyclic test envelope curve by the obtained area under the curve. This study appeared the energy dissipation on semi-rigid connections. The program of the test specimens was examined 48 cyclic loads applied on specimens of the welded-bolted double angle at web, bolted-bolted double angle, flush end-plate, top seat angle, and extended end plate connection. The energy dissipation was investigated for each specimen and related. The cyclic load applied through the actuator and the loading measured by the load cell. The displacement measured by two LVDT. Global rotation of the connections was obtained from divided displacement to distance of potentiometer wire. The applied moment was calculated from multiplying the actuator force recorded by the distance from the face of the column to the center of the actuator.

[4], nine one-story steel frame systems with different infill partition properties were established under horizontal cycle reverse loading simulating a seismic load. The specimens were tested under the force-displacement mechanism. The horizontal load was applied to the specimen by unfixable loading frame consist of various steel profiles. The horizontal displacements calculated by LVDTs located at the
necessary place at top and bottom of the steel frame, loads were the measurement by using load cell connected with hydraulic cylinder jack. Each specimen was tested under displacement control. Because the properties of each specimen, therefore, each frame was calculated according to horizontal displacement and \((\delta/h)\) ratio and compared by other specimens. After the test, for each test sample, energy consumption graphics, strength envelope, and rigidity decline graphics were achieved and these consequences were compared with each other.

3. Experimental Program

3.1. Material

The materials included in this study are as follows:

- Mild carbon steel HW125 × 125 is a standard carbon steel section conforming to the Chinese specification, which was used as a structural member of the columns in the steel frame. The mechanical properties of this section are founded by tensile testing according to Standard Test Methods and Definitions for Mechanical Testing of Steel Products ASTM (Methods A370 − 17a) [5], in the laboratories of the Faculty of Engineering – The University of Diyala and as shown in Table (1).

- Mild Carbon Steel IPE160 is standard carbon steel that conforms to European specifications, which is used as a beam member of the steel frame. The mechanical properties of this section were found by tensile testing as shown in Table (1).

- Shear tab connections with dimension length, width, and a thickness equivalent to 110×90×8mm respectively. The tolerance of these shear steel plates were measured at yield and ultimate stages as shown in Table (1).

| Member | Yield Strength (MPa) | Ultimate Strength (MPa) | Elongation (%) | Elastic modulus (MPa) |
|--------|---------------------|-------------------------|----------------|----------------------|
| Column | 250                 | 400                     | 35             | 1.95×10^5           |
| Beam   | 250                 | 400                     | 32             | 1.87×10^5           |
| Plate  | 312                 | 422                     | 31             | 2.11×10^5           |

Four steel bolts two bolts on each side are used to bolt the shear tab connections at the web of the beams. Multi bolts diameters are tested on laboratories of the faculty of engineering to confirm the failure at the bolts, 7mm diameter Grid A307-N 7mm × 35mm are selected for this study with tensile stress \(F_{nt} = 600\text{MPa}\) and shear strength \(F_{nv} = 302\text{MPa}\). The rubber properties were established at the applied sciences laboratories-university of technology. The compression test for the rubber was founded according to standard test method for compressive properties of rigid plastics (D695 − 15), [6], the rate of alteration in sample length at each load points were taken to the extent of failure than the results of the compression test rubber are achieved as the Table (2). The tensile rubber test got from the standard test method for tensile properties of plastics 1 (D638-14)[7], by using the Jianqiao Testing Equipment, the tensile test is founded equally to 15.09 MPa. Finally the hardness for these rubber that is used on this study founded as to standard test method for rubber property—durometer hardness [8], where the rate of five readings are taken by using the Shore (A) Hardness Tester Th200, the readings were 84.7-89.9-82.7-84.7-86.3 and the hardness for this rubber was taken 85.66 Shore A. These rubber were used to cover the steel bolts and taken it’s from old and used tires, Figure (1) shown the process of manufacture the composites steel bolts/rubber in the laboratory.
### Table 2. Compression Test of Rubber

| Force (N) | $\Delta L$ (mm) | $\sigma = P/A$ (MPa) | $\varepsilon = \Delta L/L$ | Elastic modulus (MPa) |
|-----------|-----------------|----------------------|-----------------------------|----------------------|
| 0         | 0               | 0                    | 0                           | 0                    |
| 500       | 1.24            | 20                   | 0.124                       | 161.4                |
| 700       | 3.94            | 28                   | 0.396                       | 70.7                 |
| 900       | 8.72            | 36                   | 0.872                       | 41.28                |

