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Various methods for retrofitting prestressed concrete members: A critical review

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ABSTRACT

Structures of a building can get exposed to adverse conditions resulting from overloading situations, which would eventually contribute to massive building degradation. The choice to repair the building structures seems to be very costly. The possible step that could be taken is by implementing a method of reinforcing and strengthening the building structures. For the past years, strengthening methods by implementing various innovative technologies has been seen to become a modern scientific topic in the fields of environmental and civil engineering study. Previous related studies on the reinforcement of pre-stressed concrete beams (PSC) by adding different elements have been observed by past researchers. The tests were carried out to evaluate the shear and flexural capacities of the building structures after the mechanisms were installed. A large number of scholars have conducted such studies with different types of interacting factors. In this study, a review will be presented by analyzing various techniques that have been implemented by multiple researchers for strengthening pre-stressed concrete beams, as well as their shear and flexure performances of the beams.

Keywords: Pre-stressed concrete beams (PSC), Shear, Flexure, Strengthening

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1. Introduction

Building construction and maintenance cost enormous amounts of money for businesses and developers all over the world. Bridges, housing systems, school facilities, stadiums, and sewer systems are only a few facets of infrastructure that have been designed to last for a prolonged period. These facilities were usually constructed of buildings made of precast pre-stressed concrete materials. However, many causes, primarily environmental circumstances, lack of pre-stressing, corrosions and crashes, and the rising volume of load affected by the construction materials, may affect the durability of these structures. Much of the cases, demolish and rebuild the damaged facilities is not the right choice to follow because the fees might be the top consideration. Other causes that contribute to girder damage may include unsafe storage, treatment, and transportation of materials or building structures. Fractures and beam malfunctions caused by unsafe treatment will necessitate repairing such structures, increasing the cost of reconstruction. As a result, more people have chosen to straighten and renovate their systems, believing that this solution would save them money over the method of reconstruction. Construction management must find a safer, more dependable way to reconstruct the beams on the worksites instead of passing the beams to the production facilities. Many steps should be taken to ensure that the girders can be reinforced or retrofitted in order to recover flexibility and strength [1]. Concrete systems have high compressive strength but a low-tension strength. The tension strength could range between 8% and 14% of the compression potential. Since the stress potential is limited, concrete members are more susceptible to induce flexural fractures during the early stages of development. A hollow or irregular force is exerted in the lateral axis of the beam system to minimize or prevent the formation of these fractures. This force eliminates crack formation through the process of removing or severely decreasing strain pressures at the crucial location and supporting sections at the applied mounting, thus improving the structures' stretching, shearing, and compressive strengths. In terms of tensile strength, the pieces are likely to perform admirably. While all stresses are applied to the structure, the whole compression power of the concrete can be used comfortably across the whole width of the concrete sections [2]. The development of effective pre-stressing methods is undeniably a significant advancement for the field of study that concerns concrete structures. It made it possible for precast concrete to compete in industries previously dominated by synthetic structures, such as long bridges, rising construction building systems, as well as naval bases. Pre-stressing, and more broadly, post-tensioning, has become a well-established approach that enables functional, low-cost, and advanced models to perform a wide range of tasks. The difference among partly and fully PSC beams is referred to as an acceptable strain. Fully pre-stressing is defined as eliminating tension stresses in large structures or allowing for limited load stresses, which may solely be handled by concrete, while partly pre-stressing allows for more significant pressure in concrete and cracks under higher loadings [3].

