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An Experimental Study to Investigate Shear Performance of Anchor Bolt to Strengthen an RC Frame Against Lateral Load

Fulya Kale[1*], Orhan Doğan[2]

[1]*Department of Civil Engineering, Kirikkale University, Kirikkale 71450, TURKIYE*

[2]*Department of Civil Engineering, Kirikkale University, Kirikkale 71450, TURKIYE*

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Abstract

The use of structural steel profiles as an external shear bracing is one of the most preferable simple, time saving and cost-efficient strengthening method for an inadequate existing reinforced concrete (RC) structure against earthquake lateral loads in comparison to the other interrupting, irritating and destructive traditional in plane strengthening methods which need evacuation of houses. With the use of this method, inhabitants of building can continue their daily life as usual during the strengthening site work.

With this experimental study it is aimed to determine the shear performance of anchor bolts used to connect the steel lama to an RC single span frame depending on embedment depth. For this purpose, a special steel construction loading system has been designed and constructed and six RC column-beam frames are prepared and five of them were strengthened using steel lama connected to the frame with different numbers of anchors in different depths. And also an equation was found related with the shear performance of steel anchor bolts depending on the anchor embedment depth.

Key Words

"RC Beam-Column Frame, Strengthening of RC Structures with Steel Bracings, Strengthening Against Earthquake, Steel Anchor Embedment Depth, Shear Performance of Steel Anchor Bolts

***Sorumlu Yazar:** hamidiyefulya@gmail.com*

1. Introduction

The majority of horizontal loads should be compensated by means of inelastic behavior of the system elements to prevent existing buildings from uncover able damage or totally collapse. Resistance of structural elements and systems with an over linear elastic deformations and with a large deflection under overloads is known as ductility. Ductile behavior is also described as energy absorber during cycling loading by over linear elastic displacements and deformations. Collapses of buildings during earthquakes are usually occurred due to inadequacy in ductility of structural members.

Before strengthening of existing building against earthquake, existing structural damages should be observed and evaluated. An improved seismic vulnerability index methodology is formulated on the basis of eight modeled parameters that are designed according to earthquake-resistant design concept and derived from the empirical vulnerability index that was initiated by the Group of National Defense against earthquake, named as GNDT Level approach. The results of this study indicated that there is a good correlation between the analytical modeling approach and the observed fragility features during in-situ field investigations. To prove that the proposed methodology is accurate and reliable, the verification of the current methodology is performed through the experimental testing related to school building damages during Ranau Earthquake (Kassem et al., 2022).

As much as the strength and the energy absorption capacity of structural members are important, redistribution of applied loads by inelastic behavior of the system members are also very important (Chao et al., 2007). It is possible to provide an inelastic RC building system by adding strengthening steel elements and connectors behaving ductile.

Various traditional methods have been developed for strengthening of RC structures against earthquake. One of these methods is to strengthen existing RC structures with steel bracings. All the other methods are destructive except external strengthening method by using steel bracing (Kawamata and Ohnuma, 1981; Youssef et al., 2007; Yılmaz et al., 2018; Ahmad and Masoudi, 2020)

Structures having weak and soft storey can be preliminarily strengthened by using steel diagonal braces. Also for strengthening of same structures linear viscous dampers can be used. Viscous dampers reduce both displacements and accelerations. While steel diagonal braces reduce the displacements, they increase the storey accelerations which cause increment in earthquake forces. Depending on their locations and quantities, steel diagonal braces also concentrate at storeys which have less stiffness compared to other storeys (Aydin et al., 2012).

The lateral load performance of the reinforced concrete frames can be increased by using different steel bracings such as X, Diagonal, Knee and Z. In the light of experimental studies, it has been observed that such strengthening with a stronger ductile connection than the steel bracings is effective in increasing the energy absorption capacity and shear force resistance of RC building (Sharma and Tiwary, 2020). However, if there is a weaker connection than the strengthening steel bracings, unexpected pre-failure will occur in RC structures and the steel bracings will not perform ductile, fully reflect its capacity and also overloads will not be transformed from the structure to the steel bracings. In this type of strengthening, the design of connectors is the key stage of design (Maheri and Sahebi, 1997).

During an in-plane strengthening of an existing building, the column and beam joints are supported with a steel plate covering to increase the shear performance and moment carrying capacity of the junction (Torabi and Maheri, 2017). However, the strengthening of a building by using in-plane reinforcement method will cause an increment in expenses and weight of building and waste of time because of additional reinforced shear wall sand also will force to move the residents due to the replacement of existing walls. It is possible to increase the capacity of the building by using external strengthening method to minimize the horizontal displacement of the relative floor displacement with the mechanisms created with additional steel frames and braces applied on the outer surface of the RC building (Korkmaz, 2007; Formisano et al., 2020).