![Image](image_url) **Figure 1. The Process of Covering the Steel Bolts by Rubber**

#### 3.2. Specimens Design

Six specimens of the steel portal frames are designed according to the American Institute of Steel Construction Manual AISC-14th (2011), LRFD method Figure (2) shown their layouts. The steel portal frame is composed of two steel columns HW125 × 125 sections by length 1500mm and one of a steel beam section IPE160 by length 1000mm. The columns and beam connected by using single shear tab connections with dimensions length, width, and a thickness equal to 110 × 90 × 8mm respectively. The single shear tabs were welded at the flanges of columns and bolted on the web of the beam. The weld size was equal to the 0.75 of the plate thickness on all specimens were tested. Four steel bolts were used to connect the shear tabs at the beam two bolts on each side that were on reference frame FR1 and FR4 only. Another specimen, composite steel bolts/rubber were used instead of these conventional steel bolts to connect the shear tabs at the beam. The plates and beam were drilled as the standard holes on reference specimens FR1 and FR4, while the holes on the rest specimens were a short-slotted hole and another long-slotted hole as shown following:

1. Standard hole (STD) = D (in) + $\frac{1}{16}$ (in) = 8.5mm → FR1-FR4
2. Short-slotted hole (SSL) = D (in) + $\frac{1}{4}$ (in) 13.35mm → FR2-FR4
3. Long-slotted hole (LSL) = 2.5 D (in) = 17.5mm → FR4-FR6

Where: FR1 to FR6 = Specimens (frames) are tested.

The columns were welded on the bases of steel plates, one of these bases was a pinned support and another one was fixed support. Bases of steel plate dimensions are equaled to the 450mm length, 450 mm width, and 32mm thickness. The bases were fixed at the concrete by eight anchor bolts with diameter 32mm and length 700 mm type B7. On all specimens, the stiffeners were used to reinforce the welded and prevent the torsional buckling at the fixed columns that can happen during the test.
3.3. Test Setup
The Northridge earthquake 1994 had motivated to develop the testing requirements of connections as a result of fractures of the beam-to-column moment did result in buildings. To develop the performance of connections in future seismic activity, laboratory testing is necessary to identify probable problems in the design, materials or construction methods, detailing may be used on connections. The analytical means only cannot be sufficient to predict the requirement and behavior of the connection, where these requirements and behavior can be found by testing the specimens under severe cyclic loading. Load-displacement hysteresis can be used to simulation seismic effect based on [9], Structural Analysis and Design of Tall Buildings, ANSI/AISC 341-10, through of applied the cyclic load on specimens by loaded the end of the column or end of the beam. For achieved and investigated the connection for resist seismic effect as well as loaded the specimens by this way, machine test is manufactured as shown in Figure (3). The machine test is consisting of two vertical columns steel section IPE450 with height 2200mm connected with steel beam section IPE220 with length 4000mm. The columns and beam fixed by inclined bracing member steel section IPE450 with length 2540mm to prevent any deflection during the test. Steel
frame bolted at the reinforced concrete foundation. Two hydraulic jacks are fixed at the columns. Each jack can be applied horizontal and inclined cyclic load individually. The inclined jacks are sloping on the horizon by 10 degrees. All two jacks are pinned at each end, permitting them to rotate freely as the column or beam specimens undergo translation and rotation. Each hydraulic jack could be available push-force 300 kN and all-out stroke displacement 500mm. Servo- motor is responsive to the load, the velocity of stroke jack, number of cycles for this hydraulic jack, this servo motor could be controlling through of digital control panel.

