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REHABİLİTATİON OF REİNFORECED CONCRETE BULİLDİNGS AFFECTED BY 2023 TÜRKİYE EARTHQUAKE

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Abstract

Earthquake is a natural disaster that threatens many regions worldwide. Occasionally, earthquakes cause significant damage to the infrastructure of the surrounding area; this is related to the intensity and location of the earthquake. When a destructive earthquake occurs, the greatest loss following the loss of life is the loss of building stock. This is because the number of available habitable dwellings decreases. This problem can be partially solved by evaluating buildings based on their damage and recommending reinforcement techniques according to the condition of the affected buildings. Researchers have shown in their studies that the results of reinforcement are very positive for both building elements and the overall structural system. In this article, several examples of damage caused by the earthquake on February 6, 2023, will be reviewed. These buildings are generally good in terms of the structural system but have damage in specific elements. Then, an appropriate reinforcement method will be proposed according to the type of damage. The results of the researchers indicate that after the reinforcement process, the elements can perform better than their original state. Thus, it may be possible to quickly restore buildings to service and partially compensate for the building stock.

Keywords: Strengthening, Earthquke effect, Reinforced concrete frame

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1. INTRODUCTION

Due to the presence of active fault lines in many countries around the world, numerous buildings are exposed to Horizontal force due to earthquakes. Predicting and determining the Horizontal force to be applied to reinforced concrete structures due to earthquakes is too difficult. Therefore, the software used during the design of reinforced concrete structures and the approximately predicted Horizontal force may not always perfectly match the direction and intensity of actual earthquakes.

For a newly constructed cast-in-place reinforced concrete structure, if the structure is designed according to the "advanced" performance target, the performance objective of the building will be Controlled Damage (DD-1) for both DD-1 and DD-2 level earthquakes, i.e., "Life Safety." This is the minimum target allowed by the Turkish standard, and upon request of the owner, a more advanced performance target can be selected. However, all standard practices are carried out with the "Controlled Damage" (KH) performance target.

In other words, in a classical structure that is fully compliant with the latest earthquake standard and meets all the application conditions specified in the same standard, both of structural and non-structural elements will incur damage (DD-2) when experiencing the designed earthquake (KH). This damage level could be light, moderate, or severe, but the building will not collapse, and people inside can be safely evacuated. The structure will not be usable after the earthquake, and depending on the level of damage, repairs or complete demolition may be necessary.

Assessing the condition of buildings after an earthquake, reinforcing them can often be a more economical and quicker solution. Especially when structural damage is limited to a certain extent, strengthening the existing structure may be less costly than constructing an entirely new one. Additionally, reinforcement procedures can typically be completed in a shorter time frame, accelerating the process of making the structure usable again. Therefore, reinforcing buildings after an earthquake is generally preferred as a more practical and economical approach.

1.1 The importance of rehabilitation

Emmanouil Golias (2021) Says ‘’The necessity of ensuring the long-term sustainability of existing structures is increasing, particularly in seismically active regions where many reinforced concrete (RC) structures lack the necessary earthquake-resistant capacities. Urgent attention is needed for inexpensive, fast,

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and long-term strengthening strategies for RC structures, both before and after destructive earthquakes. Retrofitting existing buildings to extend their service life, rather than demolishing and rebuilding, offers economic and environmental benefits.’’

Strengthening reinforced concrete structures is a critical aspect of ensuring their durability, longevity, and resistance to various loads and environmental conditions. One notable study by Li et al. (2020) explores the use of externally bonded fiber-reinforced polymer (FRP) composites for strengthening reinforced concrete structures. The research investigates the effectiveness of different FRP materials, such as carbon, glass, and aramid fibers, in enhancing the flexural and shear capacity of concrete elements. Through experimental testing and numerical simulations, the study provides valuable insights into the optimal design and application of FRP strengthening techniques.

1.2 Rehabilitation of concrete beam

About repair with carbon fiber Maaddawy and Sovudki say’s ; Corrosion of the steel reinforcement significantly reduces the yield and ultimate loads of RC beams. The reduction in the yield load was almost proportional to the reduction in the steel mass loss. For the beam ultimate strength, reductions of about 12, 14, 14.5, and 24% were recorded at steel mass losses due to corrosion of about 9.7, 15.4, 22.8, and 30%.

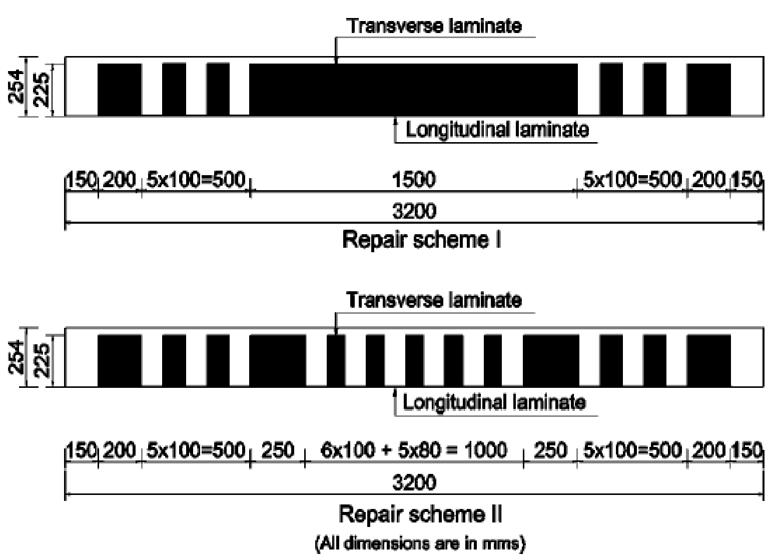

Fig 1: Two different examples of rehabilitation. (Ref. 2)

CFRP repair that consists of one flexural laminate along with U-shaped transverse strips is effective in increasing the strength of corroded RC beams at all levels of corrosion damage ~up to 31% steel mass loss! to levels higher than the strength of the virgin uncorroded beam. For example, the ultimate strength of a beam repaired with CFRP laminates at 31% steel mass loss was about 73% higher than that of a similar corroded and unrepaired beam and about 31% higher than that of the virgin beam that was neither corroded not repaired.

1.3 Rehabilitation of concrete beam-Column joint

Kazem , kheyroddin and emami conducted studies and reached the following results ; Load–displacement curves, given at Fig below, show the variation rates and increasing of load capacity in the retrofitted specimens relative to those in the control specimens.

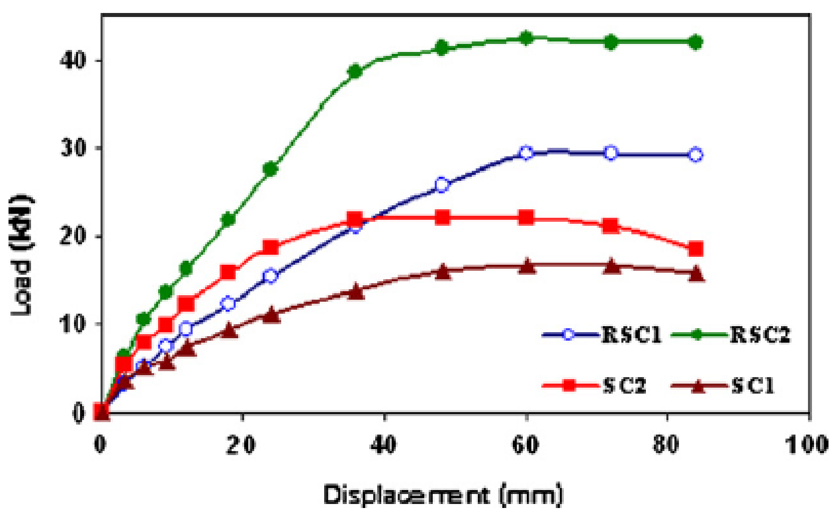

Fig 2: Comparison of load-displacement envelope curves of the control and retrofitted specimens. (Ref.3)