2. The use of FRP laminates to improve shear and flexure conditions in PSC

Polymers of Fiber-reinforced have many advantages over conventional reinforcement methods due to the lightweight properties, higher tensile attributes, damage tolerance (e.g., against corrosions), reliability, and convenience of management and upkeep. As a result, they were used to reinforce a couple of large bridge systems [4]. FRPs have a greater resilience proportion, a higher stiffness-to-weight proportion, structural stability, anti-corrosion, high tensile strength, and ease of use. Many researchers have experimented with the management of FRP sheets attached to concrete beams. The adhesive that is joined to the fiber-reinforced polymers has proven to be a viable option for a variety of concrete structures, including pillars, walls, bricks, and ceilings. FRP materials are frequently being used for external reinforcement of structural materials since they are anticorrosive, not magnetic, and resilient to different types of pollutants. Externally bonded carbon fiber-reinforced polymers (CFRP) may be incorporated to improve the ductility, shear, and flexure ability of re strengthened concrete beams. Flexible glass fiber plates have been proved to be extremely efficient for reinforcing pre stressed concrete beams since they can be very dynamic, easy to handle, and easy in application, as well as their high tensile strength-weight ratio and strength. The implementation of fiber-reinforced polymers (FRPs) for the restoration of the current reinforced concrete materials has increased dramatically over the past decades. According to the study, FRP may be very effective in reinforcing concrete beams that are poor in flexural strength, low in tensile stress, and deformation. FRP is a composite material that is made up of high power carbon, aramid, or fiberglass in a polymeric matrix, with the fibers serving as the primary load-carrying component [5]. Summary of the failure of PSC beams strengthened by CFRP as shown in figure (1). Kang and Ary (2012) led experimental research to show the impact of using strips of CFRP to enhance the concrete cumulative properties. The sampling contained 2 beams “pre-stressed” in the shape of “I-shaped beams” with the inclusion of the sheets of CFRP in U shape and steel I-beam supported to it with no presence of the sheets of CFRP. The analysis indicates when the distance is less than 50% of the maximum load of the “Pre-stressed Beams”, beams total shear strength increased with the reinforcement of CFRP sheets compared to the beams without it. While it must be noted that the distance of the sheets used to reinforce the component should be taken into account, higher length intervals that are half the efficient depths would not be able to boost the shear capacity of the reinforced concrete beams. In terms of the shear capacity of the beams, the length in between that is shorter than the effective ranges would yield a good result. The distance would increase capacity of shear up to 38% relative to the initial capacity, and it has also been seen to boost the durability of the reinforced beams by 28%. More in-depth research is also needed to integrate CFRP sheets into uneven concrete beams and develop an improved technique to integrate them into the sheets, mainly in more hard condition like the inside of irregular structures. Antonopoulus struggled to obtain an excellent total estimate of the reinforcement of the CFRP sheets because they had fragments of CFRP sheets in the process and were unable to provide the resolution to measure the uneven plates of the fragments on the inspected “pre-stressed concrete I-beams” [6]. Wu et al. (2003) studied the reinforcing systems when adding externally bound “Polypara-phenylene-Benzo-bis-Oxazole” (PBO) “fiber reinforced polymers” (PFRPs). Some 6 girders have been examined for shear and flexural capabilities when pre-stressed with an external and internal reinforcing scheme. Every girder length of “10m” and 1 m depth. The testing procedure was then carried out to assess the pre-stressed concrete girders' reinforcing effects on their workload capability, stability strength, durability, and resistance to fracture breaking [7]. Reed and Peterman (2004) conducted a study in which sheets of CFRPs were incorporated to enhance the flexural and shear efficiency of girders’ bridge in the armed pre-stressed concrete bridges. 3 specimens tested were collected from overload bridges were examined, each with a length of “12.2 m”, and depth of 0.585 cm, and have a thickness of 12.7 cm. The thickness of the flange was measured to be 0.127 m. The overall number of samples was three, two of which were reinforced and set, one of which was not. All three were then analyzed to check their failure mode in order to evaluate their flexural and shear efficiency. The final results revealed that the two analyses that were reinforced and fixed implemented a greater flexural capacity by up to 20%, whilst the one that was not strengthened acted as the study's test group [8]. Larson et al. (2005) performed an experimental analysis on pre-tensioned and pre-stressed T-shaped concrete beams to determine their strength to pre-stress strands load under specific conditions. The test was carried out by employing a few techniques, such as breaking the beams, reinforcing the beams with FRP carbons, and essentially increasing the number of the load to analyze their strength to tolerate live load when in a fatigue setting. The beams were originally broken to examine their stress capability at the above-fragmented parts [9]. Casadei et al. (2005) studies on control samples in order to analyze the flexural efficiency of the PC's double T-beams with a length of 4.66 m. Steel reinforced polymers (SRP) composite materials were used to stabilize the beams. In the epoxy resin, the SRP was linked with more vital steel strings. The results indicate defects in three beams used throughout the investigation: the control beam, another beam reinforced by just one ply of SRP, and a third beam reinforced by two plies of SRP secured on both sides of its end. The previous study has shown that a similar method can be implemented to bind fiber reinforced polymer (FRP) with SPR externally. The ending results indicate that it can usually increase the flexure of concrete beams. This is attributed to the fact that end anchors' involvement at the SRP U-beams is a crucial step to avoid complete separation if de bonding happens at the concrete SRP interfaces. The SRP and FRP are almost comparable in that they are both simple to mount on beams, but weight is one of the key points that has to be considered when choosing resin systems for overhead applications. The epoxy resin is notable because it is effective at “bonding the steel tape to the concrete beams” [10]. Ghasemi et al. (2016) investigated the flexural properties of constant unbounded post-tensioned HSC beams stabilized with carbon-fibre reinforced plastics CFZRP. Seven samples were used in the evaluation, comprising of six retrofitted continuous beams (2-span) HSC beams “unbounded post-tensioned”. These beams are 0.015 m wide, 2.5 m tall, and 3.3 m long, with 0.006 m retrofitted on both sides the negatively and positively by internally near-surface and outside bonded strengthening EBR installed practices NSM to guarantee beam control by prevent supporting one beam. This would also contribute to lessening the chances of loss at the de bonding end in specimens that have been upgraded using the EBR method. The project results show that CPR reinforcement could increase the operation and requirements of continuously unbounded post-tension concrete