3.4. Instrumentation
Each actuator is instrumented with a load cell capacity 300 kN to measure the applied loads can be controlled by a monitor on the control panel. The lateral displacements of the specimens were inspected by the two of the Linear Variable Differential Transducer (LVDT) fixed on the top frame used to measure the displacement during the cyclic load test. The maximum measurement of these sensors is 50 mm and made from ELE Company. The strain of the steel section of the frame measured by six of steel strain devices fixed on the important positions as illustrated in Figure (3). All these external instrumentations are cabled with electronic devices for records data over time (data logger).

3.5. Loading Program
The horizontal and inclined cyclic-quasi static loads were applied to specimens. The deformations of the specimens were controlled by using ATC-24 loading protocol [10], where this protocol is recommended by the U.S. for steel buildings test are investigated. ATC-24 was developed and used especially for steel structure components. Which it is one of the first methods are used on the United States for seismic performance using cyclic loading history. Protocol ATC-24 uses the concept of the beams elastic deformation (Δyield), where provides for loading and checking any sample requires to apply three slow cycles are practical for each load stage, Where it imposes a shed 6- cycles prior to the yield point (Amplitude <Δyield), then three cycles apply at yield deformation point (3cycles - Δyield), followed by 3– cycles with a displacement equal to two times displacement at yield point deformation (3cycles -2Δyield ), and other three cycles using a displacement equivalent to three times of displacement at yield point deformation (3cycles -3Δyield ) as presented in Figure (4). The relative increase in the loading on the
specimens continues until the failure occurs. The same test program and loading protocol are applied on the horizontal and inclined system for specimens' test.

![Deformation history for multiple-step test](image)

**Figure 4.** Deformation history for multiple-step test

Table (3) illustrates the matrix of six specimens were tested in this study, where three frames tested under horizontal cyclic loads and another three specimens tested under inclined cyclic load effect. Both of them quasi-static load used when the loaded these specimens. The purpose of the test frames under horizontal effect and other by inclined effected to investigate the influence of addition cyclic axial, shear forces, and moment, while at the horizontal case the frames will be exposed cyclic axial, shear, and the moment only. All this comparison will discuss on the results section.

| No | Description Of Specimens                  | Schedule          | Holes Type | Composite Steel Bolts/Rubber |
|----|-------------------------------------------|-------------------|------------|-----------------------------|
| 1  | Steel portal frame without rubber (FR1)   | Horizontal/Cyclic | STD        | 7.0mm                       |
| 2  | Steel portal frame without rubber (FR2)   | Inclined/Cyclic   | STD        | 7.0mm                       |
| 3  | Steel portal frame with (100%) rubber (FR3)| Horizontal/Cyclic | SSL        | 14.0mm                      |
| 4  | Steel portal frame with (100%) rubber (FR4)| Inclined/Cyclic   | SSL        | 14.0mm                      |
| 5  | Steel portal frame with (150%) rubber (FR5)| Horizontal/Cyclic | LSL        | 17.5mm                      |
| 6  | Steel portal frame with (150%) rubber (FR6)| Inclined/Cyclic   | LSL        | 17.5mm                      |

**4. Test Results and Dissections**

**4.1. Measurement Yield and Ultimate Points at the Specimens**

The test is completed for the six specimens, and the summary results are tableted as the Table (4) where the following conclusions are obtained:

- The effect of cyclic inclined load is influential more than horizontal cyclic load, where the maximum displacement for the specimens were tested by inclined effect FR2, FR4, and FR6 equal to 24.586, 32.952, and 41.212mm respectively, while the maximum displacement at the same loading stage on inclined case for the specimens are tested by horizontal effect FR1, FR3, and FR5 equal to 17.85, 32.021 and 20.442mm. That means the displacement ratio at an inclined load greater than horizontal load by 37.73%, 2.90%, and 101.6%.
Addition the rubber by ratio 100% and 150% of the steel bolt diameter at the connection rise resisting frame on both cases horizontal and inclined loading, where the ultimate resistance of frames FR3 and FR5 increase by 33.33% and 166.66% respectively compared with horizontal Reference frame FR1. While the rubber has raised the resistance at inclined frames test FR4 and FR6 by 16.66% and 33.33% relative to the reference inclined reference frame.

