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Strengthening methods for reinforced concrete sections with Fiber reinforced polymers

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Abstract: *FRP materials in strengthening of Reinforced Concrete (RC) elements tends to be more popular depends on development of civil engineer application areas in the recent years. Damaged buildings and strengthening buildings with low standards became one of the fast developing subjects all over the World. Buildings that purpose of use has been changed, old buildings not in compliance with earthquake regulation and damaged buildings need to be strengthened. In this study, the advantages of carbon fiber reinforced polymers (CFRP) as one of the strengthening technique with the other classical methods discussed due to their properties of being thin and light as shirt fabric with high strength capacity.*

Keywords -*Concrete, fiber reinforced polymers, strengthening methods*

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I. Introduction

The Carbon Fiber Reinforced Polymers (CFRP) composites are preferable material due to their light weight and easy implementation with high tensile strength and corrosion resistance for strengthening concrete structures. The fiber reinforced polymer (FRP) composite wrap has been established as an effective method, alternative to traditional strengthening techniques, such as steel plate bonding, section enlargement, and external post-tensioning applications for strengthening and rehabilitation of concrete structures. High stiffness-to-weight and strength-to-weight ratios of these materials combined with their superior environmental durability have made them a competing alternative to the conventional strengthening and repair materials.

In many civil engineering applications such as rehabilitation of RC buildings, strengthening of bridge piers, etc. usage of FRP as a composite material is one of the best option to be used as external reinforcing because of their high tensile strength, light weight, resistance to corrosion, high durability, and ease of installation [1-5].

Confinement of concrete with externally bonded FRP is an important application of FRP composites. Several methods have been researched and proven effective in increasing the axial load capacity of reinforced concrete columns. These methods include concrete, steel, and fiber reinforced polymer (FRP) jackets. Lateral confinement using FRP or spiral reinforcement has been demonstrated to increase compression strength, deformability, and energy absorption capacity of concrete. Numerous experimental studies have been conducted to examine the performance of FRP composites in retrofitting existing concrete columns [6–13]. Recently the retrofit with FRP materials with desirable properties provides replacement for traditional materials, such as steel jacket, to strengthen the reinforced concrete structural members.

II. Strengthening Methods

Externally bonded steel plates, concrete jackets, steel jacketing, External Post-Tensioning and wrapping FRP are known as common strengthening methods. The most important step in retrofitting is the selection of an suitable interference technique based on the structural type and its vacancy. On the other hand type and location of problem, availability of time and skill, appearance and cost are important factors in case of strengthening method selection.

According to JSCE, 1999[14]; Retrofitting of structures shall flowed as follows :

- Identify the performance requirements for the existing structure to be retrofitted and draft an overall plan from inspection through selection of retrofitting method, design of retrofitting structure and implementation of retrofitting work.
- Inspect the existing structure to be retrofitted.
- Based on the results of the inspection, evaluate the performance of the structure and verify that it fulfills performance requirements.
- If the structure does not fulfill performance requirements, and if continued use of the structure through retrofitting is desired, proceed with design of the retrofitting structure.

- o Select an appropriate retrofitting method and establish the materials to be used, structural specifications and construction method.
- o Evaluate the performance of the structure after retrofitting and verify that it will fulfill performance requirements.
- o If it is determined that the retrofitting structure will be capable of fulfilling performance requirements with the selected retrofitting and construction methods, implement the retrofitting work.

Concrete Jacketing: Concrete jacketing is typically applied methods of repair and strengthening of concrete members. Jacketing is one of the most generally used techniques to strengthen reinforced concrete (RC) columns. The size of the jacket , the number and diameter of the steel bars used in the jacketing process depend on the structural analysis that was made to the column., If it is required, beams, slabs, and walls can be enlarged to add stiffness or load-carrying capacity. Extensive longitudinal and transverse reinforcement is added in the new layer of concrete, enhancing the shear and flexural strength and ductility. It is necessary to provide a good bond between new and old concrete in reinforced concrete jacketing. Reinforced concrete jacketing can be applied one, two, three or four side of the column ,depending on the state of the implementation and space around the column. In order to made jacketing to a required level;