Apart from the destructive strengthening methods mentioned above, usage of steel members in the external strengthening method, the steel members can easily be fixed on the outer surfaces of a building with a minimum damage and also there is no need to evacuate the building during the strengthening.

By strengthening of an RC building externally against earthquake by using structural steel members which is the scope of this experimental study, it is possible to delimit lateral displacements and to increase the rigidity of structural system as shown in Fig. 1. Beside all these mentioned benefits, this strengthening method can be described as practical, time saving and cost efficient.

Figure 1. Externally Strengthening of RC Building

In the strengthening design of an RC building with steel profiles, the most important key point is to provide a sustainable connection. Because of the failure in connection may result after an unnoticeable tiny displacement in comparison to the failure of a long strengthening steel profile. The anchor bolts and welds must be designed both more ductile and stronger than the steel strengthening profiles (maybe more than %20) to make the failure noticeable beforehand and to prevent brittle and sudden failure of the RC frame having weak stirrup and concrete compressive strength.

In this study six single span RC frames are designed to investigate both the contribution of the steel members in strengthening of an RC frames and the shear performance of anchorage at the beam-column junction area depending on depth of anchor bolt in a similar way of the study made by Yoldas (Yoldas, 2015).

2. Materials and Testing Methods

2.1. Preparation of Test Specimens, Testing Set Up and Instrumentation

2.1.1. Preparation of Test Specimens

By considering the common floor height of RC buildings as 2.50 meters, testing specimens have been designed in a 1:2 scale single span beam and column frames shown in Fig. 2. Totally 6 single span test specimens have been prepared. Testing frames are 1000x1000mm in clearance dimension. Beams and columns were prepared in a section of 125x250mm.

To represent structures needs built to be strengthening almost in total according to the 1975 Earthquake Code before 2000 in Turkey with inadequate concrete strength, the RC frames were built aiming as a concrete strength with 10 MPa, which was prepared in the laboratory.

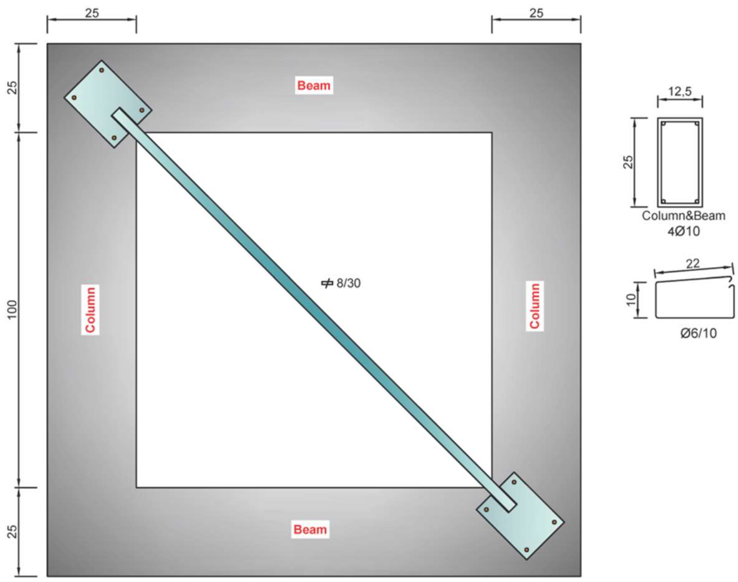

Figure 2. A Strengthened Single Span RC Frame with Steel Lama

Beams and columns were longitudinally reinforced with bars of 4Ø10 with a minimum reinforcement as indicated in Turkish Code TS-500 (TS-500, 2000) as shown in Fig.3. All specimens were prepared by using Ø6/10 stirrup bars without densification in order to represent current situation of reinforced concrete structures in Turkey.

Figure 3. Reinforcement and FormworkDetails of Beams and Columns of anRC Frame

Concrete with approximately C10 strength was aimed to represent existing buildings built before 2000 in Turkey with low-strength concrete in comparison to the individual Earthquake Code.

Five of the single span frames were strengthened using a steel lama 8x30 mm in section. 45° angled two bearing steel plates 10x150x200 mm in dimension and St-37 (σ_{em} = 220 MPa) quality were welded to the two ends of the steel lama as shown on Fig.2.

Contrary the design of the anchoring between the steel lamas and RC frames has to be at least 20% stronger than the steel lamas for strengthening, inhere it is aimed to investigate the shear performance of the anchors and to predict the prior shear failure in anchors, so the other strengthening parts such as lama and welding areas were designed stronger than anchorage.

The steel bearing plates have been fixed to the junction area of the RC frame using steel anchor bolts. To investigate shear performance of the steel anchor bolts depending on the depths of the anchors were chosen variable such as 100, 80, 60 and 40 mm. In the preparation of test frames, the depth and number of anchors were varied, however all other testing setups related with strengthening and RC frames were the same for all testing specimens.