Using the composite steel bolts /rubber at steel connections are delays the yield point at the columns sections, where the yield point appeared at 20, 40, and 40 kN for specimens FR1, FR3, and FR5 which were tested under horizontal cyclic loading system, but the yield points for specimens were examined under inclined effect appeared at 20, 30, and 30 kN for specimens FR2, FR4, and FR6. These points have given the proof that the inclined cyclic is influential more than a horizontal cyclic test.

From the Table (4) observed that using the rubber by ratio 150% of the steel bolts diameter enhanced behaviour of steel frames aseptically on horizontal test FR5 where the yield point appeared at load 40 kN and the ultimate load occurred 80 kN, as well as the inclined test for frame FR6, is 30-40 kN. This important phenomenon where the steel frame works redistribution moment to resist the applying load.

Table 4. Displacement of Specimens Tested under Horizontal and Inclined Cyclic Loading Regime

| Specimens | $P_y$ kN | Yield-Dips (mm) | $P_u$ kN | Ultimate-Dips (mm) | Max Drift Ratio (%) | No.of. Cycles |
|-----------|---------|----------------|---------|--------------------|---------------------|--------------|
|           |         | Left | Right | Left | Right  | Left | Right | Left | Right |             |               |
| FR1       | 20      | 9.152| 11.921| 30  | 17.85 | 12.59| 1.19 | 10   |       |             |               |
| FR2       | 20      | 18.98| 14.74 | 30  | 24.58 | 19.11| 1.63| 10   |       |             |               |
| FR3       | 40      | 20.24| 25.10 | 40  | 41.18 | 35.92| 2.74| 16   |       |             |               |
| FR4       | 30      | 20.30| 28.88 | 35  | 32.95 | 23.51| 2.19| 15   |       |             |               |
| FR5       | 40      | 26.99| 20.88 | 80  | 40    | 47   | 3.13| 40   |       |             |               |
| FR6       | 30      | 32.33| 23.51 | 40  | 41.21 | 31.88| 2.74| 16   |       |             |               |

4.2. Load-Deflection Behavior

The envelopes curve for the six specimens were tested under a horizontal and inclined cyclic loading system with and without rubber investigated in this section. The test of the specimens was stopped when the steel bolts or the composites steel bolts/rubber fractured. Various composites steel bolts/rubber were used in the connections of frames with different diameter 7mm steel bolt only, 14mm, and 17.5mm. The strength envelopes of these specimens were given in Figure (5). The maximum horizontal cyclic quasi-static loads were carried by frames FR1, FR3, and FR5 were found as 30 kN, 40kN, and 80 kN respectively. The horizontal frame FR3 which were used the steel bolts covered by rubber one time of the steel bolts diameters in his connections carried displacement 131%, and the horizontal frame FR5 with rubber one half time of the steel bolts carried displacement 163%, of the reference horizontal displacement that is not used the rubber in his connections. The maximum inclined loads resisting by the frames FR2, FR4, and FR6 were 30, 35, and 40 kN respectively. The amplitude displacement increased for developing inclined frames FR4 and FR6 by 34% and 68% respectively compared with amplitude displacement of the inclined reference frame.
4.3. Number of Cycles
Table (4) appeared that the number of cyclic load for each specimen was tested. Each specimen examined under the same procedure and loading protocol (ATC-24). This section has two parts, the first is compared the resistance number of cycles for the frames tested under horizontal loading system and the frames were tested under the inclined loading system individually. The second part appeared the effect of used different rubber ratio in development the steel frame connections in the number of cycles.

- The results are investigated that horizontal cyclic load has a lower effect than inclined load, where the horizontal specimens FR1, FR3, and FR5 are resisted a number of cycles more than the frame are tested by inclined effect FR2, FR4, and FR6.
- Utilize the composite steel bolts/rubber are raised the resistance of frames under two actions. Where the reference frame FR1 that was tested by horizontal action resist 10 cycles while the develop horizontal frames FR3 and FR5 resist 16 and 40 cycles respectively, that means the rubber increase the number of cycles carried by each model by 60% and 300%. As for the reference frame FR2 which is examined by inclined action carried same the number of cycles at reference frame under horizontal load 10 cycles, but in that inclined frames that used the rubber in its joints, FR4 and FR6 number of cycles is equal to 15 and 16 cycles means that the increases in the number of cycles were by ratio 50% and 60% as shown in Figure (6 to 11).

