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Reinforcing Methods for Pre-Stressed Concrete Beams: A Review

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Abstract: *Building structures get exposed to adverse conditions performing from overfilling conditions, which would eventually contribute to immense structure declination. The form of erecting structures seems to be veritably expensive. The possible system that could be taken is by employing a system of buttressing and strengthening the structure structures. For the once times, strengthening styles by enforcing colourful innovative technologies has been seen to come an important area for the experimenters to achieve long lasting concrete structures. former affiliated studies on the underpinning of pre-stressed concrete shafts (PSC) by adding different rudiments have been observed by once experimenters. The tests were carried out to estimate the shear and flexural capacities of the structure structures after the mechanisms were installed. A number of studies had been conducted in once time with different types of interacting factors. In present study, a review is presented by analysing colourful] styles that have been enforced by numerous experimenters for strengthening the pre-stressed concrete shafts, therefore to ameliorate their shear and flexure performances.*

Keywords: *Pre-stressed concrete beams, carbon fiber-reinforced polymers, flexure strength, shear.*

1. INTRODUCTION :

Building construction and maintenance, costs enormous amount of money, time and sources for development over the world. Bridges, casing systems, academy installations, colosseums, and seamster systems are only many angles of structure that have been designed to last for a prolonged period. These installations were generally constructed of structures made of pre-stressed concrete accoutrements. Still, numerous causes, primarily environmental circumstances, lack of pre-stressing, attritions and crashes, and the rising volume of cargo affected by the construction accoutrements, may affect the continuity of these structures. important of the cases, demolish and rebuild the damaged installations isn't the right choice to follow because the freights might be the top consideration. Other causes that contribute to girder damage may include unsafe storehouse, treatment, and transportation of accoutrements or erecting structures. Fractures and ray malfunctions caused by unsafe treatment will bear repairing similar structures, adding the cost of reconstruction. As a result, further people have chosen to unbend and patch their systems, believing that this result would save them plutocrat over the system 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].

1.1. Concrete System

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].

1.2. Pre-stressing of concrete

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. Application of Carbon Fiber-Reinforced Polymers (CFRP)

2.1. Carbon fiber-reinforced polymers (CFRPs)

Carbon fiber-reinforced polymers have many advantages over conventional reinforcement methods due to the lightweight properties, higher tensile attributes, damage tolerance, reliability, and convenience of management. As a result, they were used to reinforce a couple of large bridge systems. CFRPs 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 CFRPs 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. CFRPs 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 (CFRPs) 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 Carbon fiber-reinforced polymers (CFRPs) for the restoration of the current ireinforced concrete materials has increased dramatically over the past decades.

2.2. Strength improvement using Carbon fiber-reinforced polymers (CFRPs)

According to the study, CFRPs may be very effective in reinforcing concrete beams that are poor in flexural strength, low in tensile stress, and deformation. CFRPs is a compositei material thati is made up of high-power carbon, aramid, or fiber-glass in a polymeric matrix, with the fibers serving as the primary load-carrying component [5]. Kang and Ary (2012) led experimental research to show the impact of using strips of CFRPs 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 CFRPs in U shape and steel I-beam supported to it with no presence of the sheets of CFRPs. 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 CFRPs 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 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 CFRPs 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 [6].
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]. Ghasem et al. (2016) investigated the flexural properties of constant unbounded post-tensioned HSC beams stabilized with carbon-fiber 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. The results show that reinforcement could increase the operation and requirements of continuously unbounded post-tension concrete beams. 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. 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 reinforced beams [11].