beams. It has been demonstrated that the EBR procedure does not seem to be effective than the NSM procedure, especially in the creation of fractures and in the presence of higher load. The fracturing loads of the reinforced beams tend to raise more than those of the control beam. It is demonstrated that the resulting loads that will cause the crack diameter to increase due to beam reinforcement may increase. It is marginally stronger for increasing beam loads reinforced using the NSM procedure than for strengthening beams using the EBR procedure. The existence of an externally bonded reinstallation may improve flexural strength, particularly if the beams lose bonds. It may also reduce strain un bonding in the output state by increasing fracturing weights, lowering the number of fracturing widths, and lowering beam deformation at the applied load to the FRP implementation. The beam reinforcement with CFRP reduces the displacement ratio of the fortified components in general. Thus, the use of CFRP laminates would inevitably reduce the transfer ratio at the core of the reinforcement from “38.15% to -7.91% and from “-22.89% to 4.74%” at the shear span for fortified and unreinforced beams [11]. Afefy et al (2016) conducted studies on actual pre stressed and pre-fabricated “double-tee concrete beams” and reconfigured them with CFRP sheets which were externally bonded. The plates of CFFP were used to adjust “3 pre-cast pre-tensioned double-tee DT” girders with different grades of degradation in this analysis. The girder stems have been supported in flexure utilizing nonlinear U-shaped CFRP plates, and all of the other girders were reinforced at the mark poles at the very same time. Each girder was gradually flexure up to the point of failure. However, at each load applied, the girder deflection and ongoing stresses created on both the concrete and CFRP sheets were reported. Three full-scale pre-tensioned double-tee girders were identified to be pre-cracked due to poor transport and delivery. It was later an impedance to CFRP systems. U-shaped CFRP plates were used to stabilize two girders in flexural strength at the center portion. The other three remaining girders have been supported in tensile stress at the end with plates of CFRP. A CFRP-enforcing design for each girder was added to regain lost power, due to the measurements of the concrete of the girders, the internal shear strengthening, and the internal pre stressing strands. Experiment findings validated the effectiveness of the adopted strengthening method in terms of final capacity and longevity. The modified girders intensity of flexural and shear was 60% higher than the measurements feasible in the declared specifications. When the CFRP identifiers were introduced to the girders, their productivity increased. This is demonstrated by the exclusion of cracks in the CFRP sheets when subjected to full load. However, if fractures continue to occur, the situation will be simplified because the formed strains will be unable to stretch to one-half of the fracturing strains. Furthermore, one of the most common reviews made by previous experiments was on the failure of CFRP sheets to retain strong durability, even though this research eventually showed that durability would dramatically increase from reinforcing sheets of CFRP [1]. Truong et al. (2018) investigated the flexural efficiency T-beams (UPCs). CFRP sheets have externally stabilized under the static rate of loads given to it with and without U-strip CFRP anchoring systems. In the dimension of the sample beams, there are nine UPC T-beams with thicknesses of 0.36 m, widths of 0.2 m, lengths of 6 m, and spans of 5.6 m. One unreinforced beam act as a control specimen, and eight beams act as externally reinforced beams with a combination of sheets of CFRP with two, four, and six folds. Two examples of lateral CFRP U-strip anchoring systems were also redesigned to accommodate the shear range. The results showed that rising the flexural stability of CFRP sheets resulted in significant changes. This is up to 37%, which decreased functionality displacement, improved malleability, and diminished fracture diameter by up to 48% of the beams tested. The maximum strain in reinforced UPC T-beam CFRP sheets ranged from 38.7% to 69.3% of the fracture strain of sheets of CFRP and began to decrease as the CFRP sheets' ratio improved. The lateral U-strand anchoring system and CFRP sheets had a substantial influence on stress in reinforced beam bands [12]. Nguyen-minh et. al (2018) investigated the flexural behavior of UPC beams reinforced with CFRP. The explorative inquiry involves nine thick UPC T-beams with heights of 3.6 m, flange widths of 0.2 m, web widths of 0.11 m, rim diameters of 0.9 m, beam lengths of 6 m, and total spans of 5.6 m. They were then fortified with various CFRP sheet components, both with the present and without the anchors which are CFRP U-wrapped. The research analysis showed that using CFRP sheets and CFRP U-wrapped anchors had a substantial effect on the bands' stress. The tensile test, durability of the beams, mid-span displacement and crack width were all improved by FRP. The overall amount of CFRP layers is decreased as efficiency is increased. The structure of Carbon Fiber Reinforced Polymer U-wrapped anchors affected the CFRP pads' friction, the breakup process, and the beam action. The use of sheets of CFRP led to a substantial improvement in UPC beams' flexural strength of, that is 37%. Nonetheless, as the ratio of CFRP sheets rose, this growth began to decrease. The fracturing load was increased by up to 26%, and fracturing widths were reduced to “1.55 and 3.6” times in efficiency, durability, and last state, respectively. Maximum displacement and degradation of the strengthened beams' energy UPC have increased to sixty and one hundred respectively. U-wrapped CFRP anchors and CFRP sheets pose a significant impact on the operation of band. At the comparable peak stress, the pressure descend in armored beams is more significant as comparing to the reference one, averaging from “23% to 50%”. Sheets of CFRP incorporation has increased the average tension ascending for bands from “11% to 18%” for beams without anchors presence and from “25% to 60%” for beams with attached anchors. This increase is proportional to CFRP layers number. CFRP U-wrapped anchors and CFRP sheet proportion controlled the failure process of the UPC beam [13]. Kalfat et al. (2020) conducted analytical research into the implementation of anchorage systems (symmetric fiber patch anchors) to improve FRP sheets' efficacy in strengthening post-tensioned beams for shear tension. A total of three big post-tensioned T-beams with depths of 1.05 m and spans of 5 m were examined. All three samples have been examined in a three-point loading configuration. The unreinforced control beam was allocated to the first sample, while the second sample was reinforced in tensile stress with 0.1 m wide 0.0014 mm thick FRP coatings positioned at 0.3 m centers inside the vital shear band. Whereas the 3rd beam was reinforced with side-bonded FRP sheets and 2 layers of 45° bidirectional fiber patch anchors mounted at every part of the laminate's end. According to the experimented report, the reinforced beams broke at a loading condition that was 32.7% and 19.6% more than the highest demand achieved in the unreinforced samples. The reinforced beams achieved the greatest highest capacity with patch anchors, which was 60.2% and 63.9% greater than the unreinforced sample. The anchors were shown to substantially enhance the participant's shear ability and FRP sheets strain optimization before failing [4].