![Figure 5. The Load-Displacement Envelopes Curves for Specimens](image-url)
Figure 6. Horizontal Load – No of Cycles for Specimens FR1

Figure 7. Inclined Load – No of Cycles for Specimens FR2

Figure 8. Horizontal Load – No of Cycles for Specimens FR3

Figure 9. Inclined Load – No of Cycles for Specimens FR4

Figure 10. Horizontal Load – No of Cycles for Specimens FR5

Figure 11. Inclined Load – No of Cycles for Specimens FR6
4.4. Cumulative Energy
The cumulative consumed energy achieved by calculated the area under the envelope curves for the above specimens mentioned as shown in Figure (12). The Figure indicated that the cumulative consumed energy was equaled to 205 kN.mm after 10 cycles for the specimen FR1 and 836 kN.mm for FR3 after 16 cycles and 1600 kN.mm for FR5 at the end of 40 cycles. From the energy, The Figure observed that the specimens with rubber ratio 150% and 100% consumed energy more than reference frame system without rubber under lateral loads. So the inclined frames FR6 and FR4 with rubber ratio 150% and 100% consumed energy 891 kN.mm and 616 kN.mm after 16 and 15 cycles respectively, more than the reference frame that was tested with steel bolt only under inclined loading system where consumed energy about 428 kN.mm after 10 cycles. From the results above observed that use composites steel bolts/rubber with ratio 150% of steel bolts consumed energy for two type actions horizontal and inclined loads more than rest specimens. In addition, the horizontal frames FR1, FR3, and FR5 consumed energy 108%, 35%, and 79% respectively more than FR2, FR4, and FR6 inclined frames systems.

Figure 12. Cumulative Energy for Specimens Test

4.5. Mode of Failure
Failure patterns were similar in almost specimens were investigated under the horizontal and inclined cyclic loading system, in general, fractures of the steel bolts were prevalent. The sequence of failure for the horizontal reference frame FR1 was LBF, Local buckling appeared near the base of the fixed column at the ninth cycle when the load arrived at 20kN. Bearing effect appeared in the shear tab connections, then the steel bolts were fractured. Two of the steel bolts are fractured at the fixed column side and bearing another two bolts at a pinned column as shown in Figure (14).
The failure modes for the specimen FR2 was (BF), bearing effect appeared in the shear tab connections when the inclined loads reach to 20kN then the conventional steel bolts were fractured when the applied loading attained 30kN. The test investigated that four steel bolts were fractured when testing the specimen FR2 under inclined cyclic system while two steel bolts were fractured when tested the specimen FR1 under horizontal cyclic loading effect. Fractured of the all-steel bolts in the connections of this frame indicated the inclined loads were a stronger effect than horizontal loads due to the vertical shear forces components that were generated by an inclined cyclic loading system.

Failure modes for this specimen FR3 were (BF) marked bearing in the shear plates firstly then fracture the composites steel bolts/ rubber at the shear tab connections. The bearing effect appeared on the fourteenth cycles and the bolts were fractured on the sixteenth cycles. Weld failure between the columns and shear plates not accorded that means the rubber reduced the stresses at these points as well as the rubber prevents the local buckling failure accorded at columns. Using the rubber by 100% of the steel bolts ratio given this frame damping properties, especially when the strain effect reduced about three times of the strain readings in the reference frame. Little bearing effect in the right and left shear plate connections were appeared and the four composite steel bolts were the fractures in the right and left hands.

Modes failure for the specimen FR4 was (BF), where the bearing failure appeared in the shear plate connections when the number of cycles was about 12cycles. The rubberized connections delay the bearing failure accorded on the shear plate connections by six cycles compared with bearing failure in the inclined
reference frame FR2. The composites steel bolts/ rubber were fractured when the number of cycles reaches to 15 cycles.

