Compare Among Methods for Re-Habitation Damaged Concrete Beams-Ferrocement, Steel, FCRP and Nano-Materials Sections

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Abstract. The complicated and costly of concrete structures as well as the exposure to risk, owing to several factors such as ecological, design and construction, has resulted in a wide variety of methods for residential concrete structures, such as ferrocement sections technology, steel section technology, FCRP technology, and nano-material technologies. In this article the four approaches employed for rehabilitation of damaged concrete were compared. The questionnaire is given to 100 construction engineers and project management professionals to determine their preferred methods and advise them on their strength, effort, time and cost. To confirm the results, the researcher conducted an experiment to compare among these methods. research result, recommendations for future research, and conclusions were discussed in detail.

Keywords: construction, re-habitation, ferrocement, steel section, (FCRP), nano-materials

1. Introduction

The concrete constructions at danger as a consequence of natural earthquakes and storms or as a result of an exposure to shock loads may have been mistaken or misfunctioning throughout the design, as if some of the concrete parts were not armed enough to withstand the stress that. [1]. A decreased enhancement due to rust and corrosion or a change of purpose and greater service loads to its structure can lead to failure of concrete buildings. [2].

Increasing the dimensions of the members' sections has been the means of increasing the efficiency of reinforced concrete members, as this method works to strengthen the concrete elements and to increase their stamina, but at the same time affects the dimensions of space, especially in the case of deep bridges, which led to resorting to other means, such as increasing the number of supports on which the thresholds are based, or increasing the proportion of reinforcement in the concrete section, or shortening the space for concrete roofs, or the use of pre-voltage reinforcement [3]. In contemporary times there were numerous techniques shown to reinforce and consolidate damaged concrete instead of rehabilitating the concrete structure. The following approaches may be divided into three groups:

1. Injection into cracks, voids, or honey-combed areas.
2. Surface treatment
3. Removal and replacement of defective or damaged material/area.

Restoration and strengthening of concrete members The restoration and protection of concrete structures primarily mean carrying out the necessary repairs and modifications to the basic structural elements (such as foundations, retaining walls, columns, thresholds, and load-bearing walls) in order to increase
their bearing strength to withstand the stresses that the concrete structure will be subjected to with sufficient safety consistent with what was mentioned in standard specifications and application rules for the design and implementation of concrete structures [4]. Different between restoration and protection is concrete members: In the case of defects of the structural elements, which reduce the resistance of these elements to stresses to which the structure is undergoing, the concrete structures will be restored. In this case, the structural elements should be repaired accordingly, in order to return their original condition. Cases for restoration of concrete buildings:

- The occurrence of various cracks in the concrete elements, and these cracks may widen and reach a complete collapse of the concrete element.
- Steel reinforcement steel.
- Unauthorized denting of concrete columns.
- Column's slope
- A decline in the bases and foundations.
- Corrosion occurs in concrete surfaces as a result of exposure to water, chemicals, or friction factors [4].

While, the concrete structures are strengthened to increase the efficiency of concrete elements due to their exposure to loads greater than the loads that these elements bear with sufficient safety and not because of the presence of apparent defects in these elements such as cracks, iron rust, or others [5].

The reasons for using strengthening concrete structures:

- Discovery of errors in the structural design after completion of implementation.
- Discovery of defects in the materials used that affect the quality of concrete.
- The desire to increase the efficiency of the structural elements after the completion of the implementation to make adjustments in the building such as increasing the height or changing its uses.
- Detection of building exposure to loads not taken into account in the design.

Several approaches for the treatment and rehabilitation of damaged concrete structures have been identified in research and studies:

- Fixing steel sheets to the outer surface of the concrete structure using epoxy to increase its resistance.
- Fixing steel sheets to the outer surface of the concrete structure using screws to increase its resistance.
- Cover the damaged concrete with additional concrete with or without linear or transverse reinforcing steel.
- The use of pre-tensioned concrete members with strings that have a high bearing capacity.
- Cover the concrete with ferrocement (which is a cement and sand mortar with iron grates), affixed to the concrete surface using epoxy or screws or both[6].
- Cover the concrete with fiber carbon-reinforced polymer (FCRP), affixed to the concrete surface using epoxy or screws or both.[5]
- Cover the concrete with nano-materials, affixed to the concrete surface using epoxy or screws or both.[7]

The research compares four approaches in time, effort, strength and cost for rehabilitating damaged concrete. Those methods are the technology of ferrocement sections, the technology of steel sections, the technology of fiber carbon-reinforced polymer (FCRP), the technology of nano-materials all these methods are included in the surface treatment group using epoxy and screw [8].