Herein, anchor bolts in diameter of 10 mm were preferred because the thin bolts show more ductile and nonlinear behavior in comparison to the thick connectors (Dogan et al, 2021). In accordance with the thickness of t^*_{min}=1.0 cm steel plates and the diameter of anchor bolts, using the Eq.(1), four slots were drilled on the steel plates with the diameter of 12 mm (less than d) and on the junction area of the RC frame with the diameter of 14 mm.

$$d \leq \sqrt{5\, t^*_{min}}\text{-}0.2 \tag{1}$$

And then each plate was fixed properly to the concrete using 2 or 4 numbers of anchor bolts as shown on Fig.4. Steel lamas were welded to the steel plates at corners of lamas considering maximum load to prevent failure in welding areas. Lamas were welded to the steel plates and weld thickness and size of weld was calculated as a=6 mm and L_k=60 mm considering plate thickness in accordance with (3mm<a=6mm<0.7tmin=7mm) and (10a<L_k=60mm<100a) rules due to avoiding from failure in welding areas.

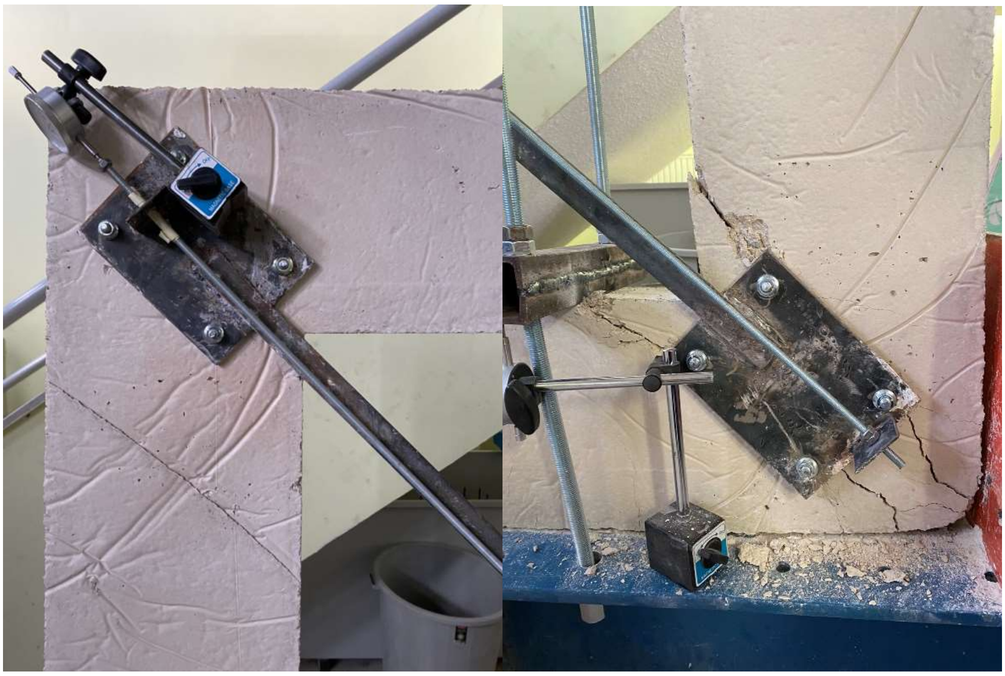

Figure 4. Fixing Steel Lama and Placement of Comparator on RC Frame using Anchor Bolts

Anchor numbers and depths of testing specimens are given in Table 1.

Table 1. Anchor Numbers and Depths of Specimens

Specimen No	Anchor Number & Depth (mm)
C1	-
C2	2*40 mm
C3	2*100mm
C4	4*80 mm
C5	4*100 mm
C6	4*60 mm

2.1.2. Testing Set-up

To test reinforced concrete frames, a special steel construction loading system has been designed and constructed. The loading system is composed of two numbers of vertical and horizontal I300 profiles and a diagonal I200 profile as a strut. Total length of steel construction loading system is 5100 mm and total height is 2060 mm. Horizontal steel I300 profile was anchored to the ground by means of M14x20 steel dowels. An additional upper plate having 15 mm thickness was welded on the horizontal I300 profile and Ø15 holes were drilled with the space of 100 mm. In order to fix the test specimens, two triangular form supporters of 200x300 mm were prepared and fixed on the additional plates.

An additional plate having 15 mm thickness was welded on the loading façade of the vertical I300 profile and Ø15 holes were drilled with the space of 100 mm. Another triangular support of 200x300 mm were designed and fixed on the additional plates of vertical I300 profile to put loading hydraulic jack. Hydraulic jack was placed over this support in order to apply lateral load to the RC frames specimen as shown in Fig.5.