![Figure 15. Bearing of Plates and Column Local Buckling for Specimen FR4](image)

**Figure 15.** Bearing of Plates and Column Local Buckling for Specimen FR4

Failure modes for the fifth specimen FR5 were (BLF) bearing in the holes of shear plate connections and local buckling in the fixed column then the composites steel bolts/rubber fractured. When the hydraulic jacks began to apply loads on the specimen the bolts were slipped firstly, at this position the rubber in the joints of the frame was worked to damping and reduced the pressure between the bolts shanks and the holes of shear tabs until the rubber reached to the fatigue condition at loads 60kN as illustrated in Figure (17). The local buckling effect observed in the bottom fixed column as well as in the top flange of the pinned column when the applied loads reach to 70kN at this stage notable that the shear plate connections accorded to the bending failure as shown in the Figure (18). When the loads reached to the 80kN the weld between the column and triangular stiffener fracture as shown in Figure (19). An important note in this specimen, only one bolt is fractured. The other three bolts have not been cut. The test in this specimen stops because of the steel bolts are extrude out of the plane of shear tab connections.

![Figure 16. Bolts Failure for Specimen FR4](image)

**Figure 16.** Bolts Failure for Specimen FR4
Figure 17. Bering at Left Plate  
Failure for Specimen FR5  
Figure 18. Local Buckling and Bearing  
Failure for Specimen FR5  
Figure 19. Plate Flexural Bending  
Failure for Specimen FR5  
Figure 20. Local Buckling and Weld  
for Specimen FR5

Modes of failure for the specimen FR6 was (BF), where the bearing failure observed when the number of cycles was about 12 cycles and the composites steel bolts fractured in the 16 cycles. The rubber by ratio 150% of the steel bolts diameter reduced the effect of shear forces in the steel bolts and prevent the contact between the shanks and holes of the bolts of plates to some extent of the applied loads. The rubberized steel connections by these rubber ratio work to enhance the damping properties for reduced the frame movementsunder the loading and unloading of the cyclic effect.

5. Conclusion
The results have been founded by the experimental tested were obtained by the following:
- From the results, the seismic effect can be simulated by applying lateral cyclic loads by using two actuators load works alternately, applies the load on the top end of the frames.
- The results investigated that the inclined cyclic loads influential than horizontal cyclic load, where the inclined displacements were greatest of the horizontal displacements by 37.73%, 2.90%, and 101.6% when compared the two actions at same load and number of cycles.
- Used the technique of composite steel bolts/rubber in the shear tab connections by (1.5d<sub>bolt</sub>) developed the behavior of steel connection under two actions horizontal and inclined loads individually, where
this technical has increased the resistance of the horizontal frame system by 166.66% of the horizontal reference frame, and 33.33% of the inclined reference frame.

- The readings of strain gauges appeared that use the rubber by ratio 150% of steel bolts diameter thrust between the yield points and ultimate points, that was cleared on horizontal steel frame where the yield point visible when the loads reach to 40 kN and the ultimate point occurred at 80 kN. So the yield point for the inclined frame founded at load 30 kN and the ultimate point equaled to 40 kN. This means there was a difference between the yield points and the failure point, it is given sufficient time to evacuate buildings and reduce the risk to occupants of those buildings.

- The rubberized connections reduced corrosion between the bolts and holes of plates in the joints of specimens when exposed these frame to dynamic loads.

- Using the composite steel bolts /rubber increased the number of cycles which are carried by specimens where the number of cycles for frames FR3 and FR5 increased by 60% and 300% of the horizontal reference frame, while the increases at the number of cycles that are carried by inclined group system was 50% and 60% of the inclined reference frame.

- Finally, the consumed energy amount for the horizontal frames were 205,836, and 1600 kN.mm for the FR1, FR3, and FR5 respectively. But the amount of the energy that consumed by the inclined frames were 428,616, and 891 kN.mm for the specimens FR2, FR4, and FR6 respectively.

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