Ferrocement sections technique: Ferrocement layers are used for reinforcement or repair on damaged concrete beams. It removes the concrete cover, thereby increasing the surface roughness. Filtering dowels with enough embedded length are drilled into the concrete. The pieces of the steel mesh encircle the specimen, and cement mortar is put on the layer. The cast layer will be cured until full configuration is guaranteed. For each layer of ferrocement, the process is repeated. Finally a washer is attached to the threaded dowels that combine all the layers of ferrocement. In 2005 masoode et.al they undertook a practical study to show the extent of the effect of encapsulating reinforced concrete thresholds with ferrocement material, taking into account all elements that have a clear effect on the properties of the
virus, namely the number of lattice layers, the thickness of the ferrocement layer, the shape of the ferrocement packaging, the amount of structural iron, the effect of its distribution, fixation and bearing cement mortar, the nature of the surface between the reinforced concrete and the ferrosement element, they found the reinforced concrete thresholds strength increase eight times the original strength [9, 6]. The technology of steel sections: This method is done in two steps, the first is to prepare the iron section, clean the surface of the concrete and paint it with epoxy. The second step is to attach the iron sections to the damaged concrete surface and fasten using epoxy and screws. According to M. Alhassani .2013 he used the steel sheets to rehabilitate the damaged concrete sills, as he used two methods, the first method was to paste the steel sheets on the concrete surface with epoxy, while the second method is to install the steel plates by screws, where it was found that the strength of the concrete increased by 10 times the regular concrete and found that the method of adhering the iron to the concrete surface Better than the way it is attached to the bolts, as the screw creates a hole inside the concrete, which reduces its resistance [10]. The technology of Fiber Carbon Reinforced Polymer (FCRP): In the first process, the beam surface is broken and the external weak surface of the concrete may be removed. This beam grinding method is performed with a flap disk, then wash the area repaired with acetone, before applying a resin coating to the surface. Just before applying FRP materials, the surface is cleaned with acetone. This is because the hardened primer has to be removed from the carbonization layer. Secondly, The surface of the one layer of epoxy and a layer of FRP material were painted. a further layer of resin was painted on the face of the preceding layer before applying the second layer of FRP. In 2007 Ali [11] conducted a study to see the effect of polymer fiber adhesion on the strength and resistance of reinforced concrete, where they found that it increases the resistance of reinforced concrete by 23% higher than that of ordinary concrete [12]. Technology of nano-materials: This method is done by covering the damaged concrete section with a mixture of nanomaterials and an iron clip and leaving it for 28 days. In 2017 Wail Nourildean et.al [13] experimented to rehabilitate reinforced concrete thresholds using nanomaterials, where they used methacoline to create nanoparticles fixed to the surface of the damaged concrete, Furned Silica, and Superplasticizers to fill cracks in the damaged concrete, where they found that the resistance of concrete thresholds increased 80% of the resistance of ordinary concrete.

2. Objectives
The mean Objectives for this study:

- Knowing the opinion of professional engineers and project managers regarding the rehabilitation of concrete thresholds and their utility.
- Comparing among four methods used to re-habitation damaged concrete.
- Evaluate the result got it from the questioner.

3. Methodology
The purpose of using surveys was to collect detailed and factual information that describes an existing phenomenon. From a review of literature, a survey questionnaire was developed to collect data for the study the primary data was collected through this form of a questionnaire and was distributed to the target employees by google form. After that, the results were further analyzed using the descriptive statistical analysis method. The result are confirm by conducted an experiment to compare among these methods to find the best method to use. The google form was distributed to 100 professional engineers in the field of construction and project management in Iraq. 8 reinforced concrete beams (2200x200x150 mm) were cast and tested under point load at mid-span to limit the failure. Then tested thise beams after repairing it by using several re-habitation techniques. these methods are: Ferrocement section, steel plate, fiber carbon reinforced polymer (FCRP) and nano cement section.