2.3. Strength improvement using pre-stressed method integrated with carbon fiber-reinforced polymers

Afey et al (2016) conductedi studies on actual pre stressedi and pre-fabricated "double-tee concrete beams" and reconfigured them with CFRPs sheets which were externally bonded. The plates of CFRPs 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 exercising nonlinear U-shaped CFRPs plates, and all of the other crossbars were corroborated at the mark poles at the veritably same time. Each girder was gradationally flexure up to the point of failure. still, at each cargo applied, the girder deviation and ongoing stresses created on both the concrete and CFRPs wastes were reported. Three full- scale pre-tensioned double- tee crossbars were linked to be pre-cracked due to poor transport and delivery. It was latterlyi an impedance to CFRPs systems. U-shaped CFRPs plates were used to stabilize two crossbars in flexural strength at the center portion. The other three remaining crossbars have been supported in tensile stress at the end with plates of CFRPs. A CFRP- administering design for each girder was added to recapture lost power, due to the measures of the concrete of the crossbars, the internal shear strengthening, and the internal pre stressing beaches. Results validates the effectiveness of the espoused strengthening system in terms of final capacity and life. The modified crossbars intensity of flexural and shear was 60% advanced than the measures doable in the declared specifications. When the CFRP identifiers were introduced to the crossbars, their productivity increased. This is demonstrated by the rejection of cracks in the CFRPs wastes when subordinated to full cargo. still, if fractures continue to do, the situation will be simplified because the formed strains will be unfit to stretch to one- half of the fracturing strains. likewise, one of the most common reviews made by former trials was on the failure of CFRP wastes to retain strong continuity, indeed though this exploration ultimately showed that continuity would dramatically increase from buttressing wastes of CFRPs [1]. Truong et al. [2018] investigated the flexural effectiveness T- shafts (UPCs). CFRPs wastes have externally stabilized under the stationary rate of loads given to it with and without U- strip CFRP anchoring systems. In the dimension of the sample shafts, there are nine UPC T- shafts with density of 0.36 m, extents of 0.2 m, lengths of 6 m, and spans of 5.6 m. One unreinforced ray act as a control instance, and eight shafts act as externally corroborated shafts with a combination of wastes of CFRP with two, four, and six crowds. Two exemplifications of side CFRPU-strip anchoring systems were also redesigned to accommodate the shear range. The results showed that rising the flexural stability of CFRPs wastes redounded in significant changes. This is up to 37%, which dropped functionality relegation, bettered plasticity, and lowered fracture periphery by over to 48% of the beams tested. The maximum strain in corroborated UPC T- ray CFRPs wastes ranged from 38.7 to 69.3 of the fracture strain of wastes of CFRP and began to drop as the CFRP wastes' rate bettered. The side U-strand anchoring system and CFRPs wastes had a substantial influence on stress in corroborated ray bands [12]. Kalfat et al. (2020) conducted logical exploration into the perpetration of harborage systems to ameliorate CFRPs wastes' efficacity in strengthening post-tensioned beams for shear pressure. An aggregate of three big posttensioned T- shafts with depths of1.05 m and spans of 5 m were examined. All three samples have been examined in a three- point lading configuration. The unreinforced control ray was allocated to the first sample, while the alternate sample was corroborated in tensile stress with 0.1 m wide 0.0014 mm thick FRP coatings deposited at 0.3 m centers inside the vital shear band. Whereas the 3rd ray was corroborated with side- clicked CFRPs wastes and 2 layers of 45° bidirectional fiber patch anchors mounted at every part of the laminate's end. According to the experimented report, the corroborated shafts broke at a lading condition that was 32.7% and 19.6%, further than the loftiest demand achieved in the unreinforced samples. The corroborated shafts achieved the topmost loftiest capacity with patch anchors, which was 60.2 and 63.9 lesser than the unreinforced sample. The anchors were shown to mainly enhance the party's shear capability and FRP wastes strain optimization before failing [4].