Figure 1. Summary of the failure of PSC beams strengthened by CFRP [4]

3.1. The method of strengthening of PSC beams with the "near-surface mounted" (NSM)

Near-surface mounted techniques have long been used to strengthen concrete beams in the built environment. This method integrates using "Epoxy Resins" as an adhesive type within FRP implementation, where the adhesive was utilized to bind the bars of FRP or in the pre-cut grooves coating at the surfaces of the concrete. Grooves work as a reinforcing technique, particularly in their capacity flexure on tensile structures of reinforced concrete sampling. The incorporation could help with shear reinforcement on the concrete beams' edges. Approximately 50% of the groove is crammed with epoxy resins which act as an adhesive, and the composites of FRP were to be placed into the grooves [14]. Figure (2) shown the failure mode of PSC strengthening by NSM. Kuntal, Chellapandian, and Prakash (2017) investigated the feasibility of various NSM strengthening methods to enhance the flexure and shear performance of PSC beams by integrating CFRPs sheets. The evaluation employs a number of twelve samples, in which a few of them have been incorporated into the established reinforcing procedure. Some were denied it; particularly, half were given suspenders, whereas the other half were not given. Every beam was 0.018 m long, with a 0.0165 m gap between them. They were assessed for flexure and shear capacity after the combination with the reinforcing process. The findings revealed that adding NSM strengthening strands to pre-stressed concrete beams improves their tensile stress and shear power, in which both of them were incorporated with and without the need for CFRP stirrups. The combination of NSM and CFRP laminations adds more convincing durability to concrete beams in an effective method due to they can evade the shear fractures growth. Control beamed with no strengthened and stirrups with CFR sheets showed a substantial incremental increase, with the power increasing by up to 15%. The control beams' failure mechanism was based on its state in shear cracks, and fragile is presently occurs among the laminations of CFRP and NSM. The sheets of CFRP stabilized the control beams with no use of current stirrups. They were seen to significantly impact the compressive strength and prevent any breakdown circumstances by up to 52& and 34.4%, respectively. The most advantageous aspect that may be found was that the fragile state was changed to a better result, increasing the durability flexure state [15]. M. Abdullah et al. (2019) demonstrated the way of using steel strips as the classification of pre-stressed NSM will enhance the condition of beams of the concrete. This research was carried out by performing a series of experiments on strengthening pre-stressed beams, each of which has a dimension of 0.15 m width, 0.3 m height, and 3.3 m length. The efficient period is 3 m, and the sheer productivity and efficiency are 1.25 m. Everyone was then constructed to be reinforced with "NSM pre-stressed steel strands". The whole of them has been tested, with one beam reinforced to serve as a tested specimen. Although no stresses were applied, one of the beams was reinforced with the NSM steel strand. The rest of the beams (five other beams) were then strengthened by adding tension to them, which ranged from 30%, 40%, 50%, 60%, and 70%, respectively. This technique of strengthening the beams with NSM strands is an efficient means of improving them. This can be studied in which the total efficiency was shown to increase due to the new NHS strengthening process, which aids in dropping the displacements, delaying the presence of any cracks, and reducing the widths of the cracks. In another way to describe this process, incorporating NHS strands into enhancing the compressive strength of the concrete beams improves the flexural strength of the pre-stressed beams at operation and other stages significantly. This has been very well shown by the reinforced beams' capability to offer much greater protection to the beams integrated with greater loading conditions. As contrasted to beams without NHS steel strands, it offers a more stable maximum strength state to the beams from the loads upon it. This research demonstrated the potential of NHS strands to aid in the fulfillment of a greater incentive of the reinforced concrete samples of a house [16].

