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Alternative Ferrocement Panels for Reinforcement of Reinforced Concrete Structures Damaged on the 6 February 2023 Turkey Earthquake

İsmail HOCAOĞLU[1*], İlker Bekir TOPÇU[2], Cenk ÖCAL[3]

[1]Afyon Kocatepe University, Bolvadin Vocational School, Construction Department, Afyonkarahisar, Türkiye
[2]Eskişehir Osmangazi University, Department of Civil Engineering, Eskişehir, Türkiye
[3]Isparta University of Applied Sciences, Department of Civil Engineering, Isparta, Türkiye

[*]Sorumlu Yazar/Corresponding Author
E-mail: ihocaoglu@aku.edu.tr

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ABSTRACT

Most of the reinforced concrete framed buildings commonly used in developing countries are not secure against earthquakes. Studies on seismic performance of reinforced concrete framed structures showed that; lateral stiffness often needs to be improved. In this study, in order to rehabilitate the structures, performances of ferrocement panels can be used to strengthen the existing hollow brick infill walls such that they act as cast-in-place concrete in fills improving the lateral stiffness is researched. Ferrocement panels are not only to be as light as can be carried by two people easily, but also from the low cost and usefulness against tensional and loads point of view. Previous research results indicated that strength, stiffness, energy dissipation and drift characteristics of the reinforced concrete framed building structures can be rehabilitated by the eco-friendly, cost effective and practically applicable seismic retrofitting technique that does not need evacuation of the building with these high-performance ferrocement panels.

Keywords: Reinforced concrete, Retrofitting, Ferrocement, Earthquake

6 Şubat 2023 Türkiye Depreminde Hasar Görmüş Betonarme Yapıların Güçlendirilmesi için Alternatif Ferrocement Paneller

ÖZ

Gelişmekte olan ülkelerde yaygın olarak kullanılan betonarme çerçeveli binaların çoğu depreme karşı güvenli değildir. Betonarme çerçeveli yapıların sismik performansları üzerine yapılan çalışmalar göstermiştir ki; yanal sertlik çoğu zaman yetersizdir. Bu çalışmada, yapıların rehabilite edilmesi amacıyla, mevcut boşluklu tuğla dolgu duvarların güçlendirilmesinde kullanılabilecek ferrocement panellerin yerinde dökme beton dolgu görevi görerek yanal rijitliği iyileştirme performansları incelenmiştir. Hafif agregalı ferrocement paneller, iki kişinin rahatlıkla taşıyabileceği kadar hafif olması, çekmeye karşı dayanıklı, hafif, düşük maliyetli ve kullanışlı olması nedeniyle tercih edilmektedirler. Önceki araştırma sonuçları, betonarme çerçeveli bina yapılarının dayanım, rijitlik, enerji yayılımı ve kat ötelenmesi özelliklerinin, bu yüksek performansla binanın boşaltılmasına ihtiyaç duyulmadan, çevre dostu, düşük maliyetli ve pratik olarak uygulanabilir sismik güçlendirme tekniği ile iyileştirilebileceğini göstermiştir.

Anahtar Kelimeler: Betonarme, Güçlendirme, Ferrocement, Deprem

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1. Introduction

Recent global earthquakes have highlighted that a significant portion of the current building inventory in numerous developing nations prosseses insufficient seismic resilience thus demands substantial restoration (Baran, 2005). Factors such as earthquake-induced destruction and evolving building codes contribute to such prevailing predicament (Baran, 2005). On February 6th, 2023, an earthquake with a magnitude of 7.8 occurred in the Pazarcık district of Kahramanmaraş province in Turkey. The seismic event reverberated across multiple urban centers (AFAD, 2023) (including Hatay, Adıyaman, Kahramanmaraş, Malatya, Gaziantep, Osmaniye, Adana, Kilis, Diyarbakır, Şanlıurfa, and Elazığ), resulting in the structural failure of numerous edifices (Figure 1). As per the AFAD report, the region experienced a total of 224 with the most significant registering at a seismic events between 1900 and February 6th, 2023, magnitude of 6.0 (AFAD, 2023). Information from the report published by the Turkish Ministry of Environment, Urbanization, and Climate Change reveals that roughly 590,250 structures suffered minor damage, while 45,500 buildings incurred moderate damage (MEUCC, 2023). Given the substantial expense associated with reinforcing extensively damaged structures, the act of strengthening such buildings becomes impractical.

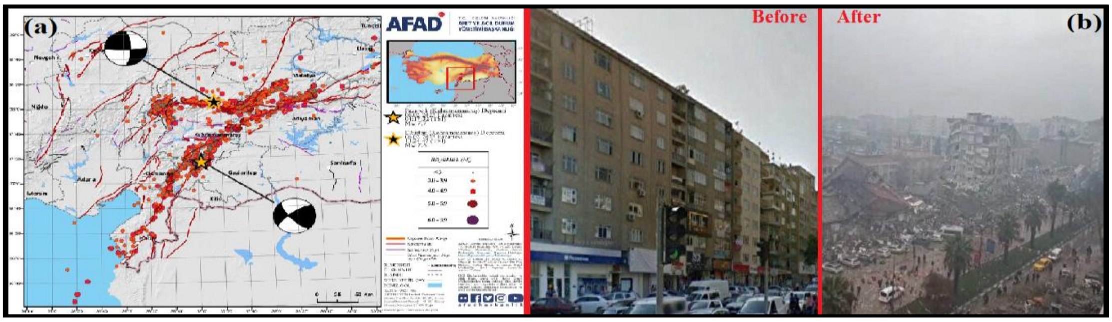

Figure 1. The earthquake map (a) and damage image caused by the earthquake (b) (AFAD, 2023; URL-1, 2023)

Rehabilitation needs for this high ratio of the existing building stock are urgent, especially in regions with high seismic activity. Studies on building rehabilitation have highlighted inadequate lateral stiffness as a significant cause of damage in reinforced concrete framed structures. Scientists have suggested that reducing the dead load of buildings can help mitigate the loss of life and property. The scientists concluded that reducing the unit weight of concrete is essential to reduce the dead load (Spiesz and Hunger, 2017). Besides using lighter materials to reduce the dead load, properties like load-bearing capacity and heat insulation can also be enhanced (Topçu, 2004; Topçu, 1999). Topçu and Uğurlu (2004) reported that earthquake-resistant structures can be constructed using steel wire. Some scientists have produced ultra-light concrete with densities below 800 kg/m^3 (Yu et al., 2015). Ultra-light concretes, however, typically exhibit compressive strengths of up to 10 MPa (Spiesz and Hunger, 2017; Yu et al., 2015). Furthermore, ultra-light concrete is unsuitable for reinforcing existing structures, prompting scientists to explore alternative solutions.