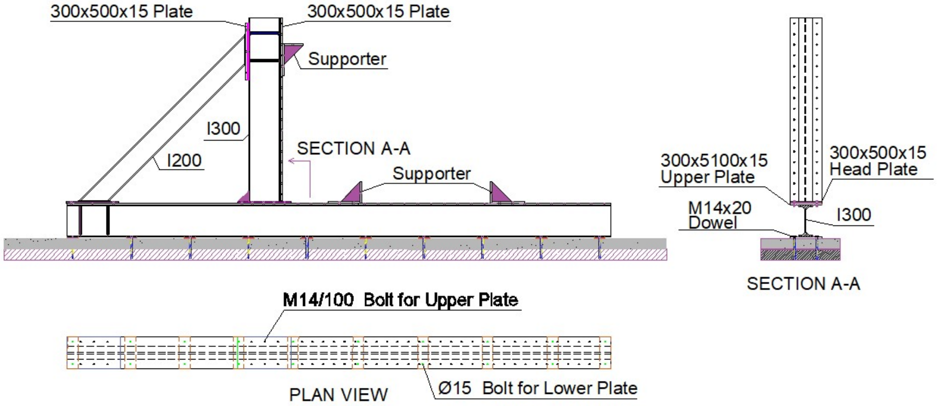

Figure 5. Details of Steel Construction Loading System

Steel construction loading system was designed to keep the specimens in horizontal testing position and to allow the displacement manometer (comparator) instrumentations. Vertical stability of specimens not to lift it up was assured to connect box profile to the loading system with two numbers of stem bars. Horizontal stability was assured by additional strengthened L250.150.10 profile mounted at the rear side-bottom of specimen as shown on Fig.6.

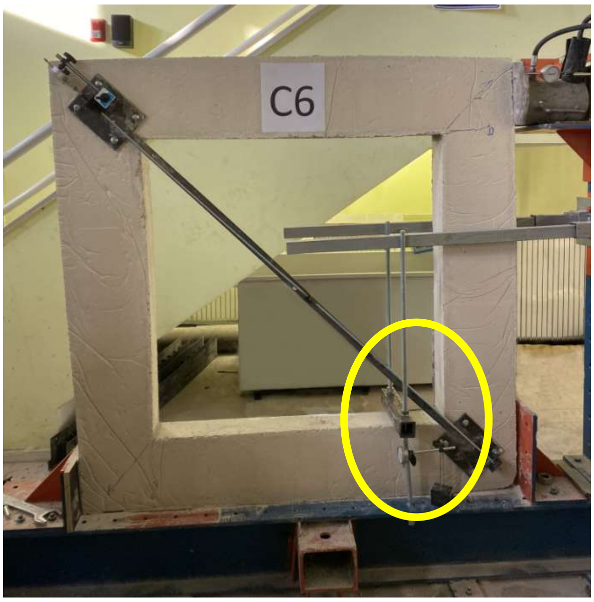

Figure 6. Details of Loading Setup Frame, Supporters and Tightening Bars

In order to create lateral load on specimens a hydraulic jack with 3000 kN capacity was placed over steel construction loading system. This test set-up was designed and manufactured in order to perform tests by an easily applicable way.

2.1.3. Instrumentation

In order to measure the displacements three longitudinal comparators were placed; the first LVDT-1 laterally at the top and the second LVDT-2 vertically at the bottom of the frame and the third one LVDT-3 fixed to another steel bar parallel along the steel lama in the direction of steel lama as shown in Fig.7. In here one and of the steel bar fixed to one end point plate and displacement was measured from the other end of the steel bar. The applied loads were measured using hydraulic dial gauge fixed on hydraulic pump unit. Absolute deformations ($\Sigma\delta$) of the frame were calculated taking the differences of horizontal (δ_1) and vertical (δ_2) displacements (lifting up) by using Eq.(2).

$$\Sigma\delta = \delta_1 - \delta_2 \quad (2)$$

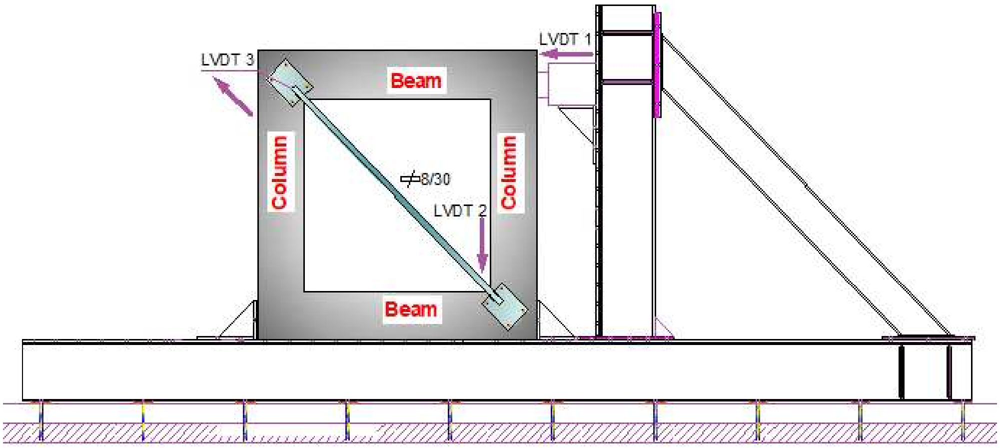

Figure 7. Positions and Directions of Comparators

2.2. Experimentation

By these tests it is aimed to investigate the performance of strengthened RC beam-column frames using steel lamas depending on the depth of steel anchor bolts. All these quasi-static tests were carried out manually using a hydraulic pump unit. Prior to tests hydraulic jack and comparators were calibrated properly. All these instrumentations were fixed properly to the specimens. The hydraulic jack was placed to apply the load laterally from the upper end of the frame.