- o Strength of the new material must be greater than existing one
- o Min 10 cm thickness of the jacket for cast- in –situ concrete
- o New reinforcement and concrete must be collaborated with existing concrete and reinforcement

This method application is difficult to construct in some active buildings such as hospitals, schools, industry etc. because of the implementation is taken time, made noise and many other limitations. In most cases Size of the columns or reinforced concrete members increased by concrete jacketing. Reinforced concrete jackets are build by enlarging the existing cross section with a new layer of concrete and reinforcement Fig 1 show that the enlargement of concrete and reinforcement [15].

Fig.1. Typical concrete jacketting of reinforce concrete columns

Steel Jacketing and Externally Bonded Steel: Strengthening method with steel plate bond or steel welding in reinforced concrete is concerned are fast and effective .The steel jacket retrofit has been used as a method to enhance the shear strength and ductility of reinforced concrete (RC) columns in buildings Confining reinforced concrete column in steel jackets is one of the remarkable methods to improve the axial load carrying capacity.

As compared with conventional hoops or spirals, steel jacket has an effective utility of easily provide a large amount of transverse steel, hence strong confinement to the compressed concrete and to prevent spalling of the shell concrete

The jacketting of the column with thin steel plates placed at a small distance from the column surface, with the occurring space being filled with non-shrinking grouts shown in Fig 2. A steel jacket usually consists of two half shells of steel placed around the column, and welded together after placing. The space between the jacket and column is filled with pure cement grout. A space between the jacket and the joining member, to avoid the probability of direct load carrying action of the jacket, it could cause local buckling in the jacket. The jacket provides a passive confinement effect. The jacket can be considered as similar to continuous hoop-reinforcement.

The simplicity and speed of the jacketting application provide a solution for critical intervention time immediately after a strong earthquake, particularly for special buildings such as hospitals and schools [16].

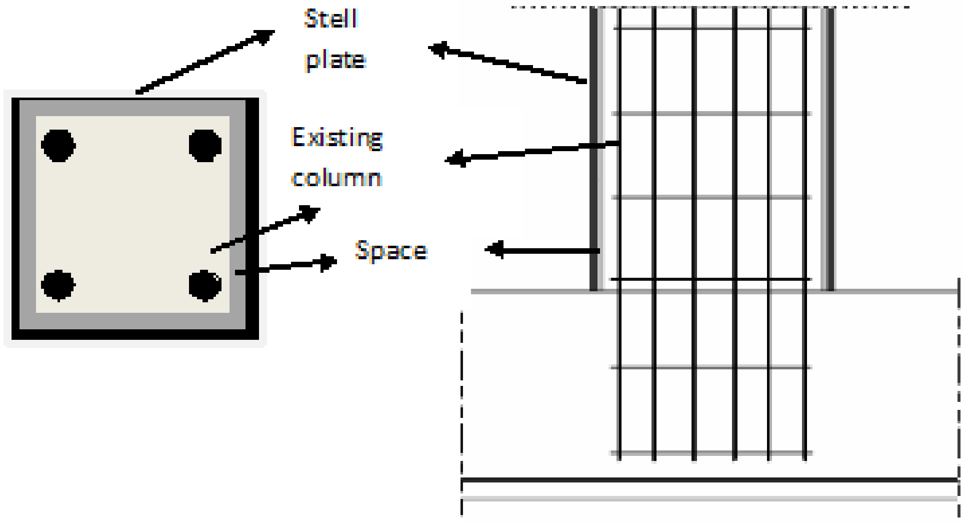

Fig 2. Strengthening of RC column with Steel jacketing

External Post-Tensioning Method: Post-tensioning is a method of strengthening concrete or structural member with high-strength (prestressing) steel, strands, cables or bars, typically referred to as tendons. Post-tensioning tendons are regarded “active” strengthening as prestressed concrete members. The steel is influential as reinforcement even though the concrete may not be cracked. It can be applied to reinforced and prestressed concrete members.