Research on enhancing lateral stiffness has focused on strengthening existing hollow brick infill walls through the application of ferrocement panels as cast-in-place concrete infills (Hago et al., 2004). The seismic rehabilitation of a significant number of existing building stocks, as suggested by Hago et al. (2004), often necessitates construction evacuation and may not be feasible without causing significant disruption to occupants.

The expected attributes of a reinforced concrete structure include strength, durability, cost-effectiveness, functionality, and aesthetics. Buildings require maintenance, repair, and property rehabilitation. However, earthquakes reveal these vulnerabilities. Structural strengthening is beneficial from both engineering and economic perspectives. Often, this leads to demolition and reconstruction. This situation results in the loss of materials, workmanship, and time. While ferrocement panels excel in low cost and rapid production, among other advantages (Murali et al., 2020). Ferrocement is a thin reinforced composite made from cementitious mortar (ACI, 1997). While ferrocement gained widespread usage in the 20th century, it offers additional advantages compared to traditional reinforced products in the construction (concrete) sector (Batson, 2000; Topçu, 2000). Reinforcement bars are typically sandwiched between two layers of steel wire meshes (Figure 2) (Murali et al., 2020). In the production of ferrocement panels, the outer surface is initially created using a cement-based material. Following this, a mesh arrangement with steel fibers is created, typically resulting in ferrocement shells with thicknesses ranging from 10 to 25 mm. Subsequently, another layer of cement-based material is poured (Figure 2). Finally, the produced ferrocement panels should undergo mechanical testing for adequacy.

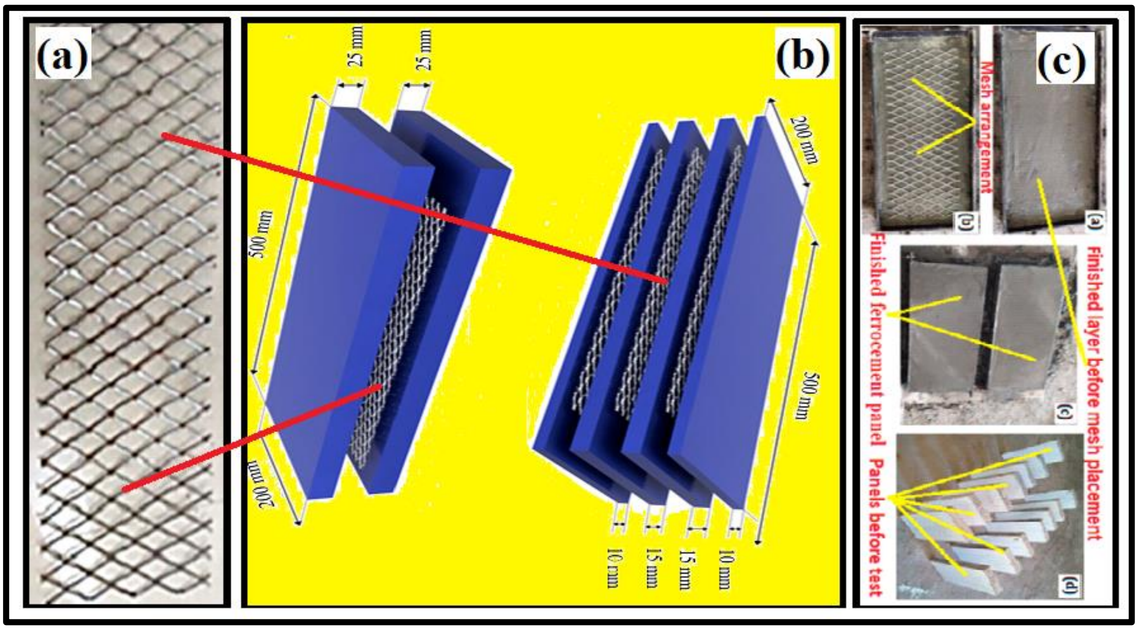

Figure 2. Construction stages of the ferrocement panel (a- a view of wire mash, b- Placing the wire mash, c- a view of after hardening) (Murali et al., 2020)

The critical fact is that wire mesh panel shells are produced with a very high-strength cementitious mortar. Ferrocement is particularly intriguing in developing countries for the reasons mentioned below (Tankut et al., 2004).

- The fundamental raw materials used in ferrocement are readily available in many countries.
- Production can be carried out in any environment.
- It is durable and cost-effective compared to many materials, including steel.
- Skills for ferrocement applications can be acquired easily.
- Ferrocement can absorb high rates of impact energy (Abdul-Ameer, 2000).
- Ferrocement structures can withstand fire for approximately 2 hours (Riyadh, 2005).
- Ferrocement production is cost-effective compared to other methods but requires skilled workmanship. A structure constructed with ferrocement panels is depicted in Figure 3.

Figure 3. Building construction with ferrocement panels (Patil et al., 2023)

Today, technological advancements enable the production of new-generation ferrocements. Previous studies have demonstrated that pouring concrete up to 400 mm high into a thin, 3D mold is feasible (Lloret-Fritschi, 2021). Burger et al. (2022) manufactured ribbed concrete slabs using a 3D printer.

According to official statements, approximately 50,500 people lost their lives in the earthquake in Turkey on February 6th, 2023. Approximately 1.5 million people were left homeless after the disaster. About 2.3 million people have been affected housing problem. Economically strengthening structures that sustained minor or moderate damage in the earthquake is crucial for rapidly rehousing people. This article reviews the mechanical properties of ferrocement for reinforcing masonry and reinforced concrete structures and explores technological advancements in prefabricated ferrocement panels for building strengthening.

2. Producing ferrocement panels

2.1. Framework preparation

A framework is constructed using lightweight steel or wire mesh. The framework is shaped according to the desired dimensions and structural requirements of the panel. Square wire mesh and chicken wire mesh wires are used in ferrocement panel production and shown in Figure 4 (Rameshkumar et al., 2022). The cost, including labor cost, for a two-layered wire mesh 30x240x5 cm panel is estimated at approximately $15 (URL– 2, 2023).