3. Application of Epoxy Resins integrated NSM method

Concrete beams in the built environs have long been strengthened by near-surface mounted (NSM) methods. This approach incorporates the use of "Epoxy Resins" as a kind of glue in the operation of CFRPs. The adhesive was used to bond the FRP bars or in the coating of the pre-cut grooves on the concrete surfaces. Particularly in their capability to flexure on tensile structures of corroborated concrete samples, grooves serve as a buttressing technique. The addition might prop in shear underpinning for the edges of the concrete beams. The CFRPs mixes were to be fitted into the grooves, which have about 50 percent of the groove filled with epoxy resin resins, which serve as an adhesive [14]. Because NSM and CFRP laminations can help the propagation of shear fractures, they effectively increase the abidance of concrete beams. Up to 15 percent further power was visible in the control ray with no stronger stirrups and CFRPs wastes, demonstrating a significant incremental boost. Shear cracks were the base for the failure medium of the control beams, and frailty presently exists between the CFRP and NSM laminations. Without the need of current stirrups, the CFRPs wastes stabilized the control beams. They were shown to have a major impact on the compressive strength and to shield the system from failure by over to 52.4 and 34.4 percent, independently. The most profitable aspect that may be set up was that the fragile state was changed to a better result, adding the continuity flexure state [15]. M. Abdullah et al. (2019) demonstrated the way of using steel strips as the category of pre-stressed NSM will enhance the condition of beams of the concrete. This exploration was carried out by performing a series of trials on strengthening pre-stressed beams, each of which has a dimension of 0.15 m range, 0.3 m height, and 3.3 m length. The effective period is 3 m, and the shear productivity and effectiveness are 1.25 m. After that, each of them was erected with" NSM pre-stressed steel beaches" for underpinning. All of them have experienced testing, with one strengthened ray acting as a test subject. One of the beams had the NSM steel beachfront buttressing it indeed though no forces were applied. Pressure was latterly added to the remaining five beams, bringing their individual pressures up to 30, 40, 50, 60, and 70 percent. This system of using NSM beaches to strengthen the beams is a productive way to make them better.

4. Application of Post-Tensioned Method for Strength

The practice of "external post-tensioned pre-stressing" has been applied to beam strengthening since the 1990s. Concrete beams for long-span buildings can be constructed using this method in addition to buildings themselves. The most significant advantages of using an external pre-stressing system over an internal one is the elimination of any potential friction failure to free tendons, reduced costs and improved material handling in construction projects, and simplicity in handling and configuring any substitute tendons. 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]. Herbrand and Classesn (2015) devised an experiment to investigate the impact of additional external pre-stressing on the shear strength of uniform PSC beams. Three continuous PSC beams have been created by combining six shear data. The entire length of all the tests was "11.3 m," with a 5.5 m span. The next step in the investigation was to evaluate the sheer strength of three test beams that had "parabolic internal post-tensioning and external pre-stressing variables" in each. The endurance of the pre-stressed concrete beams can be ensured by even a tiny amount of shear reinforcement. The overall sheer strength of the systems was found to be largely unaffected by the higher external load. Nevertheless, more severe fracturing may result from the continuous stress. Depending on the fundamental tensile stress qualities, this might be enhanced through shear testing, which could help identify the first condition of cracking. After, a thorough investigation, a set of recommendations for applying the principal tensile stress properties for bridge evaluations were produced. These recommendations might be incorporated into the German functional evaluation specifications for the structural components of bridges that are now in use. The delicate condition was improved to a superior outcome, raising the durability flexure state, which is an excellent finding [18]. Allaw (2017) conducted study to examine the condition of a full-sized hybrid of reinforced PSC girders under repeated, continuous loads. In this project, 4 “full-scale composites pre-stressed of I-shaped girders” with 16 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 overall reliability constraint at the control load level significantly improved along with the durability factor of the reinforced PSC girders. Ultimately, compared to the control girder, this kind of strengthening significantly increases the overall strength of the concrete girders and produces a stable result under continuous loading up to "128.4% and 116%," respectively [19].