Even though the retrofitted specimens caught their own maximum load at more displacement but no strength degradation was observed up to drift 7% at the end of test. Trends of envelope curves show that the retrofitted specimens can suffer more displacements without degradation while force degradation of the control specimens were begun from drift 5%. Based on design calculations, if steel props do not yield and not much lateral displacement is observed at curb position on the beam,

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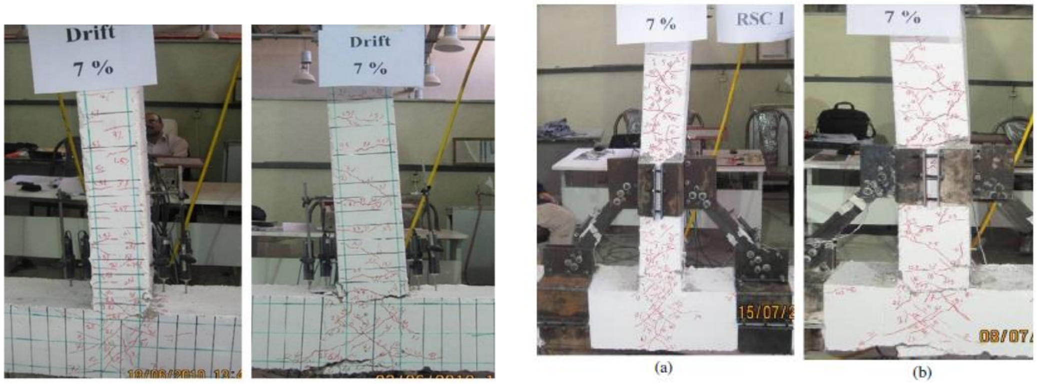

Fig 3: Condition of sample elements after the experiment (Ref.3).

the steel props can act as a lateral support and consequently the resistant moment of section can be increased up to 33% relative to control specimens while the moment arm was reduced. Despite this point, experimental results, were increased up to two times, the reason may be due to abundant confinement of concrete at the erection point of the curb and high stiffness of the joint at the side of beam–column joint.

- In another work titled ’’Effectiveness of the Novel Rehabilitation Method of Seismically Damaged RC Joints Using C-FRP Ropes and Comparison with Widely Applied Method Using C-FRP Sheets—Experimental Investigation (2021) ’’

In this study externally applied strengthening RC beam-column joints. Six full-scaled experiments were performed: two control joint specimens, two specimens rehabilitated with C-FRP sheets, and two specimens strengthened using C-FRP ropes, all subjected to increasing cyclic loading (displacement control).

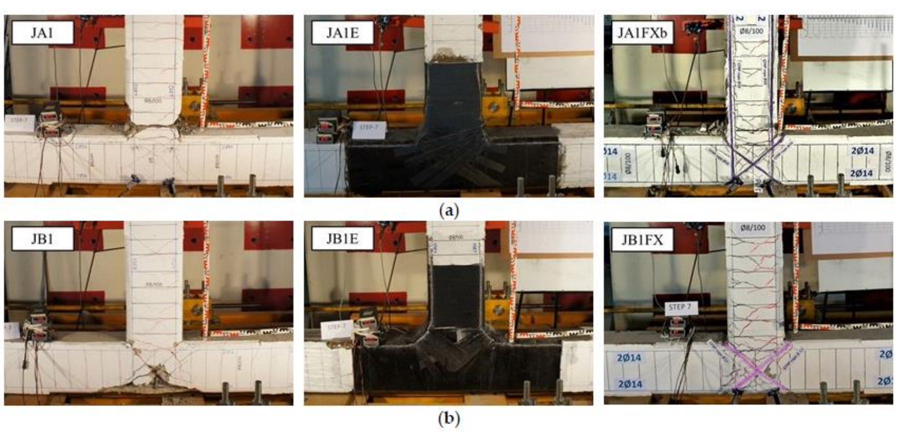

Fig 4: Strengthening process in different ways (Ref3).

The Park and Ang damage index model is used to assess the progress of damage level during the tests for all test specimens. The specimen ropes group A, which were either rehabilitated with C-FRP sheets or strengthened with C-FRP ropes, indicated a significantly improved damage index compared to the control specimens. As a result, the developing damage in the rehabilitated/strengthened joints will be significantly lower than in the control specimens. The damage indexes.

The equivalent viscous damping ratio remains nearly the same in all tests, regardless of the consumption of these systems. This viscous damping is also important in any of this rehabilitation or strengthening methods to restore the energy dissipation capacity of the damaged specimen. The strengthening technique using C-FRP ropes manages to enhance the seismic performance of the beam-column connections

1.4 Rehabilitation of concrete structure system

Hiroshi Fukuyama and Shunsuke Sugano discuss In their article ’’Japanese seismic rehabilitation of concrete buildings after the Hyogoken-Nanbu Earthquake’’ the implementation of supplemental damping and continuous fiber wrapping for the seismic rehabilitation of reinforced concrete buildings following the Great Hansin-Awaji Earthquake Disaster caused by the 1995 Hyogoken-Nanbu Earthquake (Kobe Earthquake). They also explore conventional strengthening techniques such as in-filling, bracing, and jacketing of existing framing members. The article provides an overview of state-of-the-art techniques for seismic rehabilitation of existing reinforced concrete buildings, with a focus on research and practical applications. Additionally, it addresses the response to lessons learned from the Great Hansin-Awaji earthquake.

On-the-ground research was conducted on the buildings and the following results were reached.

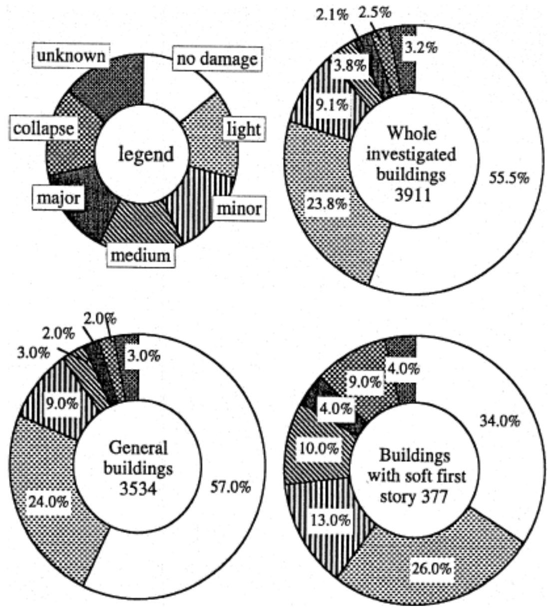

Fig 5: Damage to buildings due to Hyogoken-Nanbu earthquake. (Ref.6).

Typical strengthening techniques are summarized in Figs. New elements are added to existing frames to provide increased strength

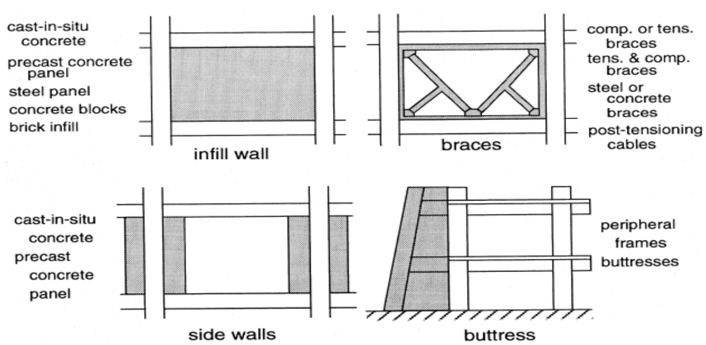

Fig 6: Typical fame strengthen techniques (Ref.6).