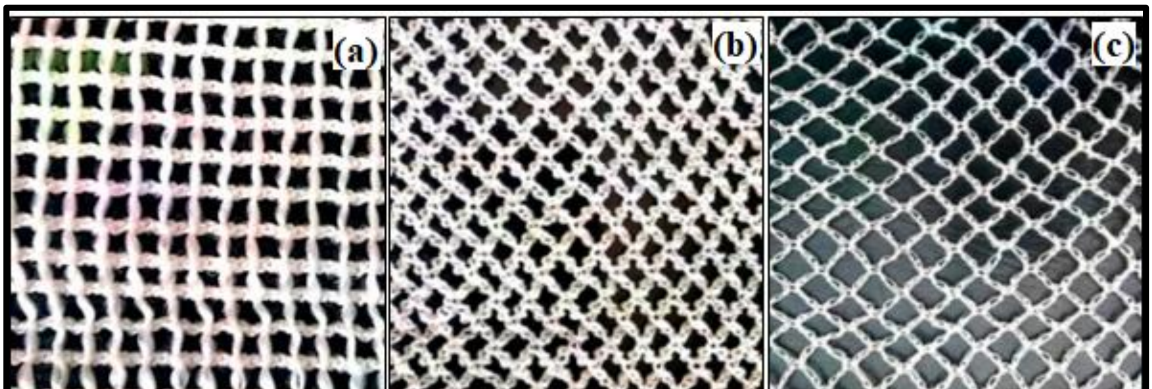

Figure 4. Wires used in ferrocement panel production (a- square wire mash 5 mm, b- chicken wire mash 5 mm, c- chicken wire mash 10 mm (Rameshkumar et al., 2022)

2.2 Mixing the mortar

A mortar mixture is prepared by combining cement, sand, water, and sometimes other additives such as admixtures or fibers. The proportions of these ingredients may vary depending on the specific application and desired properties of the panel.

2.3. Application of the mortar

The mortar mixture is applied to the framework in thin layers using hand trowels or spraying equipment. The first layer is typically applied to both sides of the framework, and additional layers are added until the desired thickness is achieved. Each layer is compacted and worked to ensure proper adhesion and consolidation.

2.4 Curing

After the mortar is applied, the panels are left to cure and gain strength (Figure 5). Curing typically involves keeping the panels moist for a specific period, which can vary depending on factors such as temperature and humidity. Curing facilitates the hydration of cementitious materials in the mortar, forming strong bonds and resulting in a durable and robust panel.

Figure 5. The drying process of ferrocement slabs after 28 days curing (Ziadoon et al., 2020)

2.5 Finishing touches

After curing, the panels can be finished according to the desired appearance and functionality. This may involve sanding, painting, or applying coatings to enhance the surface's aesthetics, durability, or resistance to environmental factors such as moisture or UV radiation.

2.6 Unit weight

The unit weight of ferrocement panels can vary depending on several factors, including the composition of the mix, thickness of the panel, and reinforcement used. Typically, the unit weight of ferrocement panels ranges from 2000 kg/m³ to 2500 kg/m³ (125 lb/ft³ to 156 lb/ft³) (Shaheen et al., 2020). This range takes into account the typical composition of ferrocement, which consists of cement mortar matrix reinforced with layers of wire mesh or other types of reinforcement. It is important to note that the unit weight can vary based on the specific design and materials used in the ferrocement panel. Additionally, different standards and specifications may have different requirements for ferrocement panel unit weights.

3. Flexural strength in ferrocement-reinforced concrete

Zisan et al. (2023) compared the flexural strengths of ferrocement-reinforced beams in 4 different conditions (Figure 6). In Figure 6, CB represents a standard reinforced concrete beam. CB-1 represents the web reinforcement of CB is replaced by wire mesh (3.5 mm wire has 25 mm mesh opening). CB-2 represents Both web and main bars of CB are replaced by wire mesh (4.7 mm wire has 25 mm mesh opening). The flexural strengths of the beams in different reinforcement conditions were compared in Figure 6.

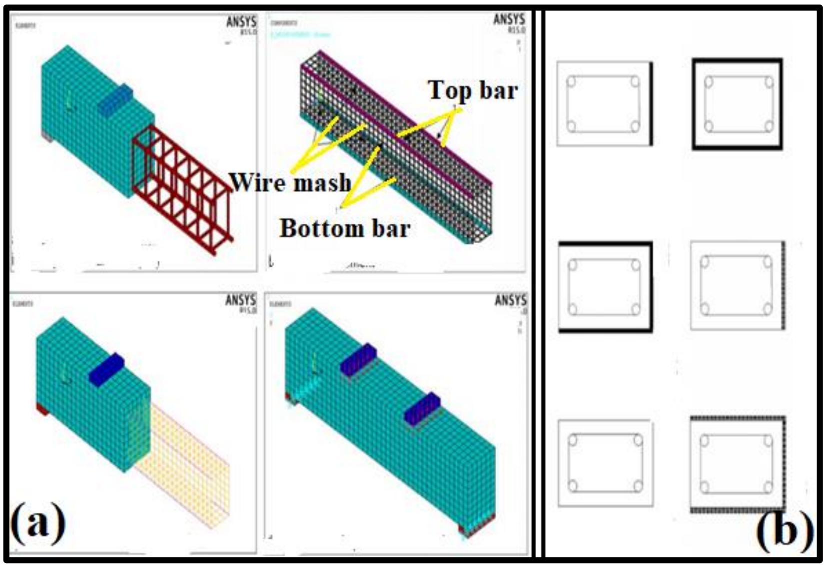

Figure 6. Reinforcement of beams with ferrocement (a- Form of reinforcement, b- Reinforcement type) (Zisan et al., 2023)

The crack width and initial crack formation in ferrocement reinforced concrete is shown in Figure 7. According to Figure 7, it was determined that the first crack formation is later with ferrocement reinforcement in beams in all series. Additionally, reinforcing concrete elements with ferrocement has been observed to reduce crack width (Figure 7b).