4. Result and Discussion

4.1. Background Information
The background data on the participants should be displayed with diagrams to present the results before analyzing the data. Diagram 1&2 shows that 65% of construction engineers, 35% of the project managers, and 25% of those with more than 20 years' experience, and 30% of those aged 15 to 20 to 10 to 15 years, which means that a study dependent on professional engineers has a strong experience.

![Figure 1. Profession statistic](image1)

![Figure 2. Experience statistic](image2)

4.2. **Experience and perspective on concrete beam rehabilitation**

All research sample agreed to use methods of rehabilitating damaged concrete in Iraq because most of the buildings in Iraq are old and date back to the eighties and it is already dilapidated and in need of rehabilitation in addition to the fact that more than half of the buildings have changed their purpose and increased the loads imposed on it to double the intended load and increase use it that agrees with frank,2018 says most Iraqi buildings need to rehabilitating, this is because of it old and the change in the main purpose for which it was established, and consequently the increase in the imposed loads [14]. Of 100 participants there was 85% of them already use methods of rehabilitation of the concrete. The research sample agreed that choosing the appropriate method for the rehabilitation of the damaged concrete depends on the type of damage affected and maybe need one or more methods to fix it, in the case we assume similarity of the damage in concrete and the conditions exposed to it [15].

4.3. **Compare among four methods in term of time, effort, cost, and strength**

Research sample confirmed the time should take to the rehabilitation of the 8 reinforced concrete beams (2200x200x150 mm) using Ferrocement sections technique fixed by epoxy and screws around between (31-40) days, while the duration was (1-10) days when using both Technology of steel sections and Fiber Carbon Reinforced Polymer (FCRP), while ranged between (21-30) days using Technology of nano-materials. This due because the time it takes for the epoxy to dry is about 7 days, while the concrete needs to dry 28 days, this is for the Ferrocement sections technique, while steel sections and Fiber Carbon Reinforced Polymer (FCRP), the time it takes to install is approximately one day because it is ready and needs time for the epoxy to dry only, nanoparticles sections need 21 days to prepare and 7 days to dry the epoxy [13] figure 3. 60% of responding agree the effort exerted to rehabilitate a concrete threshold using Technology of steel sections is less than the effort exerted to qualify the same threshold by using Fiber Carbon Reinforced Polymer (FCRP), Ferrocement sections technique and Technology of nano-materials respectively, and this result is consistent with the result of the previous question, as the fixing of steel sections on the surface of concrete requires less time than its counterparts, and therefore It needs less effort, While 25% of them emphasizes that the Fiber Carbon Reinforced Polymer (FCRP) requires less effort than Technology of steel sections, due to the ease of use of carbon clips and
attaching them to the concrete surface in figure 4 can see the responding answer about the effort [16, 20].

**Figure 3.** Explain the time required for the rehabilitation of concrete beams by various methods

**Figure 4.** The responding answer about the effort required to rehabilitate the concrete beams

When asked the research sample about the strength of the concrete beams after rehabilitating them by the aforementioned methods, they confirmed that the strength of the concrete beams had increased after rehabilitation to reach twice the strength before rehabilitation and the order was as follows: 55% said the first rank was steel sections, followed by Fiber Carbon Reinforced Polymer, then ferrocement sections, and then nano-materials, 30%. Fiber Carbon Reinforced Polymer, and then steel sections, ferrocement sections, then nano-materials, while 15% were in the order of ferrocement sections, and then steel sections, Fiber Carbon Reinforced Polymer and finally nano-materials sections [17]. In term
cost figure 5 the research sample confirmed that the lowest cost of rehabilitating the concrete thresholds was using nano-materials sections and then ferrocement sections, steel sections, and finally Fiber Carbon Reinforced Polymer. This is consistent with Al-Rifaie et al. (2017), where it has been proven by practical experience that the cost of rehabilitating 8 concrete thresholds with dimensions (2000 * 200 * 150) mm using nano-materials sections was $55, $60 for ferrocement sections, $61 for steel sections and $80 Fiber Carbon Reinforced Polymer [13].