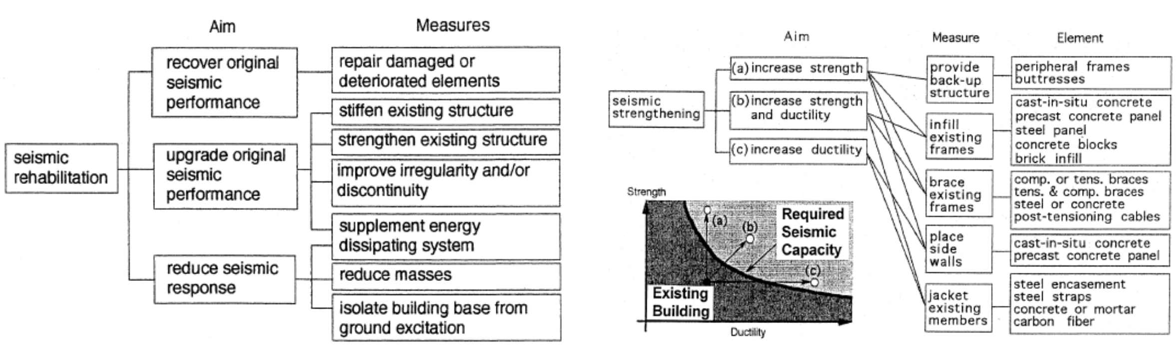

Fig 7: Strengthening techniques according to their purposes (Ref.6).

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1.5 The must Used Retrofit Techniques

- Concrete Jacketing
- Concrete Structural Walls
- Steel Bracing
- Fibre-reinforced polymer (frp) confinement

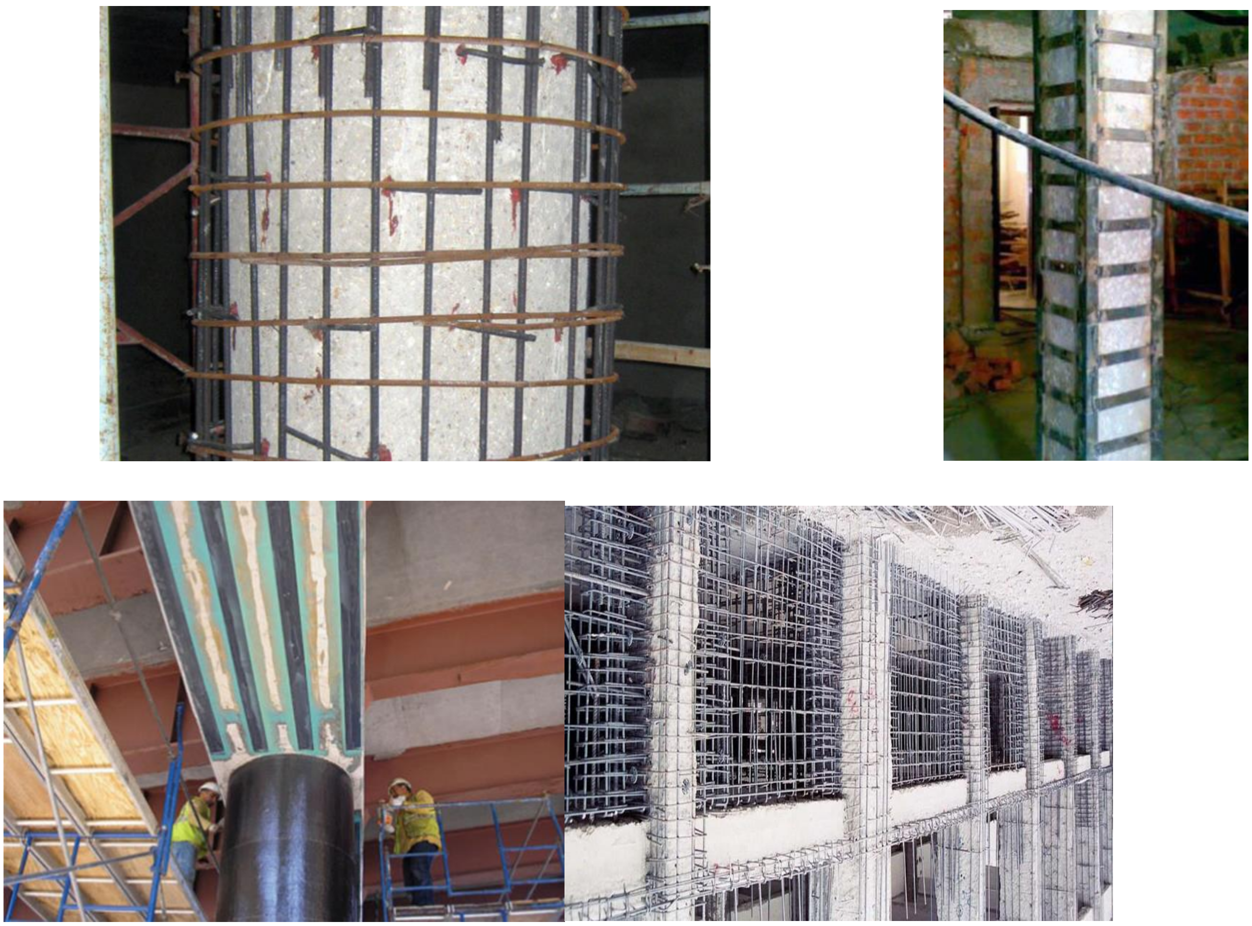

Fig 8 : Application examples.

2. OBJECTİVE OF THE RESEARCH

- In this study, we aim to assess the damage caused by earthquakes in buildings. We will do this by collecting samples from buildings that have experienced seismic events. These samples will allow us to analyze and determine both the type and the extent of the damage incurred. By studying these samples, we can

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gain insights into how different types of buildings are affected by earthquakes and the severity of the damage they sustain.

- Once we have identified the types of damage observed in the buildings, we will proceed to evaluate the structural elements affected. By understanding which loads each element is insufficient against, we can devise appropriate strengthening methods.
- Understanding the types of damage observed due to earthquakes is crucial for informing the design of new structures.

3. SİGNİFİCANCE OF THİS STUDY

Strengthening the repairable damage is crucial for these reasons;

- it allows us to preserve the building's integrity and functionality. Instead of resorting to demolition, which can be costly and time-consuming, strengthening the damaged parts enables us to restore the building to a safe condition. This not only ensures the life safty but also helps retain the historical or architectural significance of the structure.

- Strengthening is often a more cost-effective solution compared to constructing a new building from scratch. The expense involved in reinforcing the damaged areas is typically lower than the cost of demolishing the existing structure and building a new one. By opting for strengthening instead of rebuilding, we can allocate resources more efficiently and achieve the desired level of safety at a lower cost.
- Reinforcing damaged buildings to make them safe and usable again is beneficial in terms of time-saving and resource preservation. Instead of waiting for a new building to be constructed, which can take months or even years, strengthening allows us to quickly restore the functionality of the structure. This is particularly important in scenarios where the building serves essential functions, such as housing, offices, or community centers. Additionally, preserving a portion of the existing building stock through reinforcement helps maintain the cultural and architectural heritage of a region while also reducing the environmental impact associated with demolition and new construction.

4. EXPERİMENTAL WORK

5. 4.1 M 7.8 - Pazarcik earthquake, Kahramanmaras earthquake sequence:

On February 6, 2023, a significant seismic event rattled the region of southern Turkey near the northern border of Syria. Initially, a formidable M 7.8 earthquake struck, followed approximately 9 hours later by a M 7.5 earthquake about 90 km to the north. These quakes occurred within the transition zone between the Dead Sea and East Anatolian fault systems, with the epicenter of the M 7.8 situated close to a triple junction involving the Arabian and African plates alongside the Anatolian block.