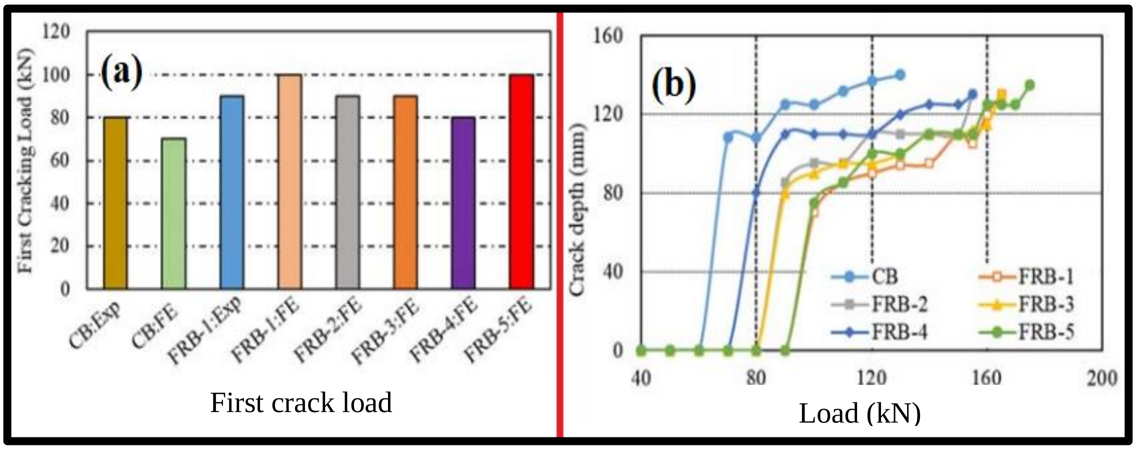

Figure 7. Initial crack formation (a) and crack width (b) in ferrocement reinforced concrete (Zisan et al., 2023)

4. Ferrocement panels fixed to frame elements

Since ferrocement panels fixed to frame elements by epoxy anchorage rods improve the earthquake behavior of structures and increase the lateral stiffness considerably, this method is also expected to heal the system. To ensure that prefabricated ferrocement panels can be easily transported, passed through doors, and installed quickly by two people, wall strengthening often requires the use of multiple small panels, rather than a single large panel. In that case, the bond between panels and frame elements is crucial. The bonding aspect is especially important for applied strengthening. Ensuring that panels unite effectively with each other and framing elements to approach the behavior of cast-in-place concrete is important. This is achieved by using epoxy anchorages and mortar, as mentioned by Baran (2005; 2021).

Since earthquake loads can impact the structure from any direction, it is advisable to anchor panels on the walls in both the X and Y directions.

Columns and cast-in-place concrete walls are known to resist earthquake loads in the structure (Joy et al., 2016). When a column initially faces earthquake loads in a building, it acts as a means of transferring such loads to other columns. If there is no concrete wall between these columns, the axial load can transform into energy. This can lead to damage to the walls. The delayed load will transfer to other walls, causing similar damage in walls of the same direction. Based on this understanding, panels can be used to strengthen the existing hollow brick infill walls to act as cast-in-place concrete infills improving the lateral stiffness (Baran, 2021).

5. Mechanical strength of ferrocement panels

The flexural strength of ferrocement panels is determined by a 3-point or 4-point loading test (Figure 8) (Sakkarai and Soundarapandian, 2021; Murali et al., 2020). Then, a compressive strength test can be performed. Previous studies have determined that the 28th day the flexural strengths of ferrocement panels vary between about 4-4.5 MPa, and their compressive strengths were between about 18-20 MPa (Işıkdağ, 2015).

A study performed in Turkey evaluated the effects of reinforcement parameters on mechanical properties like bending rigidity, stress at first crack, bending strength, and impact strength. Test results showed that strength at first crack load and maximum load increases with reinforcement percentage and passes from a maximum point. The best results obtained from square wire mesh (Özdemir and Kocataşkın, 1984). According to research conducted in the USA showed that modular housings produced by using compressed ferrocement panels at exterior walls, slabs, and roofs were found to be more resilient than masonry structures and demonstrated comparative resistance to dynamic loads when well-constructed (Chang and Nanni, 1985). It was also observed in the People's Republic of China that a 5-storey-1000 m^2 usage area building constructed with ferrocement lightweight panels showed property of resistance to earthquake (Wang, 1985).

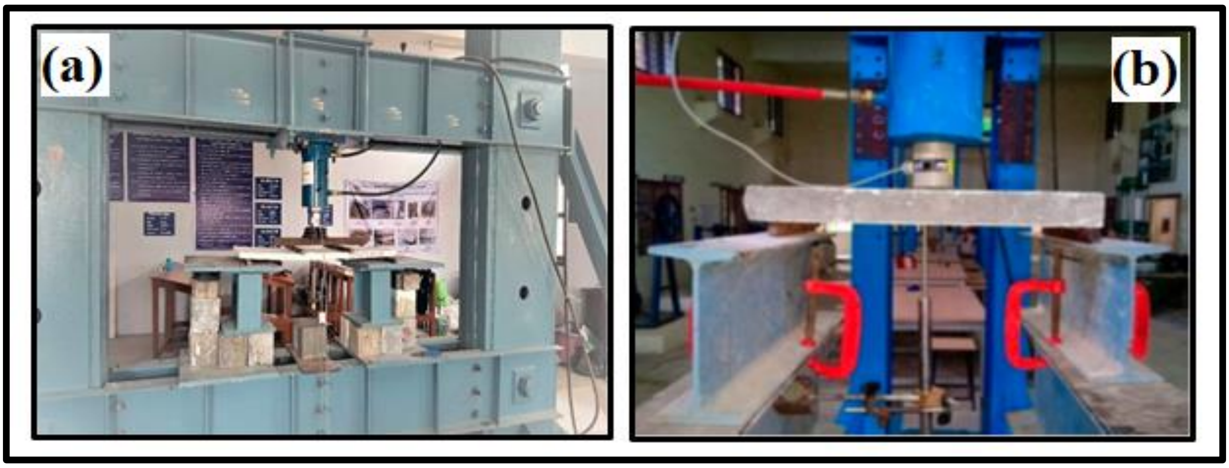

Figure 8. Flexural test (a- 3 point, b- 4 point) on the GF flat panel (Sakkarai and Soundarapandian, 2021; Murali et al., 2020)

Memon et al. (2006) investigated the mechanical strength of 8 different ferrocement panels according to different parameters (Table 1).