The loading were carried out up to the maximum failure load of the anchor bolts to observe the failure types of the bolts which is the weakest chain of the strengthened frame. Maximum load carrying capacity and energy absorbing capacity of the frames before and after strengthening were determined depending on the depth of anchors.

3. Test Results and Evaluations

Cube samples were cured in the same condition with test specimens and tested in the meantime with experiments in order to determine concrete compressive strength. Average compressive strength of concrete cube compressive strength and cylindrical strength of concrete (f_{ck}) was calculated by multiplying cube strength with 0.85 and found as 9.98 MPa.

The C1 frame was tested without strengthening to observe the maximum load carrying capacity of an RC single span frame as a reference specimen. The quasi-static test of C1 was carried out until to failure of the specimen. While there were no cracks in any of the beams and columns, C1 failed with cracks in the beam-column junction areas due to the maximum bending moment at these areas as shown in Fig.8. Precursor cracks were observed in the left-top corner and right-bottom corner of beam-column junction area in the direction of outer side to inner side of the frame. In the meantime vice versa another cracks were observed in the left-bottom corner and right-top corner of beam-column junction area in the direction of inner side to outer side of the frame.

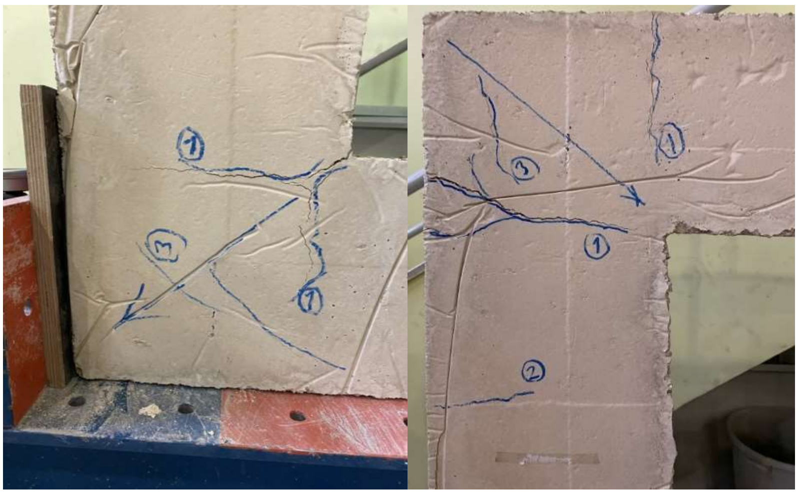

Figure 8. Failure of the Cracks at the Left Bottom Corner and the Left Top Corner of the Beam-Column Junction Area of Reference Specimen C1

With the use of steel lama in strengthening an RC frame, beam and column behaved such as a strut in compression and lama behaved such as a tie in tension of a lattice system. In another word, as a result of strengthening a frame with a lama, shear force and bending moment in beam and column were minimized and the RC frame system was partially converted to a lattice system. Just after the failure of anchor bolts, as it is expected, the failure in the junction area of beam and column the strengthened specimens were the same as non-strengthened specimens. Prior to the failure of anchor bolts the beams and columns were behaved like struts in compression so any shear or bending moment cracks were not observed in the beams and columns. Stirrups densification even if it is not applied as indicated in rules of building an RC beam or column has negligible effect on the failure type and load carrying capacity when it is strengthened.

As it is expected, prior shear failures were observed in anchor bolts as a weakest chain of the system instead of lama, welding areas and RC beams and columns. All the strengthened specimen tests were carried out until the failure of anchor bolts at a maximum shear load. Following the failure of anchor bolts, several cracks were observed at the junction areas of the beam and column. As it was expected after reaching the maximum load carrying capacity applied load declined because of the failure of anchors as shown in Fig.9. As expected, any failure was not observed both in steel lama and welding areas.

Figure 9. Failure of Strengthening Anchor Bolts at the Junction Area

It was observed that the strengthened specimens showed up to two times more load carrying capacity (P_{max}) and displacement (δ_1) in comparison to the reference specimen C1. It means that strengthened specimens showed more inelastic behavior than reference specimen C1 as shown in Fig. 10. After reaching maximum load capacity, the tests were continued out to investigate the inelastic behavior of anchors under shear force in the junction area of RC beam-column frame.