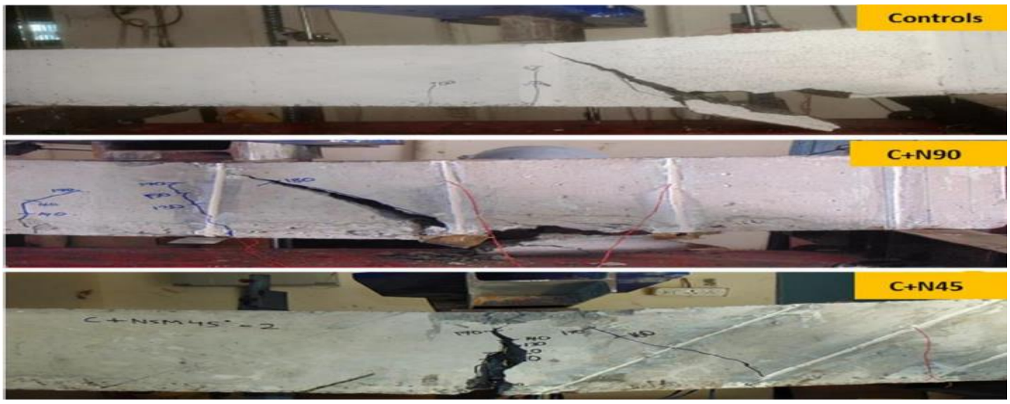

Figure 2.The failure mode of PSC strengthening by NSM [15]

3.2. Externally strengthen pre-stressed concrete beams (PSC) by implementing post-tensioned techniques

Since the 1990s, the process of "external post-tensioned pre-stressing" was used in the domain of beam strengthening. This approach can be applied to build buildings as well as concrete beams for long-span buildings. There are some benefits of implementing the external pre-stressing system over the internal pre-stressing process, the most important of which are the exclusion of any friction failure to the free tendons, the lower cost and better navigation of the materials around in the construction projects, and the ease of handling and configuration with any tendons' alternatives. The criteria for externally post-tensioned strategies are conceptually identical to those for internally post-tensioned strategies. The only distinction between the two approaches is that the first will affect based on the eccentricity change of the tendons and lack of friction caused by the higher diversion of the parts [17]. Figure (3) shown the crack pattern of PSC beam strengthening by the external post-tensioning method. Herbrand and Classesn (2015) designed an experiment to study the way the extra outside pre-stressing affects the ability of shear of consistently PSC beams. 6 shear readings have been combined into 3 continuous PSC beams. Every test had a span of 5.5 m, with an overall length of "11.3 m" for all of them. The research was then continued by assessing the sheer strength of three test beams, with all three tested beams containing "parabolic internal post-tensioning and external pre-stressing variables". Even a minuscule amount of shear reinforcing will be sufficient to ensure the pre-stressed concrete beams' durability. The increased external load was found to have only a minor impact on the systems' overall sheer strength. Nonetheless, the constant load can cause more significant fracturing. This may be increased by doing shear testing depending on the primary tensile stress properties, which may aid in determining the original cracking state. The ultimate analysis culminated in a series of guidelines for implementing the principal tensile stress properties for bridge evaluations, which could be integrated into the German functional evaluation requirements for current bridge structural components. The excellent aspect that may be found was that the fragile state was changed to a better result, increasing the durability flexure state [18]. Allawi (2017) performed research to analyze the state of a full-sized hybrid of reinforced PSC girders when a constant and recurrent load is applied to it. In this project, 4 "full-scale composites pre-stressed of I-shaped girders" with16 m span of were created to measure their capacity in the condition in which continuous load is added to it up until failure mode. As per the study's objectives, two of the girders were reinforced with the pre-stressing process's external strands, whilst the other two were kept unaltered. The compressive strength efficiency of the systems that were reinforced was then found to improve. In the case of the checked concrete girders, the breaking, fracturing, and ultimate conditions were increased up to "17.5%, 125.8%, and 118.1%", accordingly. The reinforced PSC girders' durability factor improved dramatically, as did the overall reliability constraint at the level of control load. Finally, this type of strengthening provides a significant boost to the total concrete girders, yielding a solid outcome under constant loading up to "128.4% and 116%", accordingly, as opposed to the control girder [19].