The East Anatolian fault, responsible for the westward movement of Turkey into the Aegean Sea, and the Dead Sea fault, accommodating the northward motion of the Arabian Peninsula relative to the African plate, intersect in this volatile area.

Although seismic activity in the region where the February 6, 2023, seismic sequence unfolded is typically moderate (<M 7), the Sürgü fault, where the M 7.5 earthquake struck, has shown heightened activity. This fault lies directly west of the East Anatolian fault.

Historically, southern Turkey and northern Syria have faced devastating earthquakes. Aleppo, Syria, for instance, has endured several catastrophic tremors, including an estimated M 7.1 earthquake in 1138 and another estimated M 7.0 earthquake in 1822. The 1822 quake led to tragic fatalities, with estimates ranging from 20,000 to 60,000.

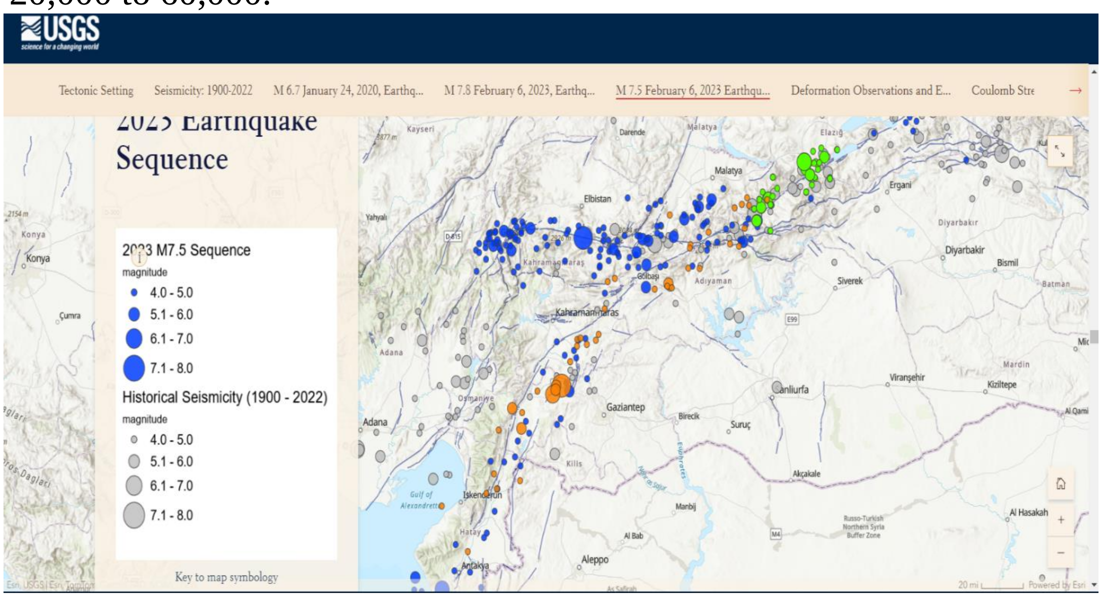

Fig 9: Earthquake map according to intensity (source:USGS).

4.2 Deformation Observations and Earthquake Source Modeling

In the immediate aftermath of the seismic activity, a coordinated effort involving satellites equipped with optical and radar sensors commenced over the affected region. These satellites, operated by various international partners, including the Japanese Space Agency (JAXA) and the European Space Agency (ESA), provided crucial data for analysis.

Through the examination of images captured by these advanced sensors, scientists were able to pinpoint the locations where surface rupture occurred as a result of the M 7.8 and M 7.5 earthquakes. Additionally, the analysis revealed the extent of surface movements surrounding these fault lines.

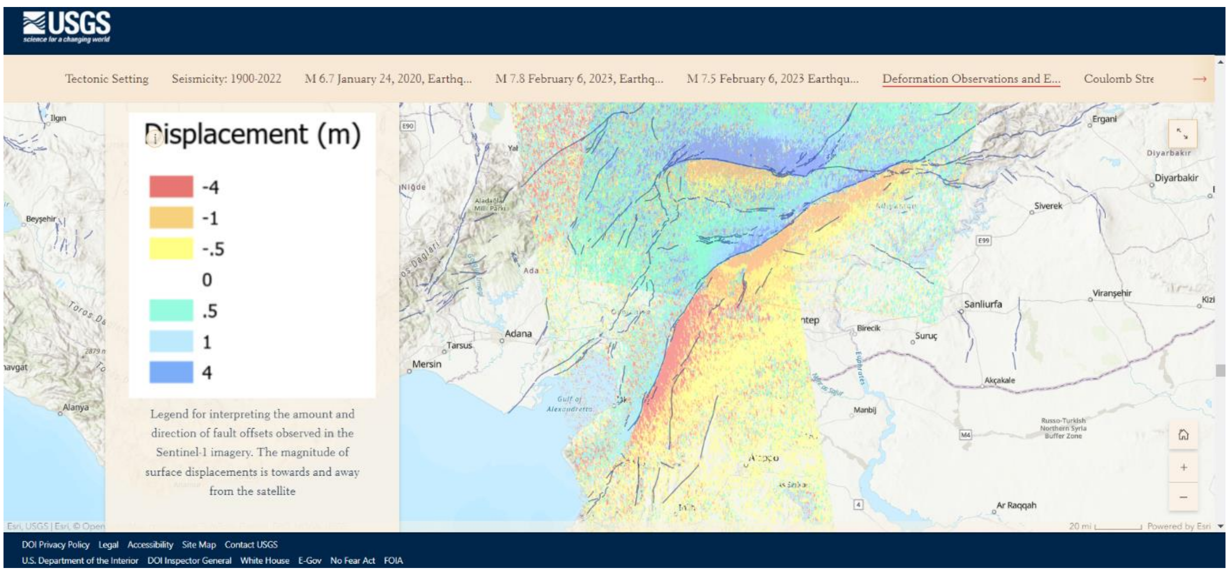

Fig 10: Earthquake map according to displacements. (source:USGS).

4.3 Pazarcık Earthquake Results

In the aftermath of the seismic events in Turkey, 11 provinces and five governorates in Syria bore the brunt of the devastation. An unprecedented 3 million individuals were displaced from their homes, with 1.6 million still residing in makeshift settlements as of June 2023, half of whom are women and children. Additionally, nearly 800,000 people are accommodated in formal displacement sites.

The initial earthquake, measuring 7.7 on the Richter scale, marked the most potent seismic event recorded in Turkey since 1939. The region experienced over 30,000 aftershocks by May 2023, with one notable 6.1 magnitude aftershock in February felt across neighbouring countries.

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The impact of the earthquakes in Kahramanmaraş was profound, affecting nearly 16 million individuals, with 9.1 million directly impacted and a confirmed death toll exceeding 45,000.

Infrastructure damage was extensive, with the Disaster and Emergency Management Presidency (AFAD) reporting 710,000 buildings sustaining heavy damage and approximately 280,000 buildings collapsing or experiencing severe damage. (Source: World Health Organization)

The significant damage caused by the earthquake has resulted in huge loss of life, as well as a decrease in the region's building stock and the emergence of migrations. In this context, official institutions affiliated with the government have initiated efforts to renew the building stock.

4.4 Work technique

Because of the the magnitude of the disaster and the necessity to rebuild the structures in short time, the process is observed to be quite lengthy. Therefore, there has been a need to work on buildings that have suffered partial damage but are capable of reinforcement. As part of this study, three samples have been taken from the structures affected by the earthquake, some of which have incurred damage, and a current condition assessment has been conducted. Subsequently, strengthening techniques for the identified damages have been proposed.

4.4.1 As built documentation

Three partially damaged buildings have been identified at different locations, and the necessary assessments have been conducted for them. Below, the basic information about the buildings will be reviewed, along with an overview of their floor plans.