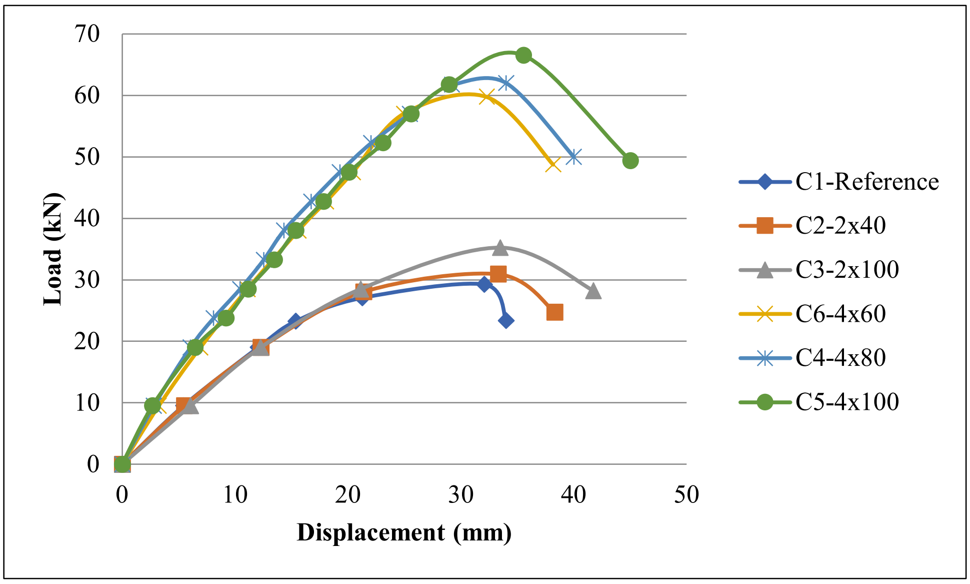

Figure 10.Load-Displacement Diagram under Quasi-Static Test of the Frames

Maximum load carrying capacity (P_{max}) was found as 29.25 kN for the non-reinforced reference specimen C1. While the specimen C5 was giving maximum load carrying capacity of 66.50 kN due to maximum anchor depth of 100 mm, the specimen C2 gave the lowest load carrying capacity of 30.90 kN due to minimum anchor depth of 40 mm. As a result, the load carrying capacity of the frames increased with the increment of anchor depth. Maximum load carrying capacity of frames are given in Table 2.

Table 2. Maximum Load Carrying Capacity of Frames

Specimen	**P_{cr} (kN)**	**P_{max} (kN)**	**P_{cr}/ P_{max}**	**δ_{cr} (mm)**	**δp_{max} (mm)**	**K**	**P_u (kN)**	**δ_u (mm)**	**μ_0= δ_u/δ_{cr}**	**Critic A_{en} (kNmm)**	**Ultimate A_{en} (kNmm)**
C1-Reference	23.40	29.25	0.80	15.42	32.08	1.5395	23.36	34.00	2.20	191.48	693.91
C2-2x40	24.72	30.90	0.80	16.80	33.30	1.5122	24.75	38.31	2.28	221.49	833.02
C3-2x100	28.20	35.25	0.80	19.90	33.48	1.4606	28.25	41.74	2.10	297.44	988.22
C6-4x60	56.76	59.75	0.95	24.84	32.30	2.3657	48.75	38.17	1.54	752.87	1506.65
C4-4x80	58.90	62.00	0.95	26.10	34.00	2.4158	50.00	40.00	1.53	866.74	1686.76
C5-4x100	63.18	66.50	0.95	30.60	35.55	2.2516	49.40	45.00	1.47	1104.97	1973.55

During the tests, applied loads to the frames and vertical, horizontal displacements of the frame and longitudinal elongation in lama were recorded using comparators and given in Table 3.

Table 3. Horizontal and Vertical Displacements of the Frames and Longitudinal Elongation in Lama

Specimen No	**Max. Load P_{max} (kN)**	**Horizontal**	**Vertical**	**Real Horizontal Displacement of the Frame**	**Longitudinal Elongation in Lama**
		δ_1 (mm)	**δ_2 (mm)**	**$\delta_H = \delta_1 - \delta_2$ (mm)**	**δ_3 (mm)**
C1 (Ref.)	29.25	32.23	0.15	32.08	-
C2	30.90	33.46	0.16	33.30	0.52
C3	35.25	33.66	0.18	33.48	0.73
C4	62.00	34.18	0.18	34.00	3.02
C5	66.50	35.74	0.19	35.55	3.25
C6	59.75	32.46	0.16	32.30	2.72

After load application to the frame, an increment in length of the lama was occurred due to tensile. Total longitudinal increment in length of steel lama (δ_3) was calculated. Tensile force of each steel strengthening lama (P_L) was calculated using Eq.(3) as given in Table 3.

$$P_L = \frac{\delta 3 * E * F_L}{L} \tag{3}$$

Herein, cross section area of steel lama is F_L=8x30 mm^2, length of lama between plates is L=1560 mm and modulus of elasticity is used as E=2.1x105 N/mm^2. Additionally, the maximum shear force (T_{1S}) in each bolt was calculated dividing the P_L in number of anchor bolts because each plate was connected to concrete with different numbers of anchor bolts as given in Table 4.