Figure 3. The crack pattern of PSC beam strengthening by external post-tensioning method [19]

3.3. Strengthen PSC beams by implementing fabric-reinforced cementitious matrix (FRCM) systems

The use of FRCM systems to reinforce concrete structures has newly been introduced in structural engineering as a suitable alternative to fix the issues with FRPs. This method is also known as "textile-reinforced mortar" (TRM), "mineral-based composite" (MBC), and "textile-reinforced concrete" (TRC). The system is made up of fabric grids made of fibers such as glass, carbon, etc, and cementitious component, that is essentially mortar which serves as a binder and matrix. The matrix used has a more remarkable thermal ability than epoxy resin utilized in FRPs, and it is highly consistent with the structures of the concrete. Since mortar is used in this method, its function is more prevalent in terms of temperature or high resistance against heat and compliance with concrete buildings, which is less strong than in epoxy resins. TRC use may be a perfect replacement as an alternate scale for the PSCs stabilization, as it might include a mixture of additional concrete surfaces and “lightweight glued CFRP stripes”, yielding a solid finding regarding bond systems and lowering the temperature sensitivity. Since the TRC does not require corrosion safety, the thin layer would suffice [20]. The steps of application textile in PSC beam are shown in figure (4). Hegger (2013) performed an analysis that involved two full-sized experiments on I-shaped PSC beams spanning “0.7 m in height and 6.5 m in length”. The beam was then constantly examined for cyclic shear stress, and it was also reinforced with the TRC system. The proposed system usually provides an effective substitute for the standard TRC since there is a mixture of lightweight glued CFRP stripes in this form, resulting in a stronger bonding for the additional concrete layers. The final analysis also showed that beam shear strength is significantly improved as a result of the TRC strengthening process being used on the concrete beam [21]**.**