The answer of the sample about the mechanism of fixing on the concrete surface confirmed the use of the epoxy method with the bolts in the case of steel, ferrocement, and nano-materials because the strength of adhesion with the concrete surface using epoxy was small compared to the adhesion strength of the carbon sections with the concrete surface while using the bolts it makes a hole in Concrete is more damaging and increases failure due to bending strength that agrees with Wail Nourildean et.al[13] a prove with practical experience that the adhesion strength of steel, ferrocement, and nano-materials sections with the concrete surface is less than the adhesion strength of carbon sections [18].

5. Experimental Program

Eight 150x200x2200 mm beams were built in reinforced concrete. The design was designed to prevent shear failure in which four bars (12 mm in diameter), 2-bars on the top and 2-bars on the bottom of the 10 mm diameter cross section were strengthened with stirrups of 250 mm c/c. Firstly, the beams have been loaded before failure and a first crack and final load have been recorded. Secondly, rehabilitate the damaged beams with four methods of repairing Fiber Carbon Reinforced Polymer, ferrocement, steel and nano-materials sections. The first crack and final load have been recorded after repair. All tested beams were cast by 1:1.5:3 (cement/fine aggregate/rough aggregate) respectively with ratio 0.4 water/cement. A solid compressive concrete cube of 32 n/mm2 was built at 28 days of cure as per B.S. 116:1989. The beams have been tested for failure load in the Mid-span of a Universal Testing Machine. After that, the concrete beams were rehabilitated by the aforementioned methods, the sections were fixed to the damaged concrete surface using epoxy and screws. Table (1) shows the comparative of all the eight beams distressed by ultimate load before and after rehabilitated, the time taken to repair it and the cost of rehabilitation.
Table 1. Explain First cracking load, Ultimate load (after and before repair), time and cost need it to repair

| Rehabilitation methods          | First cracking load (Fcr), kN before repair | First cracking load (Fcr), kN after repair | Ultimate load (Fult., kN) before repair | Ultimate load (Fult., kN) after repair | Time need to repair (day) | Cost need to repair ($) |
|---------------------------------|-------------------------------------------|-------------------------------------------|----------------------------------------|--------------------------------------|--------------------------|-------------------------|
| Steel sections                  | 15.3                                      | 16.1                                      | 51                                     | 53                                   | 5                        | 45                      |
| Ferrocement sections            | 14                                        | 14.4                                      | 50                                     | 52                                   | 35                       | 33                      |
| Fiber Carbon Reinforced Polymer sections | 15                                        | 13                                       | 49                                     | 50                                   | 8                        | 100                     |
| nano-materials sections         | 12                                        | 11                                       | 51                                     | 52                                   | 34                       | 40                      |

6. Conclusion

From the result, can conclude there is a different method that can use to re-habitation reinforce concert beams damage depend on types the damage some of them need more than one method to fix. All of the aforementioned methods give us good strength to the concrete beams that exceed its strength before rehabilitation, and it also requires effort to apply it correctly on the concrete surface. The difference between these methods lies in time and cost. From the results that we have previously presented, can find the least time of these methods is steel sections and Fiber Carbon Reinforced Polymer sections, so the comparison between them is through the cost, where the cost of beams rehabilitation using iron is one-third of the amount of rehabilitation using carbon, so we note the steel section technique gives good strength in a short time and is preferred by more than half of the sample because they have the practical experience to apply it in the ground, while only 10% prefer nanotechnology despite the low cost and good strength that it gives. From this, we conclude that professional engineers prefer to use the methods that they have already used this is because of the ease of its application and the teaching of new engineers to implement. We recommend conducting more workshops and practical research to raise awareness about modern methods that may be giving better results than its predecessors, but because of poor knowledge of them.

7. References

[1] Q. 1- Ye, L., Yue, Q., Zhao, S., and Li, “Shear Strength of Reinforced Concrete Columns Strengthened with Carbon-Fiber- Reinforced Plastic Sheet,” J. Struct. Eng. , vol. 128, no. 128,
pp. 127–134, 2002.

[2] H. Yue-lin, W. Jong-hwei, Y. Tsong, H. Chien-hsing, and L. Yiching, “Strengthening reinforced concrete beams using prestressed glass fiber-reinforced polymer—Part I: Experimental study,” *J. Zhejiang Univ. A*, vol. 6, no. 3, pp. 166–174, 2005.