Table 2 compares the compressive strengths of ferrocement panels with different types of wire mesh (Memon et al., 2006). When Table 2 was examined, it was seen that ferrocemet increased the mechanical strength in all series. In addition, it was observed that square wire mesh was more effective than chicken wire mesh in increasing compressive strength.

Table 1. According to Memon et al. (2006) ferrocement panel parameters

Sample. No.	Batch Designation	Type of wire mesh	No. of layers	Remarks
1	BC	---	----	Control block made of aerated concrete
2	B0L	---	0	Sandwich block without wire mesh
3	BCW1	Chicken wire mesh	1	Sandwich block with one layer of chicken wire mesh
4	BCW2	Chicken wire mesh	2	Sandwich block with two layers of chicken wire mesh
5	BCW3	Chicken wire mesh	3	Sandwich block with three layers of chicken wire mesh
6	BCW4	Chicken wire mesh	4	Sandwich block with four layers chicken wire mesh
7	BSW1	Square wire mesh	1	Sandwich block with one layer of square wire mesh
8	BSW2	Square wire mesh	2	Sandwich block with two layers of square wire mesh

Table 2. Compressive strengths of ferrocement panels, according to Memon et al. (2006)

Sample. No.	Batch Designation	Average compressive strength (MPa)	Increase in compressive strength (% of BC)	Increase in compressive strength (% of B0L)
1	BC	7.7	--	--
2	B0L	10.8	40.3	--
3	BCW1	12.2	58.4	13.0
4	BCW2	13.0	68.8	20.4
5	BCW3	13.7	77.9	26.9
6	BCW4	12.9	67.5	19.4
7	BSW1	15.5	101.3	43.5
8	BSW2	16.4	113.0	51.9

6. Alternative ferrocement applications for earthquake-damaged structures

One of the most significant drawbacks of concrete is its low tensile strength, as pointed out by Hocaoğlu in 2023. To address this limitation, various diameter bars are incorporated into reinforced concrete structures where high tensile stresses are anticipated, as explained by Koçak in 2021. Ferrocement reinforcement follows a similar principle. Figure 9 illustrates a beam reinforced with ferrocement and presents the results of its flexural strength test, as conducted by Bong and Ahmed in 2010. In this study, a prefabricated beam was reinforced with a 30mm high ferrocement mesh, and subsequent bending tests were performed on both ferrocement-reinforced and reference beams. Notably, a significant enhancement in the flexural strength of the ferrocement-reinforced beam was observed (Figure 9c). These results suggest that strengthening beams with ferrocement may effectively address positive bending moments during earthquakes. According to Bong and Ahmed (2010), beams reinforced with ferrocement can increase the initial crack load by up to 50%. Additionally, Muhit et al. (2021) conducted an investigation involving ferrocement retrofitting in 20 beams through bending tests and concluded that the use of ferrocement reinforcement can yield an approximate 46% increase in the ultimate load-carrying capacity of beams.

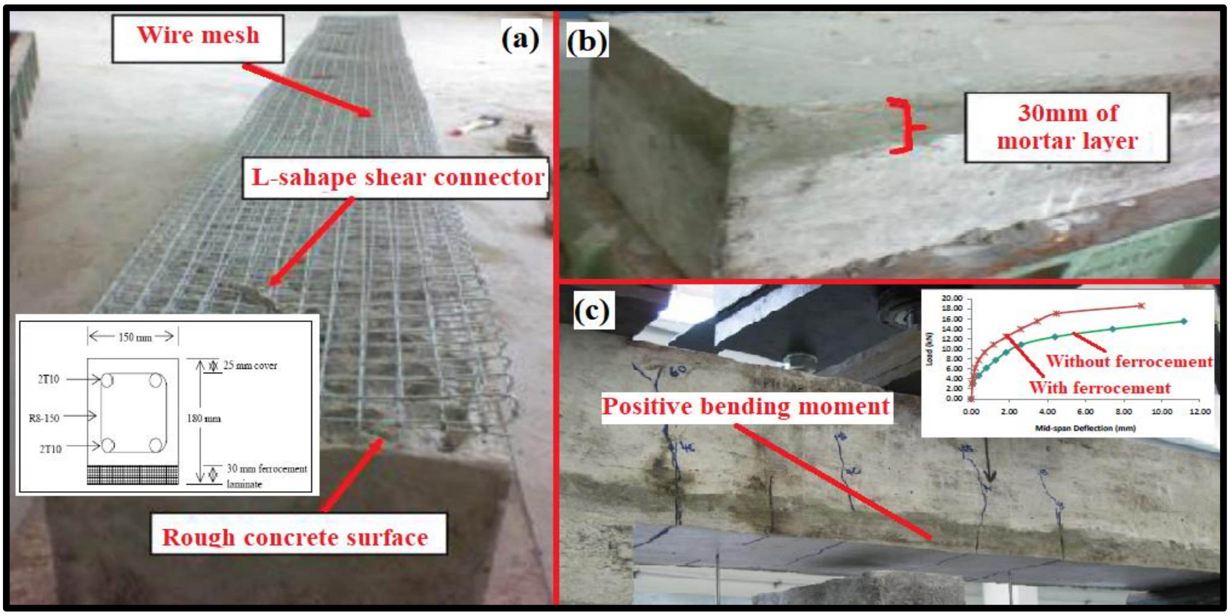

Figure 9. Reinforcement of a beam with ferrocemet laminate (a- Placing the wire mesh, b- a view of after hardening, c- bending test and results) (Bong and Ahmed, 2010)

El-Sayed et al. (2023) investigated whether ferrocement water pipes could be an alternative to steel water pipes. In their research, they produced control sample, a polypropylene fiber reinforced sample, welded mesh ferrocement pipes, and fiberglass ferrocement pipes. They observed higher mechanical strength in pipes reinforced with ferrocement (Figure 10). They also observed that the highest strength was obtained with increased layers, especially in the sample modified with fiberglass.