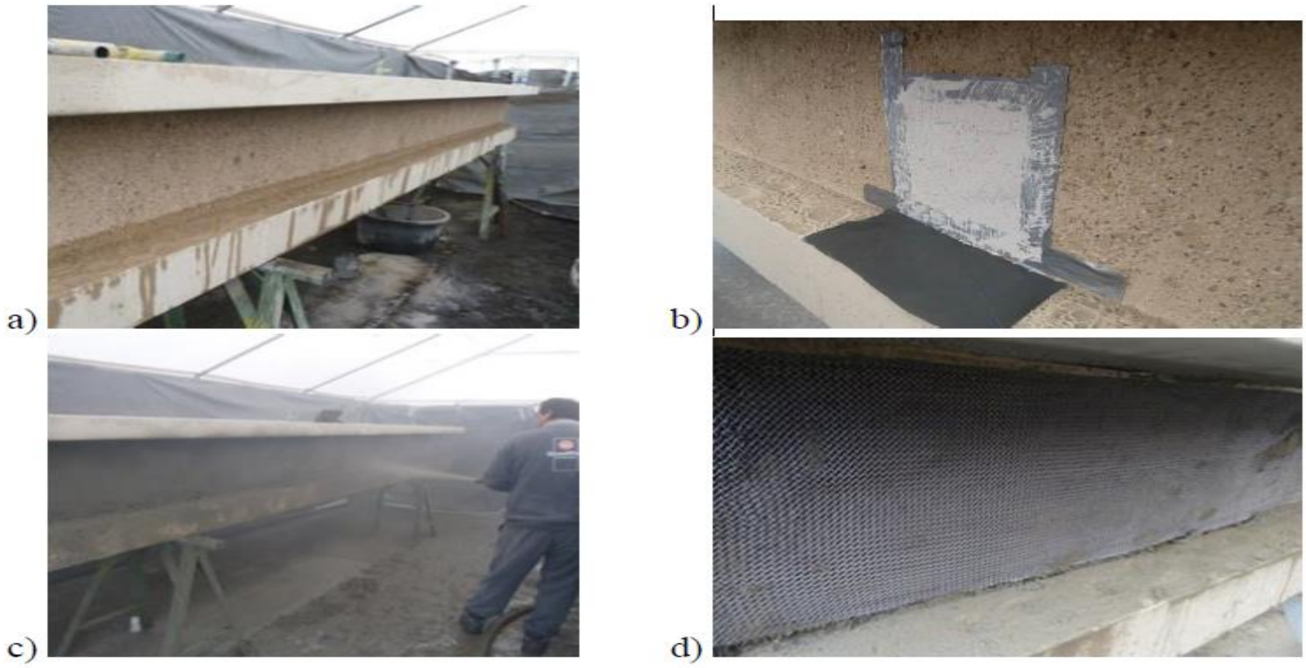

Figure 4. (a-d) Steps of application textile in PSC beam [21]

3.4. Strengthen PSC beams by gradually anchored pre-stressed CFRP strips

In one research, Reza Aram et al (2008) analyzed the ability of flexural from the supporting procedure using (CFRPs) strips. For the evaluation, 4 PSC beams with a diameter of 2.4 m and rectangular subsections of 0.25 m height and 0.15 m width were constructed. Each beam acts as the reference beam. One beam was merged with an unstressed CZFRP strip, while the rest were reinforced in two steps with pre-stressed CFRP strips. All of the beams were suspended to explore any anomalies that may have resulted from the use of the CFRP strips. In comparison to the beam that has not been unstressed, the procedure of pre-stressing the strips will have just a small impact on the reduction in diversion and fractured width of the beams. The failure load's overall potential also demonstrated that it could not be improved and would have to be decreased. The outcome of this study demonstrated that the differential anchorage strategy was ineffective when opposed to other methods previously addressed. The shear stress was found to accumulate with the shear stresses induced by the loads being applied to it. The short beam trait also allows a greater concentration of tension between the CFRP strips and the shear span's concrete components. This strategy can be more effective for beams in larger spams, such as bridge girders, where there is enough for un cracked zones anchorage length, which is less influenced by shear stress from the loads [22-25]. Figure (5) show the failure pattern of PSC strengthening by Gradually Anchored Pre-Stressed CFRP Strips.