[3] L. C. Bank, A. J. Lamanna, J. C. Ray, and G. I. Velazquez, “Rapid strengthening of reinforced concrete beams with mechanically fastened, fiber-reinforced polymeric composite materials,” WISCONSIN UNIV-MADISON DEPT OF CIVIL AND ENVIRONMENTAL ENGINEERING, 2002.

[4] M. Rashidi, E. Ancich, M. Ghodrat, and P. Buckley, “Review of the most common repair techniques for reinforced concrete structures in coastal areas,” in *Proceedings of the IABSE Conference: Engineering the Developing World*, April 25-27 2018, Kuala Lumpur, Malaysia, 2018, pp. 370–377.

[5] S. K. Sharma, S. Kumar, N. Kumar, and M. V. B. Rao, “Rehabilitation of Damaged Reinforced Concrete Beams using GFRP Plates,” 2001.

[6] A. El-Abd, I. Shabaan, and O. A. Seoud, “Using Ferrocement in Repair and Strengthening of Corner Beam-Column Joints subjected to Displacement Cyclic Loading.”

[7] A. Marla, U. CELEP, C. TÜZÜN, and R. GREEN, “TEACHING STRUCTURAL HAZARDS AWARENESS FOR PREPAREDNESS AND COMMUNITY RESPONSE.”

[8] T. M. Alguhane, A. H. Khalil, M. N. Fayed, and A. M. Ismail, “Seismic assessment of old existing RC buildings with masonry infill in Madinah as per ASCE,” *Int. J. Civ., Environ., Struct., Constr. Archit. Eng.*, vol. 9, no. 1, pp. 52–63, 2015.

[9] A. Masood, M. Arif, S. Akhtar, and M. Haquie, “Rehabilitation of RC and FRC beams by ferrocement- an experimental investigation,” *J. Struct. Eng.*, vol. 31, no. 4, pp. 321–326, 2005.

[10] P. Alagusundaramoorthy, I. E. Harik, and C. C. Choo, “Flexural Behavior of R/C Beams Strengthened with CFRP Sheets or Fabric,” 2002.

[11] D. D. Ali, “Experimental And Theoretical Investigation Of The Behavior Of Reinforced Concrete Beams Strengthened By Fiber Reinforced Polymer.” Ph. D. Thesis, University of Baghdad, Iraq, 2007.

[12] N. Naveeena and M. Ranjitham, “Numerical study on retrofitting of beam column joint strengthened with CFRP,” *Int. Res. J. Eng. Technol.(IRJET)*, vol. 3, pp. 914–920, 2016.

[13] W. N. Al-Rifaie, N. N. Ismaeel, and H. Riyad, “Rehabilitation of Damaged Reinforced Concrete Beams,” *IOSR J. Mech. Civ. Eng.*, vol. 14, no. 6, pp. 58–70, 2017.

[14] F. R. Gunter, “Rebuilding Iraq’s public works infrastructure following the defeat of ISIS,” *Foreign Policy Res. Inst. Progr. Middle East*, 2018.

[15] K. F. Sarsam and A. F. Izzet, “Retrofit of Shear Critical RC Beams with Carbon Fiber Reinforced
Polymers (CFRP),” *Eng. Technol. J.*, vol. 27, no. 12, 2009.

[16] S. A. Ahmed, “Experimental Evaluation of Repairing Techniques for Holes Made in Reinforced Concrete Columns for Core Tests,” *ZANCO J. Pure Appl. Sci.*, vol. 28, no. 5, pp. 8–18, 2016.

[17] Y. M. Alharmoosh-Alqenai, “Evaluating the properties and functionality of steel fiber reinforced concrete,” 2018.

[18] A.-H. S. Al-Nassar, “An Archaeological Examination of Economic Inequality as Seen in Domestic Early Islamic Housing in Rural Southern Iraq.” The Graduate School, Stony Brook University: Stony Brook, NY., 2017.

[19] C. PADMAKAR, “Master of Technology.” JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA, 2018.

[20] Singh, H., Singh, J., Sharma, S., Dwivedi, S. P., & Obaid, A. (2021). Comparative Performance of Copper, Graphite, Brass and Aluminium/Graphite- Based Different Tool Electrodes for Optimizing the Material Removal Rate during Die-Sinking EDM of Stir-Casted, Al6061/SiC-MMCs for Sustainable Manufacturing and Energy Applicatio. Journal of Green Engineering, 11(1), 922-938.