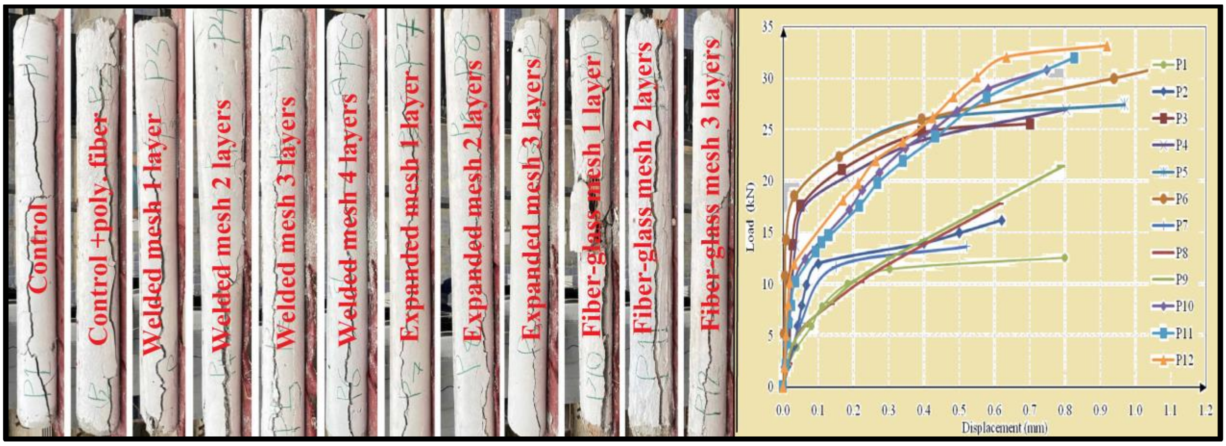

Figure 10. Production and mechanical strength of ferrocement pipes El-Sayed et al. (2023)

In the pursuit of mitigating earthquake loads, Shaheen et al. (2018) embarked on the development of ferrocement-reinforced lightweight concrete, as illustrated in Figure 11. Their methodology involved the utilization of perforated bricks within the construction of lightweight masonry. Within these perforated bricks, ferrocement wire was strategically placed, subsequently encapsulated by mortar. To finalize the construction process, the wall's surface was adorned with ferrocement wire and securely affixed. The novel approach they introduced offers several advantages, including enhanced crack resistance, heightened serviceability, augmented ultimate load-bearing capacity, and heightened energy absorption capabilities (Shaheen et al., 2018).

Figure 11. Reinforcement of a wall with ferrocemet wire (a- Steel wire mesh box reinforcement arrangement inside the holes of walls specimens, b- Walls specimens after filling the holes by mortar, c- Drilling the holes for the connectors, d- Steel wire meshes after formed into cages and enwrapped) (Shaheen et al., 2018)

Aiswarya and Mohan (2019) undertook an investigation into the seismic safety implications of ferrocement jacketing. Their study centered on the efficacy of ferrocement jacketing as a means to reinforce an existing reinforced concrete column that had been preloaded to a portion of its ultimate load-bearing capacity. Their findings revealed that columns preloaded at 70% of their capacity and equipped with one and two layers of windings experienced load-bearing capacity increases of 65% and 86%, respectively (Aiswarya and Mohan, 2019). Furthermore, they noted a significant enhancement in the ductility of the cracked columns following the application of ferrocement jacketing. Additionally, Jaraullah et al. (2022) conducted research demonstrating that the flexural strength of mortar reinforced with welded steel mesh (3mm) could be increased by approximately 61.3%.

In a study conducted by Mustafaraj et al. (2023), the reinforcement of walls using ferrocement wire was examined (Figure 12). Their investigation revealed a substantial enhancement in the shear resistance and deformation capacity of unreinforced walls due to ferrocement reinforcement. These findings strongly indicate that ferrocement jacketing is a highly efficacious method for strengthening masonry structures.

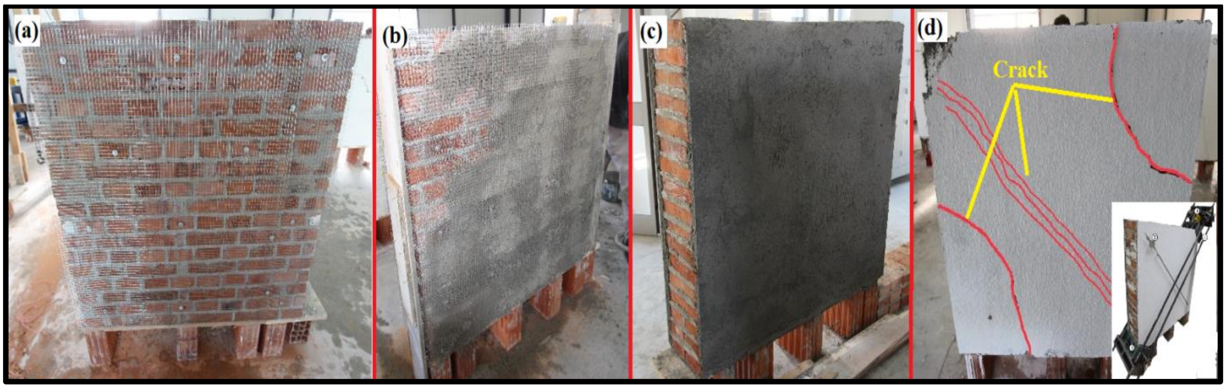

Figure 12. Reinforcement of masonry walls with ferrocement jacketing (a- installment of the mesh, b- application of the first plaster layer, c- application of the second layer, d- the failure mode of FC-strengthened panels) (Mustafaraj et al., 2023)

7. Thermal insulation properties of ferrocement panels

Ferrocement structures are not only effective in reducing vertical loads in new or retrofit applications but also have excellent thermal insulation properties. In previous studies, it has been determined that insulation can be achieved by using ferrocement panels on both walls and roofs (Al-Rifaie et al., 2014). Table 3 compares the thermal conductivity of different structural elements. It has been observed that 950% lower heat transfer occurs when using ferrocement wires on the wall compared to the concrete block. If ferrocement is used as a roof covering, a 940% higher insulation can be achieved than reinforced concrete (Table 3).