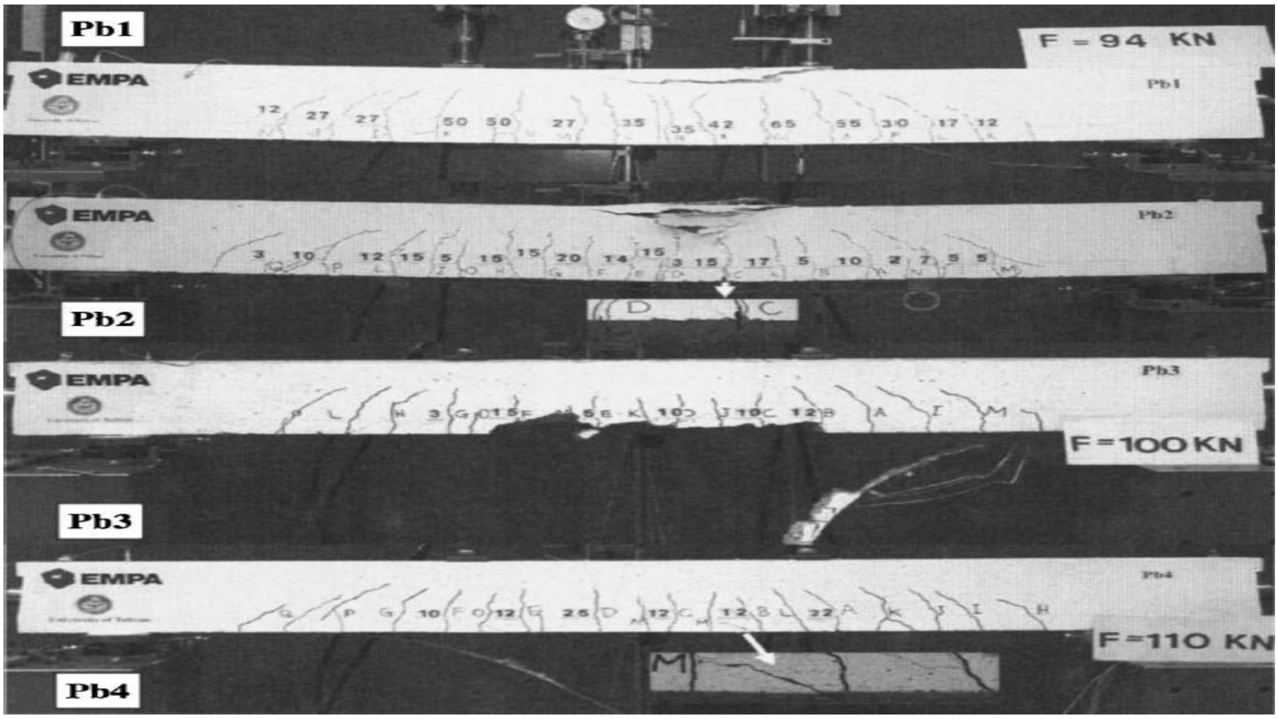

Figure 5. Failure pattern of PSC strengthening by Gradually Anchored Pre-Stressed CFRP Strips[22]

4. Conclusions

The current paper has gathered and addressed the detailed research that was performed based on the series of experiments that have been conducted on this field of reinforcing pre-stressed concrete beams using different methods. This paper highlights many of this methodology's effects on the flexural and shear strength of pre-stressed concrete beams used in several settings described in previous research. According to the analysis, the following outcomes can be drawn regarding this method.

1. The CFRP sheets would typically increase the flexural strength of the measured beams, demonstrating their potential to suppress any deformation situations, which would have extremely promising outcomes in enhancing the beams' durability and fracture, as shown by a reduction in cracking situations.
2. The situation in which the concrete could be compressed during the tensile stress could be prevented by adequately identifying and installing the CFPR reinforcing system. This is due to the possibility of preserving the ductile physical reaction of the un strengthened girders.
3. The greater the number of CFRP sheets, the smaller the chance of stressed CFRP sheets.
4. The incorporation of CFRP sheets to the bottom part of the specimen's structures can enhance flexural strength. Despite this, the NSM method of shear strengthening CFRP rectangular bars is still known as a relevant and appropriate shear strengthening system.
5. The NSM shear reinforcement of pre-stressed concrete beams with or without stir ups applying the CFRP laminates could increase the samples' strength, stability, and energy displacement. The alignment of several 45^o CFRP NSM laminates is found to become the most successful configuration since this makes shear cracks more complex, theoretically increasing overall strength and preventing failure circumstances.
6. The use of transverse CFRP U-wraps will be a massive help in imposing on other faults during debonding, particularly in externally bonded CFRP systems. As a consequence of the implementation of CFRP reinforcement, the crack situations may be prevented.
7. The shear fatigue strength will be improved as a result of the TRC strengthening operation. As a result of the TRC strengthening, the static shear capability will increase.
8. Strengthening in the U-anchorage form would be more effective in enhancing flexural strength than reinforcement in the beams' bottom. This is because of the internal tension, which will then be dispersed across the spaces for further beam defects.
9. Strengthening the external pre-stressing method could boost load-carrying capacity. This may reduce the durability and strengthen the conditions such that the diversion control system may no longer be a significant limiter at the service maximum load point.

10. Raising the NSM strands' pre-stress level will strengthen the flexural state of pre-stressed beams. The first crack load can be raised by raising the pre-stressed level of the strands of NSM.
11. Concrete that shatters on the top fiber of the beams can impair the flexural strength of the reinforced beams, which is a typical failure state and can be nearly identical to the failure of the control beams. There is no de bonding, nor are there any separations of the concrete covers in the reinforcing beams.
12. Compared to the unreinforced beam, the enhanced energy retaining potential of the beams expanded. This study demonstrates that the improved energy retaining potential of the beams with additional pre-stress was significantly enhanced.
13. The strengthened beams with pre-stressed NSM strands showed a noticeable increase in workload resilience. The added pre-stressing strain, which worked by the strand's strengthening, resulted in a higher hardness compared to the non-pressed strand. Reinforcement improved the durability of the strengthened beams until the last load was added. When exposed to the final load, the reinforced beams' adaptable nature was similar to that of the unreinforced beam, resulting in maximal disfigurement.
14. Using "textile-reinforced concrete" (TRC) offers a novel approach for strengthening phases by integrating the advantages of light-glued CFRP strips with the enhanced reinforcing properties of the applied concrete surface.
15.Strengthening with an external pre-stressing system resulted in a slight increase in load-bearing strength. This resulted in a lower durability level and higher durability constraints for failure control at the loading stem point.

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