First sample İbrahimli – Gaziantep building

The identification of earthquake-induced damages to building in the Şehitkamil district of Gaziantep has been conducted. Below are the main details of the building:

Location: Şehitkamil district, Gaziantep, Turkey

Type of Damage: Earthquake-induced damage

Building Type: residential

Number of floors: 8 floors

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Structural System: frame and shear wall

Description of Damage: shear wall bending moment

Date of Assessment: 20,02,2023

Building age: 10-15 year

When conducting a general overview of the studied building, it appears that the building consists of 8 floors and is approximately 10 years old, meaning it was constructed before the recent modifications related to earthquake regulations in Turkey in 2018. The building is located in a relatively seismically active area, as it is about 52 km away from the earthquake center located in Pazarcık. Despite the age of the building and its proximity to the earthquake center, the structural elements of the building are generally undamaged.

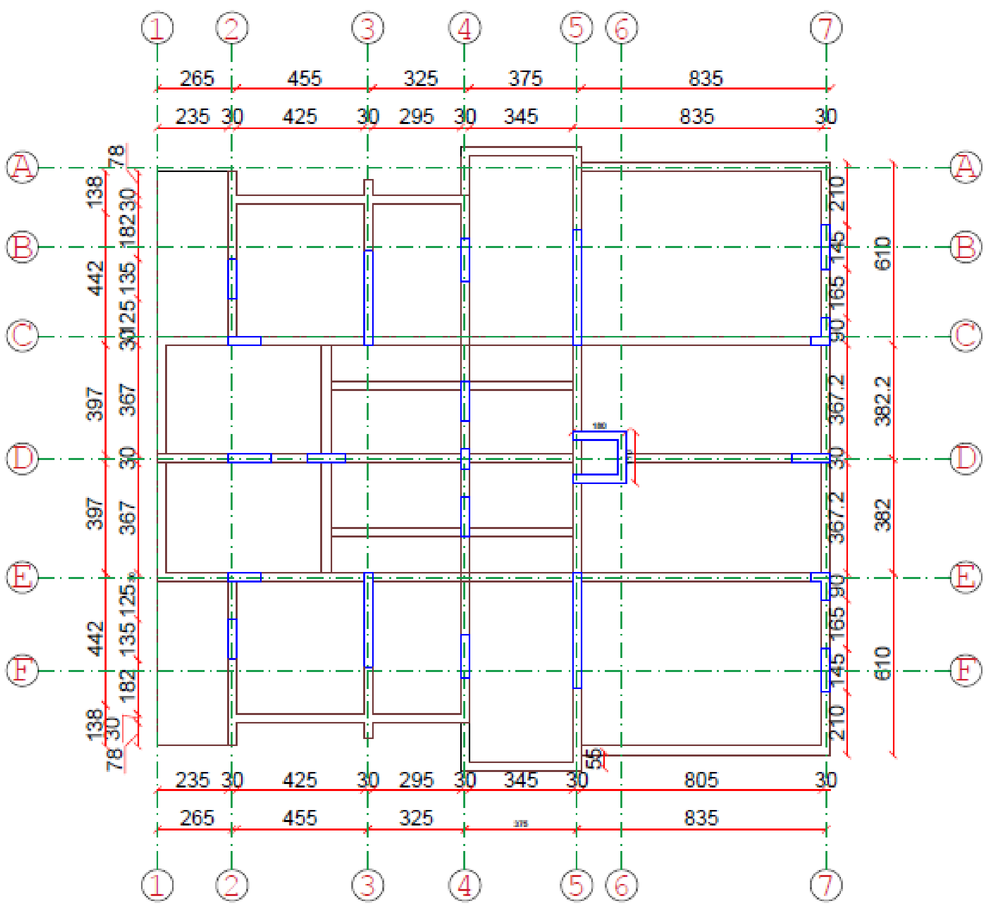

Fig 11: Floor plan for studied example.

A.1 Study the condition of the damaged element

The structure exhibits a notable predominance of reinforced walls relative to columns, a feature deemed advantageous for seismic resilience. Uniformity is maintained across all floor heights, precluding the presence of a soft floor. Noteworthy, the floor plan lacks any irregularities. It has been observed that the number of secondary beam is relatively high.

In this building, the collapse of the shear wall between the 2nd and 3rd axes and on the D axis was observed only on the ground floor. When the condition of the collapsed shear wall is examined, we notice the presence of beam connecting it from four sides. On the same axis, we also see the presence of a shear wall at axis number 2 and very close by. Aforementioned two walls are connected to each other by beams 30 cm wide and 120 cm long. It should be noted that there are non-load-bearing walls surrounding the curtain wall on the upper floors where the damage did not occur.

A.2 Study the damage caused

When we examine the damage of the shear-wall between the second and third axes and on the D axis, we see that it is damaged due to the beams in the Y direction, that is, on the 3rd axis. As we mentioned before, there is another shear wall in the x direction and at a very close distance, not exceeding one and a half meters. In addition, since the long side of the shear wall extends along the X-axis, the bearing force of the wall in the x-axis is much greater than the bearing force in the y-axis. Therefore, the moment of inertia on the y-axis is relatively weak.

Fig 12. Damaged element.

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According to field investigations, the structural elements of the building are completely intact on all floors except the element mentioned above. However, there are cracks in non-load-bearing walls and negligible surface damage on some structural elements.

Fig 13: Other elements condition in same building:

B- Third sample Türkoğlu – Kahramanmaraş building

The identification of earthquake-induced damages to building in Türkoğlu district of Kahramanmaraş has been conducted. Below are the main details of the building:

Location: Türkoğlu district, Kahramamaraş, Turkey

Type of Damage: Earthquake-induced damage

Building Type: industrial

Number of floors: 1 floor

Structural System: concrete frame

Description of Damage: Columns collapse under the influence of horizontal force torque

Date of Assessment: ١٠,0٤,202٢

Building age: ٤ years

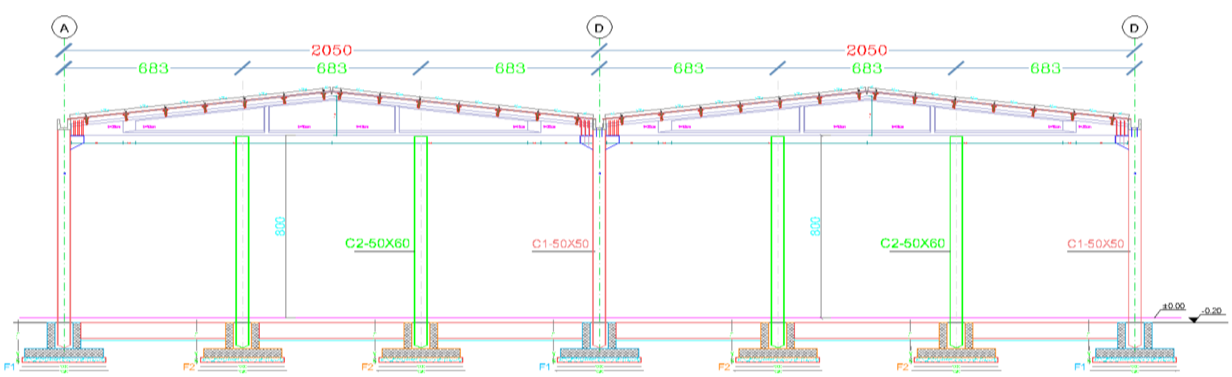

Fig 14: sconed building section

the seismic provisions of TDBY2018. Seismic data for each building was extracted based on the site from the Turkish Disaster Management Authority website and input into the program for each building. Additionally, information regarding loads

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and other relevant data for each building was inputted to obtain accurate information.