Table 3. Heat transfer coefficient for the structural panels according to Al-Rifaie et al. (2014)

Structural member	Panel system	Up= Heat transfer coefficient
Wall	Concrete block	5.485
	Clay brick	4.835
	Stone	3.5
	Ferrocement cavity wall with insulation panel positioned between the two ferrocement leaves	0.22
Roof	Reinforced concrete	2.31
	Clay brick jack arching	2.1719
	Ferrocement channel like cross-section	0.1337

8. Application areas of ferrocement

Today, ferrocement is widely utilized in various fields due to its versatility. Its lightweight properties, compared to steel, contribute to the reduction of vertical loads in structures. Reducing building dead loads not only enhances structural safety but also improves earthquake resistance. Figure 13 illustrates the applications of ferrocement in India, specifically in Delhi (URL– 3, 2023).

Research work on ferrocement shows that this composite material finds an increasing interest most-of-all at developing countries (Murali et al., 2020). Ferrocement technology made available the production of structural elements like walls (Figure 14), beams, slabs, and roofs by using not only coolie, but also local materials (Rifaie et al., 2014). It is seen that ferrocements are also used in buildings with architecturally attractive visuals (Figure 15) (URL– 4, 2023).

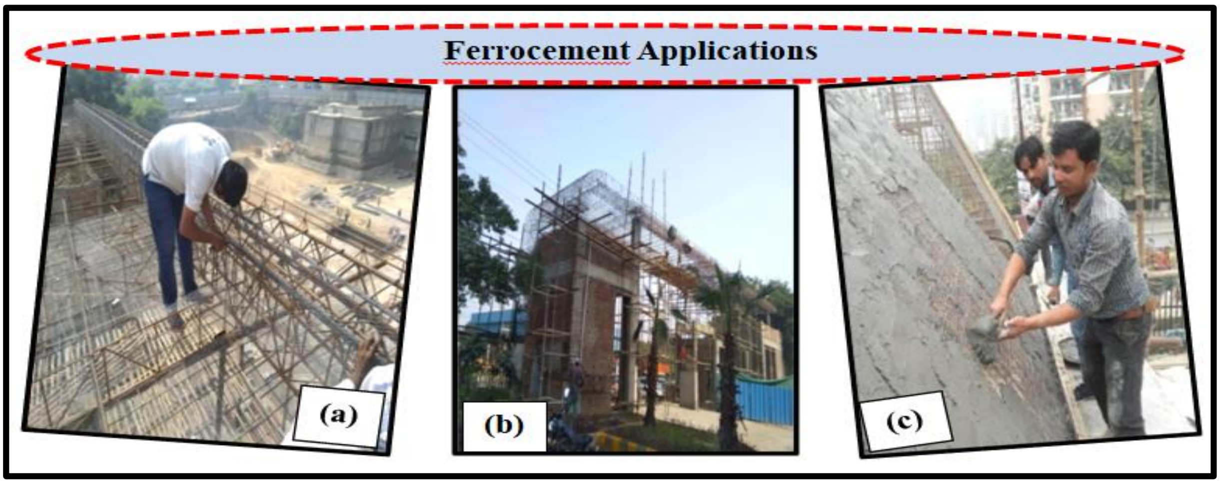

Figure 13. Ferrocement applications in Delhi, India (a- wire mesh laying, b- a view of before pouring concrete, c- the mortar application) (URL– 3, 2023)

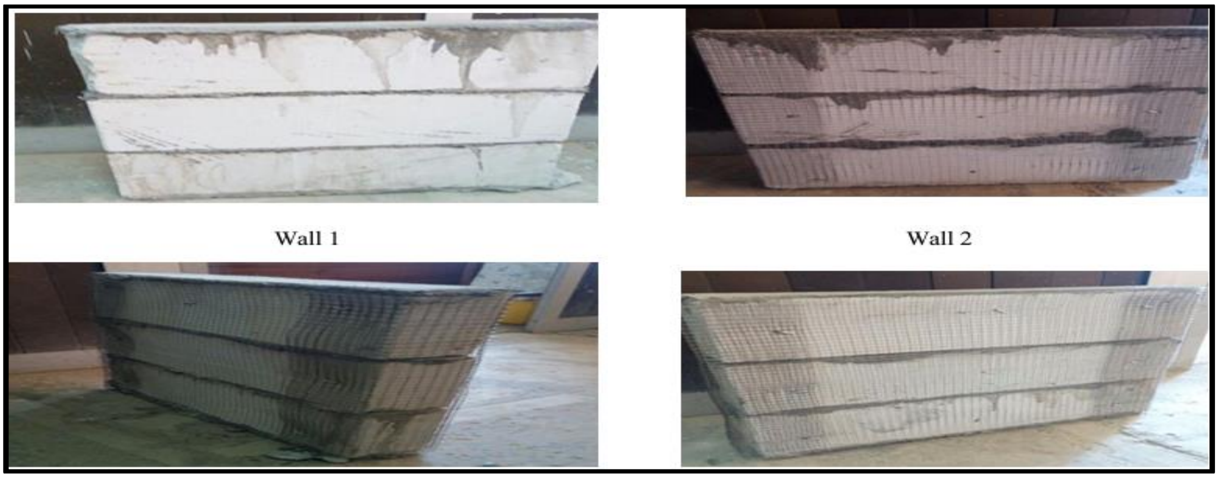

Figure 14. Wall construction from ferrocement panels (Rifaie et al., 2014)

Figure 15. Some views of structures produced with ferrocement (URL– 4, 2023)

Buildings constructed with ferrocement walls can incorporate various sustainable features such as wind turbines, solar energy panels, solar water heaters, and other materials, as depicted in Figure 16. Ferrocement kaique were also produced at Eskişehir Osmangazi University and floated in the Porsuk River (Figure 16).