Table 4. Maximum Load Carrying Capacity Depending on the Anchor Depths

Specimen No	**Anchor Depth, L_{ab} (mm)**	**Tensile Force P_L (kN)**	**Number of Anchors (n)**	**Max. Shear Force of an Anchor $T_{1S} = P_L/n$ (kN)**
C1	-	-	-	-
C2	40	16.87	2	8.44
C3	100	23.66	2	11.83
C4	80	97.66	4	24.42
C5	100	104.84	4	26.21
C6	60	87.92	4	21.98

The shear force capacity of an anchor (T_{1S}) depending on anchor depth (L_{ab}) is shown in Fig. 11.

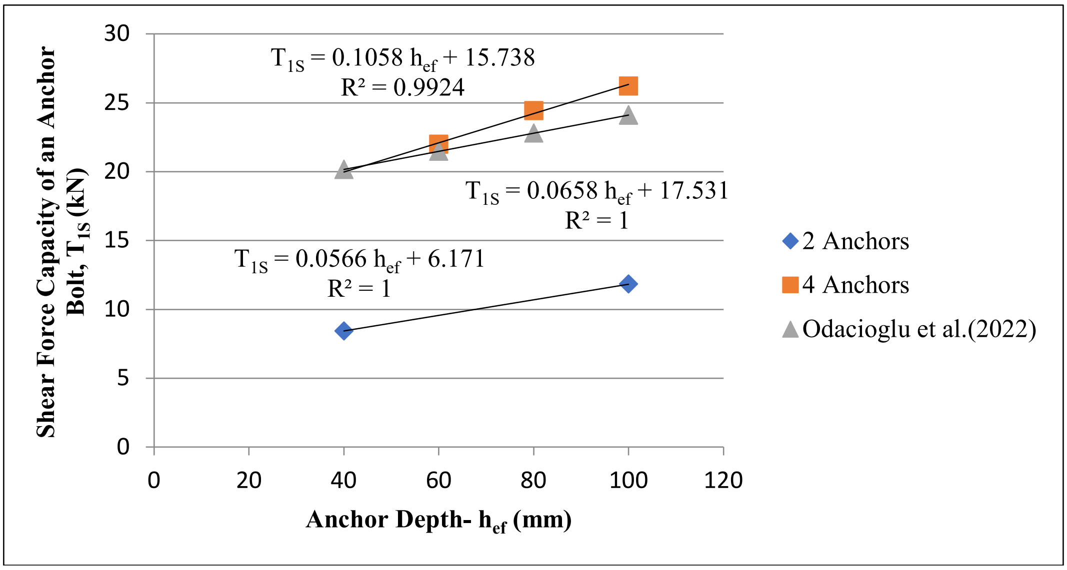

Figure 11. Shear Force Capacity of an Anchor Bolt Depending on Anchor Depth

For the three tests used four anchor bolts in diameter of 10 mm (Ø10) with concrete strength f_{ck}=9.98 MPa, the best fitted linear (with a regression value R^2 = 0.9924) for the values of T_{1S} between 60-100 mm depths of anchor bolts is given in Eq.(4).

$$T_{1S} = 0.1058 \times h_{ef} + 15.738 \quad (4)$$

For the two tests used two anchor bolts in diameter of 10 mm (Ø10) with concrete strength f_{ck}=9.98 MPa, the best fitted linear (with a regression value R^2 = 1.00) for the values of T_{1S} between 40 and 100 mm depths of anchor bolts is given in Eq.(5).

$$T_{1S} = 0.0566 \times h_{ef} + 6.171 \quad (5)$$

As indicated in the tests carried out by Odacioglu et al. (2022) used one anchor bolt in diameter of 10 mm (Ø10) with concrete strength f_{ck}=9.42 MPa, the linear equation for the values of T_{1S} between 70 and 110 mm depths of anchor bolts is given in Eq.(6)(Odacioglu et al, 2022)