5. Application of Anchored Pre – Stressed Carbon Fiber Reinforced Polymers Strips

Reza Aram et al. (2008) examined the ability to flexural from the supporting technique employing (CFRPs) strips in one study. Four 2.4 m diameter PSC beams and rectangular subsections measuring 0.25 m in height and 0.15 m in width were built for the evaluation. The reference beam is each beam. While the remaining beams were strengthened in two stages using pre-stressed CFRP strips, one beam was combined with an unstressed CZFRP strip. In order to investigate potential irregularities resulting from the use of CFRPs strips, all of the beams were suspended. The process of pre-stressing the strips will have minimal effect on the reduction in diversion and fractured width of the beams when compared to the unstressed beam. The overall potential of the failure load also showed that it would have to be reduced and could not be improved. Comparing the differential anchorage strategy to other previously discussed strategies, the study's findings showed that it was ineffective. It was discovered that the shear stresses brought on by the loads placed on it added up. Additionally, a higher concentration of tension between the CFRPs strips and the concrete components of the shear span is made possible by the short beam characteristic. The method could prove better for beams with bigger spans, such bridge girders, where there is sufficient anchorage length for uncracked zones, which is less affected by the loads shear stress [22–25].

6. Conclusion :

The present paper has compiled and discussed the extensive study that was carried out based on the numerous tests that have been carried out in the area of using various techniques to reinforce pre-stressed concrete beams. The impacts of this technology on the flexural and shear strength of pre-stressed concrete beams utilized in various locations as previously reported in study are highlighted in this paper. Based on the analysis, the conclusions about this approach made are further discussed here.

As evidenced by a decrease in cracking situations, the CFRPs sheets would usually raise the flexural strength of the assessed beams, indicating their capacity to suppress any deformation situations. These results would be quite promising in terms of improving the beams' durability and fracture. Properly identifying and installing the CFPRs reinforcing system could prevent the circumstance where the concrete could be squeezed during the tensile stress. The reason for this is that the reinforced girders ductile physical response may be preserved. The tendency of stressed CFRP sheets decreases with increasing CFRP sheet count. Flexural strength can be increased by adding CFRP sheets to the bottom of the specimen's structures. In spite of this, CFRP rectangular bars strengthened by the NSM method are still regarded as a pertinent and useful shear strengthening technology. Strength, stability, and energy displaicement of the samples might be improved by attaching CFRP laminates to pre-stressed concrete beams with or without stir-ups and NSM shear reinforceiment. The most effective design is determined to be the alignment of multiple 45^{o} CFRP NSM laminates, as this increases the complexity of shear cracks and perhaps increases total strength by preventing failure scenarios. The use of transverse CFRP U-wraps will be a massive help in imposing on other faults during debonding, particularly in externally bonded CFRPs systems. As a consequence of the implementation of CFRP reinforcement, the crack situations may be prevented. For the purpose of increasing flexural strength, strengthening in the U-anchorage shape would be more beneficial than reinforcing in the bottom of the beams. This is a result of internal tension spreading throughout the voids in order to produce further beam flaws. The external pre-stressing techinique could be strengthened to increase load carrying capacity. As a result, the diversion control system might no longer be a substantial limitation at the service maximum load point due to decreased durability and strengthened circumstances. A common failure state that can be almost comparable to the failure of the control beams is the fracturing of concrete on the top fiber of the beams, which can reduce the flexural strength of the reinforced beams. In the reinforcing beams, there is neither debonding nor a separation of the concrete covers. The beams' increased capacity to store energy extended as compared to the unreinforced beam. This study shows that the beams with added pre-stress had dramatically improved energy holding potential. Workload resilience was notably increased in the strengthened beams using pre-stressed NSM strands. In comparison to the non-pressed strand, the additional pre-stressing strain increased the strand's hardness through strengthening. Strengthened beams benefited from reinforcement until the final load was applied. The maximum amount of disfigurement occurred because the reinforced beams' adaptability to the final load was equal to that of the unreinforced beam. The load-bearing strength was marginally increased by strengthening with an external pre-stressing device. As a result, the loading stem point's durability limits increased and its durability level decreased.

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