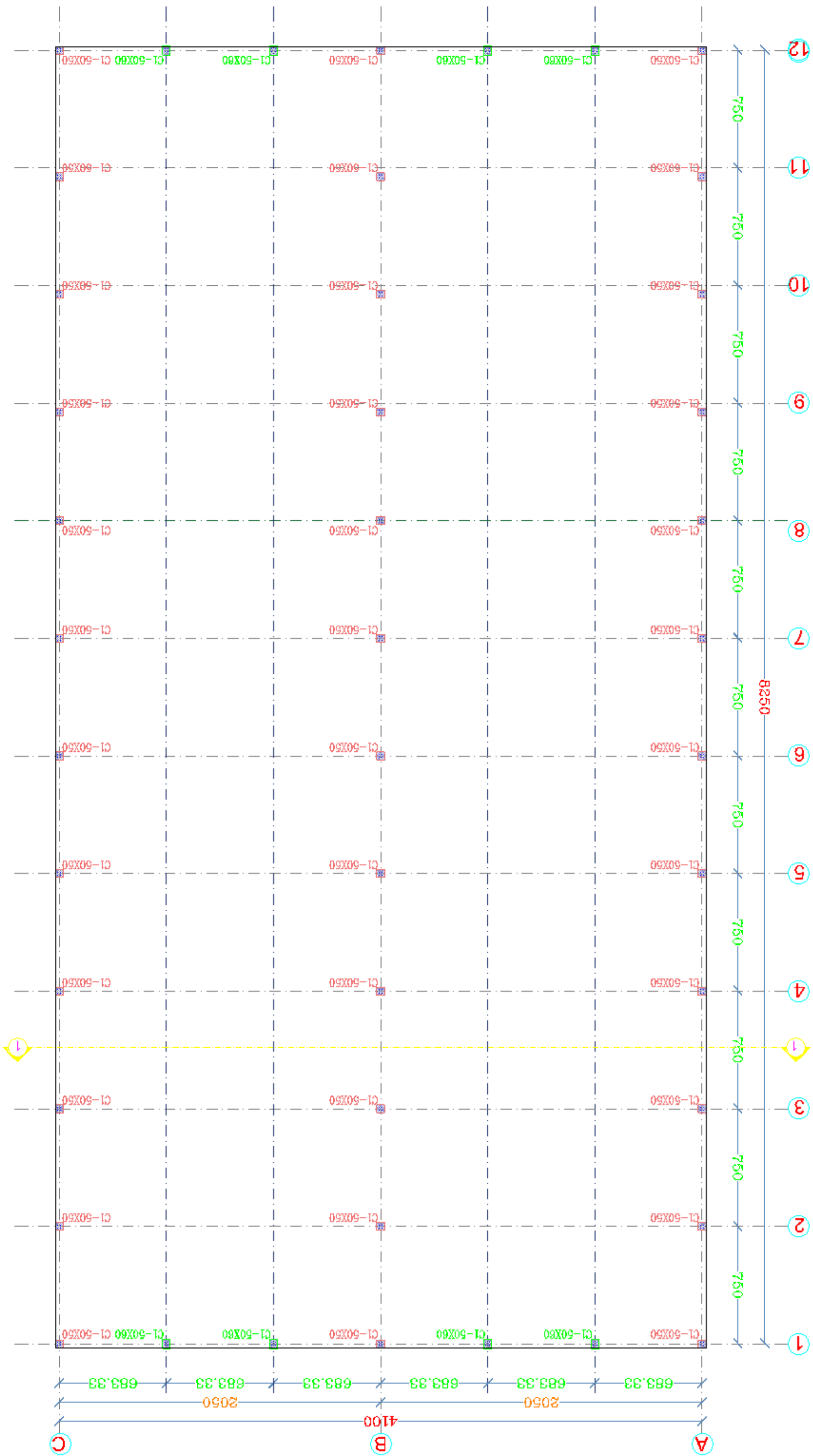

Fig 15: Sconed building floor plan.

B.1 Study the condition of the damaged element

In this building, we notice damage to the lower section of the columns in the area located approximately half a meter after the floor pit. In this type of building, the columns are hinged at the top with pre-fabricated concrete roof elements and fixed (transmit moments) in the bottom with the foundation via a bucket. That is, in this type of building, all earthquake forces are responded to by the columns. This explains why the damage occurred in this area, as the torque resulting from the horizontal forces is greatest in this area.

B.2 Study the damage caused

When reviewing the general description of the building, we find that it is an industrial building composed of prefabricated elements covered by a metal roof. The connection between the column and the roof elements is hinged so all the horizontal force is absorbed by the columns. The building consists of repeated patterns in both directions. There are no shear walls within the structural framework of the building. There are covering walls on the perimeter of the building, while the internal axes do not contain walls.

Fig 16: Damaged element.

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As we can see in the pictures, there is damage to many of the building's columns at different levels. There is one central column in very bad condition, as the reinforcing steel has reached its yield stress and the concrete has been damaged In a large percent.

5. Computer Modelling

The buildings were modelled using the analysis and design software STA4CAD, which is a program used for analyzing and designing structures according to Turkish specifications and

5.1 Şehitkamil First sample modelling:

The buildings were modeled using the analysis and design software STA4CAD, which is a program used for analyzing and designing structures according to Turkish specifications and the seismic provisions of TDBY2018. Seismic data for each building was extracted based on the site from the Turkish Disaster Management Authority website and input into the program for each building. Additionally, information regarding loads and other relevant data for each building was inputted to obtain accurate information.

1-) Şehitkamil First sample modelling:

After capturing the current real-life situation and lifting all dimensions of the building and existing structural elements, this data was inputted into the analysis software. The building was then subjected to various load combination, and accordingly, the elements were designed for the worst-case load combination.

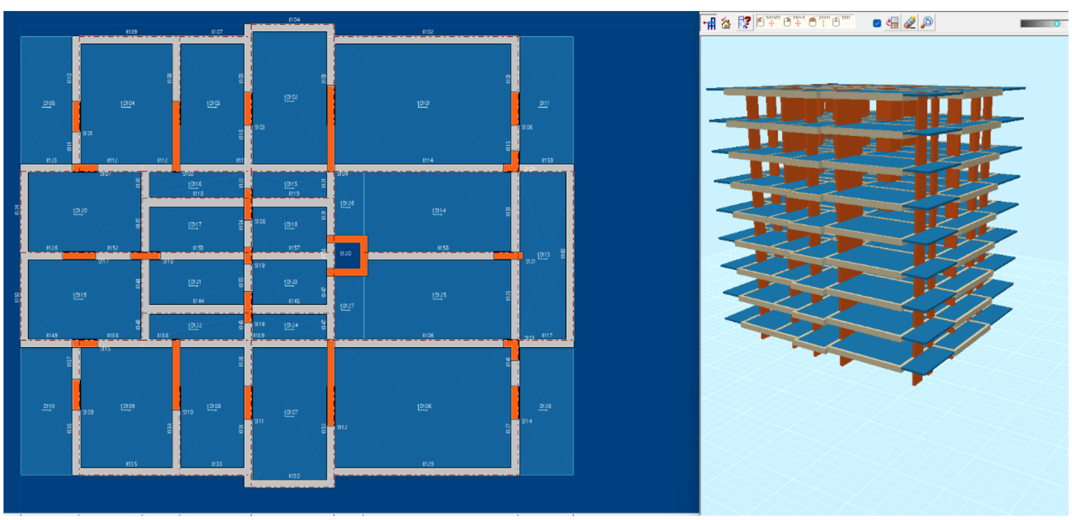

Fig 17: computer modelling (STA4CAD).

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After entering all the data into the program, analysis and design were conducted. The results related to the damaged element were obtained and compared in the current situation.