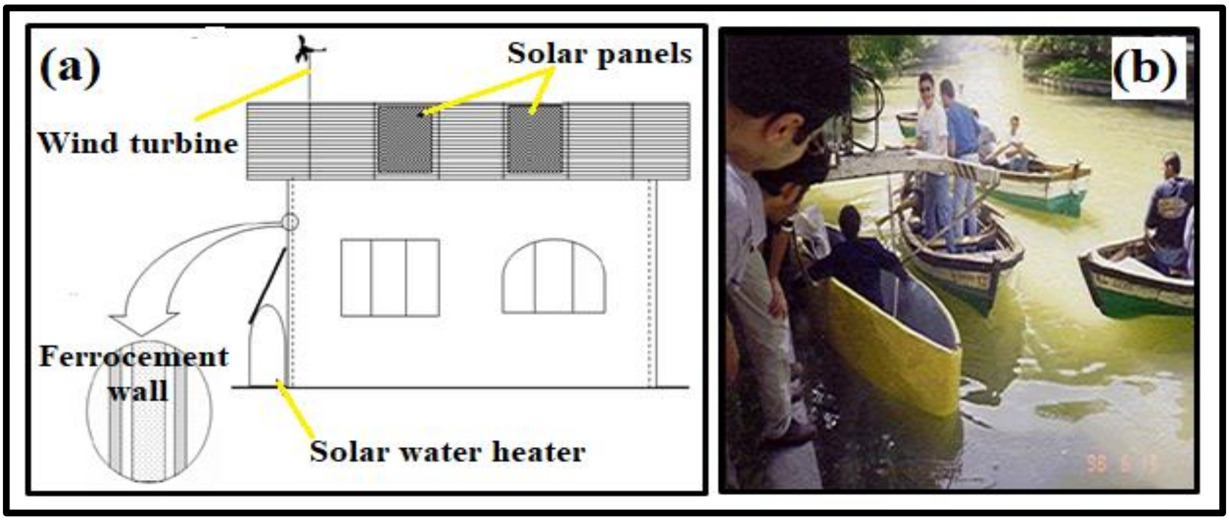

Figure 16. Proposal for the possibility of a- using solar energy or wind energy or both combined (Al-Rifaie et al., 2014) and b- ferrocement kaique (Topçu, 2006)

The increasing demand for technology enables scientists to benefit from alternative developments. Today, cement-based mortar and concrete can be produced using 3D printers. The use of 3D printers also minimizes workmanship errors. Burger et al. (2022) produced ferrocement panels using 3D technology (Figure 17).

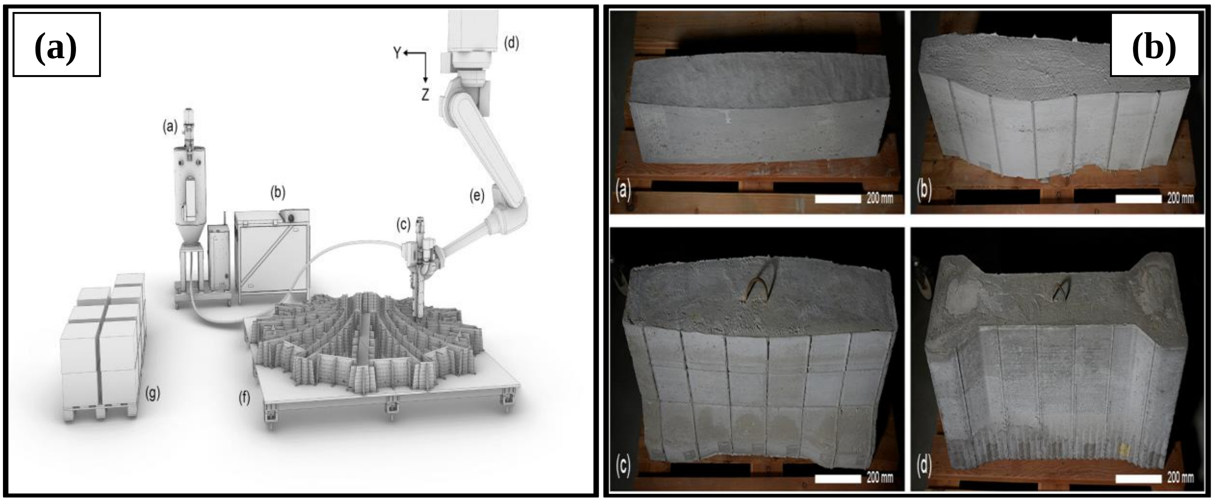

Figure 17. Using 3D printers to produce ferrocement blocks (a- while producing, b- after production) (Burger et al., 2022)

9. Conclusion

In the wake of recent earthquakes worldwide, including those in Turkey, there has been a heightened awareness of the importance of disaster prevention. Consequently, the field of seismic rehabilitation of structures has emerged as a central and essential sector within engineering. But known methods are not only difficult to apply but also need evacuation of the building. Eco-friendly, cost-effective, and practically applicable seismic retrofitting techniques that do not need evacuation must be found. In this study, using ferrocement panels and ferrocement wires to rehabilitate structural systems by increasing the lateral stiffness of buildings is appropriate from the performance, economy, and easiness of application points of view.

The results obtained in the review are summarized as below;

- Ferrocement panels can reduce the dead load of the building.
- Ferrocement effectively reinforces damaged reinforced concrete elements (columns, beams, etc.).
- The economical and speedy production of ferrocement is an alternative way to those of other strengthening methods.
- Square wire mesh performs much better than chicken wire mesh.
- It was seen that on the 28^{th} day, the flexural strengths of ferrocement panels varied between about 4-4.5 MPa, and their compressive strengths were between about 18-20 MPa.
- The montage must be completed by uniting produced panels with casted linkage elements and using epoxy to the open sections. If required, a layer of wire meshes and casted linkage elements must be increased where critically needed.
- It has been observed that ferrocement can be used for many different purposes (reducing the dead load in buildings, strengthening damaged structural elements, aesthetics, increasing the performance of water pipes, boat construction, installation of renewable energy systems, etc.).

- It has been reported that ferrocement panels can be produced using 3D printers in today's technology.

On February 6th, 2023, an earthquake with a magnitude of 7.8 occurred in the Pazarcık district of Kahramanmaraş province in Turkey. According to the report prepared by the Turkey Ministry of Environment, Urbanization, and Climate Change, approximately 590,250 buildings were slightly damaged, and 45,500 buildings were moderately damaged. Repairing damaged structures cheaply and quickly is critical to the country's economy. In this respect, ferrocement panels are effective in reducing the dead load of the building in new buildings. Furthermore, ferrocements and ferrocement panels offer a means to strengthen damaged structures rapidly and economically. Future endeavors could focus on reducing costs, enhancing ease of application, and improving performance through the utilization of alternative materials and testing methodologies.

Author Contributions

İ. Hocaoğlu: Literature research, Writing – Review & Editing; **İ.B. Topçu:** Literature research, Writing – Review & Editing; **C. Öcal:** Literature research, Writing – Review & Editing

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