$$T_{1S} = 0.0658 \times h_{ef} + 17.531 \quad (6)$$

According to the obtained equationsit was seen that the maximum shear force capacity of an anchor (T_{1S}), is increasing with the increase of embedment depth h_{ef}. Herein, the connection in the junctions areas of steel plate with four anchors gave higher performance as seen Eq.(4). However the connection in the junctions areas with two anchors gave much less performance asseen Eq.(5). Because, in the junction area, two of the four anchors was in tension zone of the beam-column junction area. The first group of two tests C2 and C3 gave much less performance than expected. That is why in the second group of three tests C4, C5 and C6 another two anchors were additionally embedded in compression zone of the beam-column junction area. The anchors used in the second group of tests where two of the specimens are in compressions and another two are in tension zone, gave quite reasonable performance in comparison to the results indicated in the tests carried out by Odacioglu et al. (2022) where there is no residual strain like tension or compression in the reinforced test specimens. According to the tests the anchors are embedded in reinforced concrete in compression gave much more performance in comparison stress the anchors embedded in reinforced concrete under tension stress or no stress. The anchors used in the second group of tests where two of the specimens are in compressions and another two are in tension zone, gave quite reasonable performance in comparison to the results indicated in the tests carried out by Odacioglu et al. (2022) where there is no tension or compression in the reinforced test specimens. As a result, the equation found by Odacioglu et al.

(2022) releated with the shear performance of anchors, is found quite preferable and reasonable as long as the anchors are embedded in a zone without tension stress of reinforced frame.

Shear capacity of an anchor connected to the conjunction area of the RC frame with concrete strength fck=9.98 MPa and anchor bolt in diameter of 10 mm (Ø10) and 100 mm in anchor depth was found 15.75 kN for four bolts and 11.83 for two bolts. However, the shear capacity of one anchor connected to RC cubic samples with concrete strength fck=9.42 MPa gave 24.11 kN found by Odacioglu which is quite higher than the shear capacity of the anchors connected to the conjunction area of an RC frame (Odacioglu et al, 2022). In here, an RC cubic samples was being forced with only shear, but the conjunction area of the RC frame was forced with both shear and bending moment which is causing cracks in the conjunction area.

4. Conclusions and Recommendations

With this study it is aimed to investigate the shear performance of anchor bolts used to connect the steel lama to an RC frame. For this purpose, six single span RC column-beam frames having concrete average strength (9.98 MPa) is prepared and five of them were strengthened using overdesigned steel lama with different anchor depths in 40-60-80-100 mm.

To investigate the shear performance of the anchor bolts used to connect a strengthening steel lama and an RC frame, 6 RC frames in total were tested and the following results were obtained:

- In comparison to the un-strengthened reference specimen, some of the strengthened frames with a tiny steel lama and 100 mm anchor showed up to two times more carrying capacity and displacement until to failure.
- As expected, damage did not occur along the beams and columns of the reference specimen. However, diagonal damages and cracks were observed due to the shear force and bending moment at intersection areas in the beams and columns.
- It is observed that, with the use of this type of loading setup and instrumentation, the determination of the contribution of strengthening steel profiles to an RC frame and the shear performance of an anchor bolt is found reasonable and efficacious.
- The use of this type of strengthening method by using diagonal steel profiles is found quite reasonable and preferable for an RC structure with insufficient stirrups because the diagonal steel profile in tension behaves like ties of lattice and reduces shear in beams and columns.
- In strengthening of an RC structure by using steel profiles, it is reasonable to fix the end points of steel profiles to the intersection area to minimize bending moment and shear force of the RC building members with insufficient concrete strength and insufficient stirrups.
- It was observed that the anchor bolts acted more ductile with longer anchor bolt. Ductile behavior of the bolts caused the transfer of overloads of some bolts to the other bolts. And also the load carrying capacity of the RC frame is increased with the increment of anchor depth.
- In strengthening RC frame with an inadequate concrete strength, a good correlation was found, between anchoring depth and shear force capacity of an anchor bolt between 40 and 100 mm depths with a regression value $R^2 = 0.9924$ for four anchors and $R^2 = 1.00$ for two anchors.
- The equation found by Odacioglu et al. (2022) related with the shear performance of anchors, is found quite preferable and reasonable as long as the anchors are embedded in a zone without tension stress of reinforced frame.
- Shear capacity of an anchor connected to the conjunction area of the RC frame damaged during the test was found quite less than the shear capacity 24.11 kN investigated by Odacioglu et al. (2022) using cubic samples effected by no other effect (Odacioglu et al, 2022). As a result, to get the maximum shear performance from anchors connected to concrete, connection area must not be affected by another shear or tensile force. It means that, the conjunction area of an RC frame is not suitable for the connection of steel bracings.

Consequently, this study showed that with the definition of shear performance of anchor bolts depending on anchor depth, the external strengthening against earthquake by using steel profiles will commonly be preferred because this type of strengthening is more reasonable (time saving, economic and undisturbed for the residents) for the existing RC buildings with/without sufficient stirrups which is commonly encountered in application.

It is recommended that, using this type or different type of loading setups, this study can be expanded;

- To investigate the performance of RC frame in filled with different types of wall with/without plaster coating,
- To investigate the shear performance of anchor bolts under the cycling loadings,
- To investigate the shear performance of anchor bolts with different concrete strength.

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