The damaged element withstands the required moments with the dimensions present in reality. However, there are differences in terms of reinforcement between the design results and the results implemented in reality. A comparison table was created below for

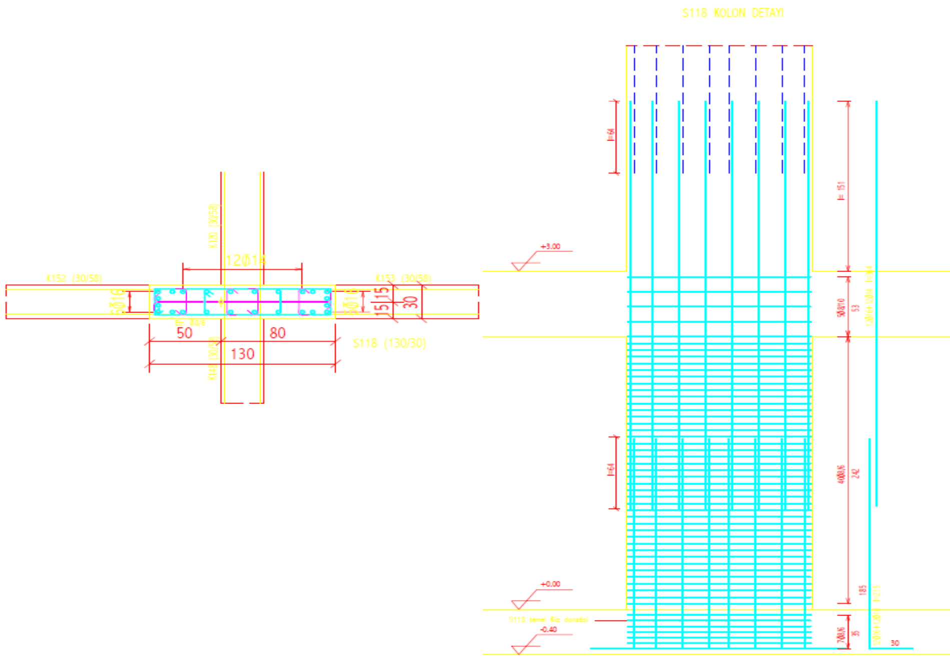

Fig 18: Design result for damaged elements (STA4CAD).

This comparison highlights that while the dimensions of the damaged element align with design expectations, there are discrepancies in reinforcement between the design and implementation phases.

Table 1: Comparison between design results and damaged element situation

	Edge Main Reinforcement Bars	Meddile Reinforcement Bars	Stirrups Reinforcement
Design Results	6Ø16	6Ø14	4Ø8/6 cm
Implemented Results	3Ø14	6Ø10	2Ø8/25 cm

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It is noted that failure occurred in the Y-axis direction, resulting from the bending moment. Therefore, it is necessary to compare the longitudinal reinforcement and stirrups.

There is a difference in the diameter of the longitudinal reinforcement despite the same number of bars. Additionally, there is a significant difference in the number and diameter of the stirrups, which explains the failure in the structural element in this direction.

Despite the significant difference in the longitudinal reinforcement of the edges, the presence of shear walls and columns on the same axis and at very close distances may have prevented damage to the element in that direction.

2-) Kahramanmaraş second sample modelling:

After capturing the current real-life situation and lifting all dimensions of the building and existing structural elements, this data was inputted into the analysis software. The building was then subjected to various load combination, and accordingly, the elements were designed for the worst-case load combination.

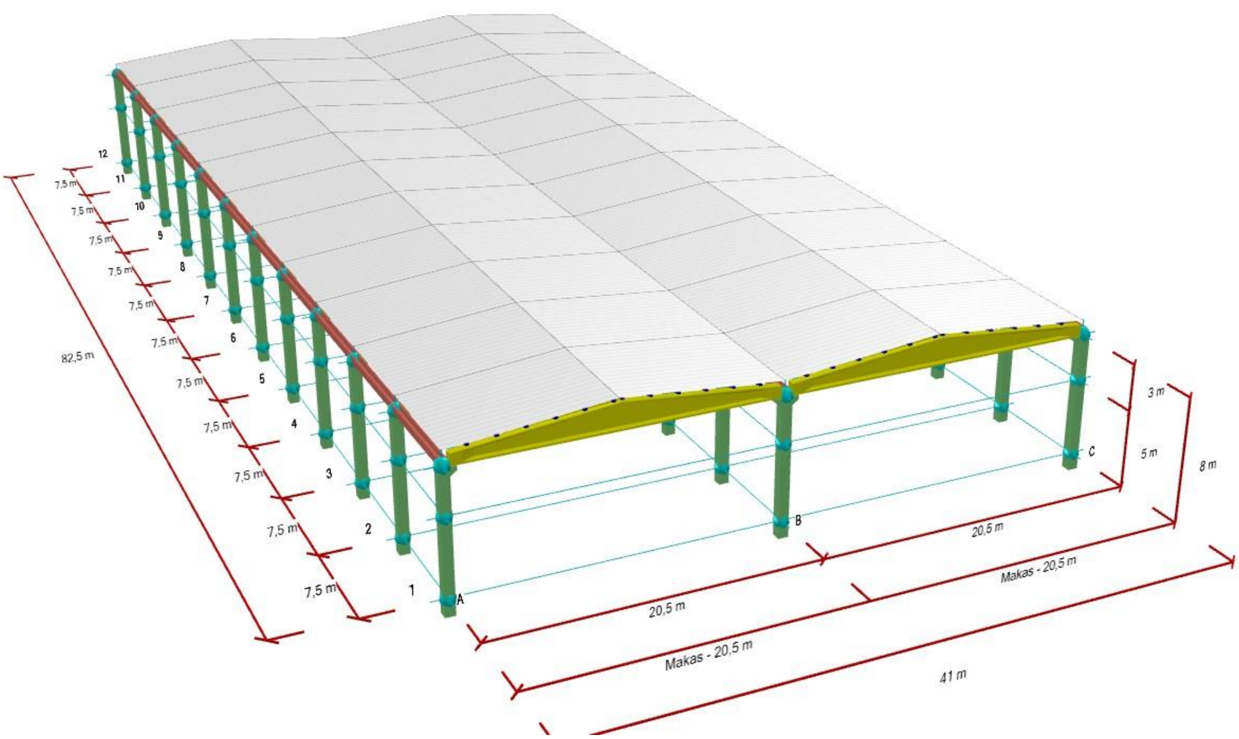

Fig 19: computer modelling for second sample (FAB2018).

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After entering all the data into the program, analysis and design were conducted. The results related to the damaged element were obtained and compared in the current situation.

When analyzing the building as it exists in reality, it became apparent that the dimensions used for the columns are insufficient, and the drift displacements are excessively large, exceeding the allowable limit according to Turkish building code TDBY-2018 requirements. It should be noted that the building was analyzed based on seismic data for the same site.

To meet the displacement requirement, it is necessary to increase the stiffness of the building, which is achieved by enlarging the cross-sections of the columns in the pinned structural framework buildings.