Post-tensioning is a technique used to prestress reinforced concrete after concrete is placed The tensioning provides the structural member with an immediate and active load-carrying capacity Post-tensioned structures can be designed to have minimum deflection and cracking, even under whole load. Post tensioning method for strengthening generally used to beam for enhanced the flexural capacity, improves the cracking performance and also have a beneficial effect on shear capacity when the application of an axial load combined with a hogging bending moment. Strengthening of a beam with external tendons with equal number of tendons are typically used on each side of the beam. Tendon force and eccentricity are adjusted until an optimum solution for the required uplift force is obtained [17].

External Wrapping by FRP: Fibers are the effective reinforcements material, as they satisfy the required conditions and transfer strength to the matrix constituent influencing and enhancing their properties as required. The performance of a fiber composite is evaluated by its length, shape, orientation, composition of the fibers and the mechanical properties of the matrix.(Pandey ,2004). The main fibre types used in civil engineering are Carbon fibers (CFRP),Glass (GFRP) and Aramid (AFRP) illustrated in Fig.3. Carbon fibers are anisotropic in nature Carbon fiber is produced at 1300ºC. High strength, excellent creep level, resistance to chemical effects ,low conductivity , low density and high elastic modulus are the advantages of carbon fibers .Carbon fibers are expensive and anisotropic materials and ıt has a low compression strength these are the weak sides of carbon fibers. Glass Fibers (GFRP) : Glass fibers are isotropic in nature and most widely used filament. Common types of glass fibers are E-Glass, S-Glass and C - Glass. The characteristic properties of glass fibers are : high strength, low cost, good water resistance and resistance to chemicals. Aramid Fibers (AFRP) : Aramid fibers widespread known as a kevlar fiber in the markets .The structure of aramid fiber is anisotropic in nature and usually are yellow in colours. Aramid fibers more expensive than glass, moderate stiffness, good in tension applications (Cables and tendons) but lower strength in compression, Aramids have high tensile strength, high stiffness. high modulus and low weigh and density .Impact-resistant structures can be produced from aramids.

Fig 3. a) Typical Carbon fibers(CFRP) b) Typical Glass fibers (GFRP) c) Typical Aramid fibers (AFRP)

FRP material are used as external reinforcement in the construction industry since 1970[18]. Today, these FRP products take the form of bars, cables, 2-D and 3-D grids, sheet materials, plates, etc. FRP products may succeed in the same or better reinforcement objective of commonly used metallic products such as steel reinforcing bars, prestressing tendons, and bonded plates as indicated by ACI 440 [19]. A typical FRP application shown in Fig.4 as strengthening materials for a concrete section to determine the confining effect of carbon fiber reinforced polymer on strength and energy dissipation capacity [20].

Fig.4. Application of FRP on concrete section for seismic retrofitting

Epoxy resins are used for small injection, surface coating or filling larger cracks or holes. If ıt is suitably applied, these materials could be bonded easily to concrete and are able to restoring the original structural strength to cracked concrete. The epoxy mixture strength is depend on the temperature of curing, lower strength for higher temperature and method of application. Viscosity must be suitable to the thickness of the crack to be injected. Cracks to be injected with epoxy resins should be between ~ 0.1 mm and ~ 6 mm in width. It is very difficult to retain injected epoxy resin in cracks greater than ~ 0.6 mm in width, although high viscosity epoxies have been used with some success. Epoxy resins cure to form relatively brittle materials with bond strengths exceeding the shear or tensile strength of the concrete.

III. Conclusion

The recent studies show that FRP strengthening or retrofitted techniques can enhance stress-strain performance of existing reinforced concrete structures. Reinforced concrete structures may need strengthening or retrofitted due to incorrect calculations and applications of project the use of unsuitable materials for standards or guidelines, the low quality of concrete, inadequate lateral reinforcement, change of usage, additional storey, environmental factors and poor workmanship etc. The usage of FRP composites in strengthening applications has superiorities due to the lightweight, high strength, resistance to corrosion, speed and ease of application and formed on site.

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