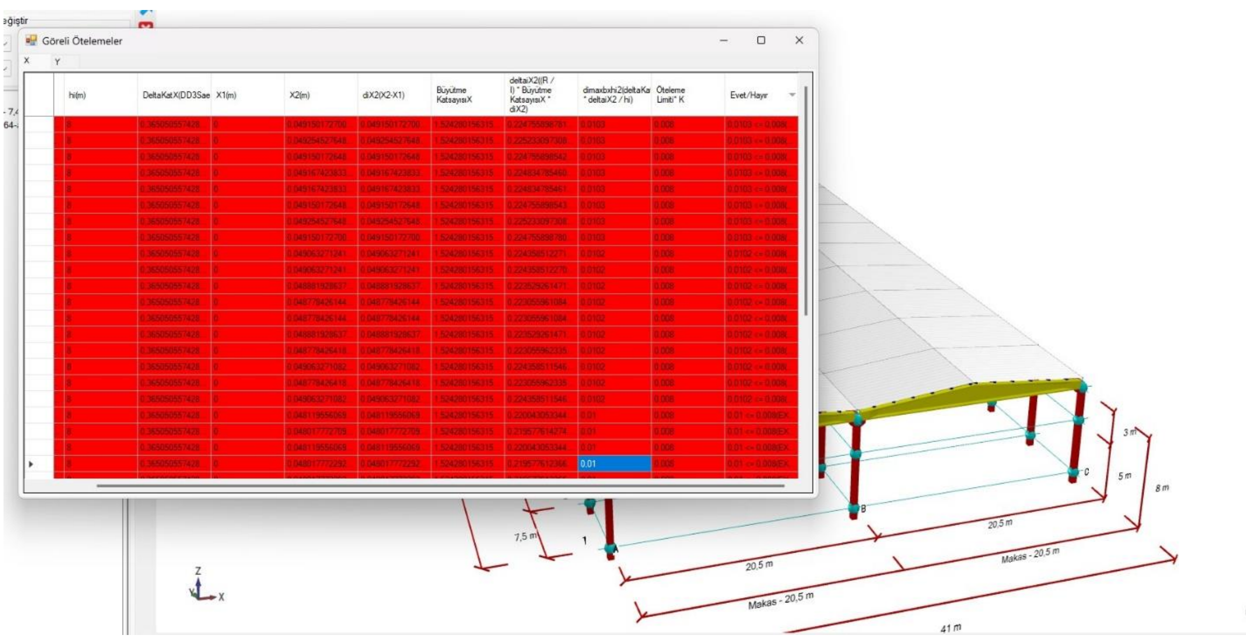

Fig 20: Column failure due to relative displacements- over drift value (FAB2018).

To obtain the correct design results, the column cross-sections were gradually enlarged to reach the appropriate column section based on the building data. It was determined that the column cross-sections need to be increased by 10 cm in each direction, changing the column section from 55*55 to 65*65, along with modifications to the reinforcement within these columns.

As we can observe, there is a significant discrepancy between the design results for the columns and the actual columns constructed on-site. It's worth noting that this building was constructed after 2018, meaning it was built according to Turkish

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seismic code requirements. It is particularly noteworthy that the confinement region of the ties terminates very close to the ground, not exceeding 50 cm. And there is a shortage in both the number and diameter of the main reinforcement bars. This likely explains the collapse of the columns under seismic forces.

Due to the substantial displacements experienced by the columns, damage to the connections between the column flanges and the roof beam (delta) was observed. A table has been formulated below to compare the design reinforcement with the reinforcement present in the studied element

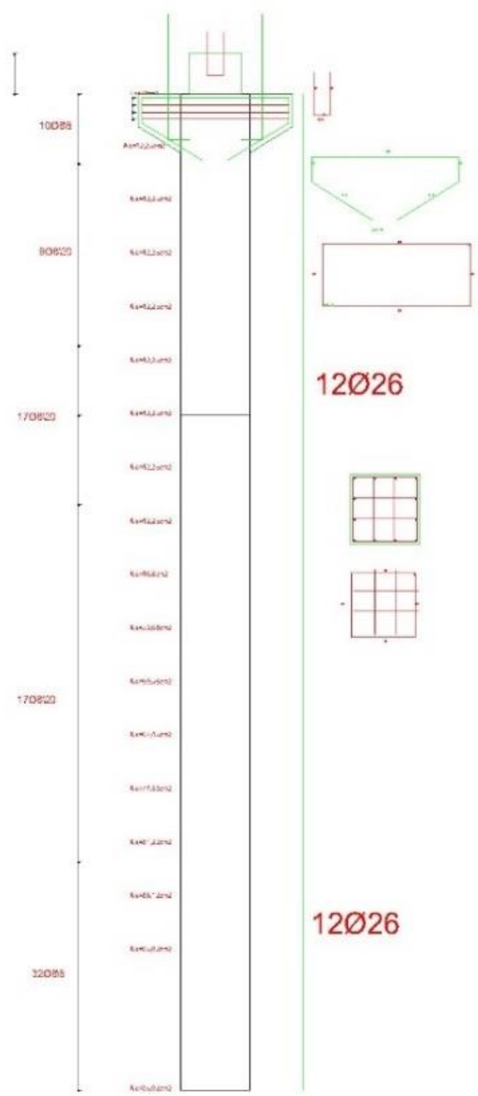

Fig 20: Design result for damaged elements.

Table 2: comparison between design results and damaged element situation.

	Colomun section	Main Reinforcment Bars	Stirrups Reinforcment
Design Results	65X65	12Ø18	3Ø8/6cm-3Ø8/20cm
Implemented Results	55X55	12Ø26	2Ø8/10cm-2Ø8/20cm

As observed in the table, there is a significant difference between the design section and the actual section in terms of dimensions, number and diameters of reinforcement bars, and ties. Additionally, the short confinement Intensification distance of the ties constitutes a major negative point for the existing columns. This explains the failure observed in this element.

6. REPAİR AND REHBALİTİON METHODS

Each case of rehabilitation will be discussed individually, taking into account the number of affected elements, the feasibility of rehabilitation on-site, available technologies for rehabilitating these elements, and other relevant factors.

6.1 Proposal to rehabilitate Şehitkamil building

After evaluating the extent of damage to the element, the following considerations were taken into account: the relatively large size of the damage in the element, poor quality of concrete in this element according to field inspections, in residential buildings usually don't prefer using methods like jacketing for architectural reasons.

In addition, considering that only one element is damaged, we propose the removal of the element and its replacement with a new one according to the required design specifications.

This element can be removed by reinforcing the surrounding elements with temporary supports. Subsequently, the element can be demolished, and a new element can be cast according to the design specifications. It is important to maintain the reinforcement steel between the rehabilitated element and both the upper and lower floors.

6.2 Proposal to rehabilitate Kahramanmaraş building

After evaluating the damage to determine the appropriate rehabilitation type, the following considerations were taken into account:

- The building is a prefabricated industrial structure, and the load-bearing elements resistant to lateral loads consist only of columns.
- There are a considerable number of damaged columns, and all columns need reinforcement because they do not meet the requirements in terms of dimensions and reinforcement.
- Being an industrial building, there are no significant architectural constraints.

Based on this, rehabilitation through jacketing can be proposed for this building. Rehabilitation can be carried out in two types:

1-) Complete compensation of the column and reinforcement area for significantly damaged columns, with the rehabilitation process extending to non-damaged or minimally damaged columns.

2-) For undamaged or minimally damaged columns with hairline cracks, compensation is made for the difference in area between the design area and the actual area executed in terms of reinforcement and concrete. The procedure involves calculating the variance between the design reinforcement and the existing reinforcement, followed by integrating an equivalent amount of reinforcement into the additional jacketing.

3-) During the rehabilitation process, it is essential to adhere to certain requirements, including:

- Roughening the surface of the existing column.
- Integrating the reinforcement of the external jacket with the column.
- Encasing the bearing claw of the roof beams with the jacket To strengthen the connection at the top.

7. CONCLUSIONS

- Based on the field surveys conducted, it was found that most severely damaged or collapsed buildings were constructed before 2018, prior to the latest code amendments, or were built in a manner non-compliant with regulations.
- If the damaged elements stabilized in partially damaged buildings, rehabilitation studies can be conducted without the need for demolition and replacement. Buildings can be brought back into service immediately after rehabilitation, saving significant time and resources.

- Previous studies indicate that rehabilitated elements can exhibit performance equivalent to or better than their previous performance.
- This study can be utilized to work on rehabilitating old buildings, especially those constructed before the latest seismic regulations, to make them earthquake-resistant. Removing all old buildings and replacing them is extremely difficult and requires significant resources. Thus, this approach allows for an increase in the stock of safe buildings.
- There are numerous methods of rehabilitation that suit various types of buildings, which facilitates the process of strengthening buildings and making them resistant to potential earthquakes.

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