Pre-stressing Techniques for structural strengthening using FRP Composites

In today’s growing economy, Infrastructure development is also raising its pace. Many reinforced concrete and masonry buildings are constructed annually around the globe. With this there are large number of them which deteriorate or become unsafe to use because of changes in use, changes in loading, change in design configuration, inferior building material used or natural calamities. Thus repairing and retrofitting these structures for safe usage of these structures has a great market.

There are several situations in which a civil structure would require strengthening or rehabilitation due to lack of strength, stiffness, ductility and durability. Some common situations where a structure needs strengthening during its lifespan are:

- Seismic retrofit according to current code requirements.
- Upgraded loading requirements; damage by accidents and environmental conditions.
- Initial design flaws
- Change of usage.

Depending on the desired properties, usage and level of damage involved members can be repaired and/or strengthened by several widely used methods. Popularly known methods for strengthening of structural elements are:

- Concrete jacketing
- Steel plate jacketing
- FRP composite Jacketing

The retrofit techniques for the reinforced concrete (RC) columns, which are arguably the most critical component of many structures, are aimed at increasing the confinement for the concrete. This follows from the well-known fact that lateral confinement enhances the strength and, more importantly, ductility of RC columns.

The first two methods are traditionally used and established techniques which are being used with various rehabilitation and strengthening situations. FRP jackets are considerably new and have been successful in many countries. With fiber reinforced polymer (FRP) materials increasingly being considered for use as wraps/ jacket/ casings, due to their high strength-to-weight and stiffness-to-weight ratios, corrosion and fatigue-resistance, and overall durability. Unlike steel jackets, where the confining pressure is constant after yielding the steel, the induced confinement by FRP materials is continuously increasing because of non-yielding properties of such materials. On the other hand, the steel yielding happens at relatively low amount of concrete dilation, while in the case of FRP, the high strength is not mobilized unless the lateral strain in the confined concrete is very high.

we can seldom fully use the superior strength properties of these FRP composites due to poor capacities of concrete and interfaces formed. A popular way of strengthening the structural elements with application of pre-stressed FRP composites is gaining acceptance. External prestressing with other materials of the existing structures have always been difficult especially in view of the materials to be used, reinforcement corrosion, lateral instability, end anchorages and of course space constraints. The advantages of resistance to corrosion and high specific strength make these materials ideal for reinforcing existing structures with minimum intrusion. Popular method adopted is bonding them adhesively to concrete structures.

Ways in which the pre-stressed FRP composites can be used are as follows

1. For columns and axial members

In the columns as we are using the confining mechanism for strengthening, the concrete crushing occurs before the strength of FRP sheets is fully utilized. Thereby, it becomes all too natural to think of prestressing the FRP wraps before applying it as a confinement, hoping that a more efficient
use of expensive composites can be achieved. By doing so, the confinement is no longer limited to passive mechanism but includes the active confinement, as well.

In this method a FRP belt is taken (either carbon or glass) which is cut to a desired length needed for wrapping. It can be either done by having single bands (Fig 1) or we can also have the band revolved many times around the column for better confinement (Fig 2).

Before wrapping or prestressing the column with FRP belts, the corners of square section have to be rounded to avoid stress concentration. After rounding, the corner concrete surface was well prepared by grinding and primer so as to provide smooth surface to facilitate prestressing of the belts. The Fiber’s are applied with epoxy so that they are rinsed in it and hence can be bonded onto the primered surface.

In case of individual wraps the distance between the wraps should be minimum and so as to accommdate the setup. The wraps are then either stressed with the help of nut-bolt system or with help of hydraulic jack.

In case of continuous wraps with one end fixed the number of revolution should not be more than 6 so that the friction does not produce hindrance and we could have localized failures. The fibre is then stressed with the help of clamp, which holds the fiber at one end, and pushed by a hydraulic jack for stressing.

In both the cases the system is left in the stressed position for atleast a day so that the epoxy is cured and the fiber composite is bonded properly to the structure.

This technique greatly increase load carrying capacity of the columns and has the added advantages of using FRP composites with it. It is also much more efficient than the more common Fiber Wrapping in which the column is confined without any stress applied to it.

2. For Flexural Members like Beam, Slabs and Cantilevers.

For increasing the load carrying capacity of flexural members the FRP Composites are used in pre-cured form commonly in strips called laminates. They come in various thickness to widths. They have been used for strengthening of structure by directly applying to the members. This includes externally reinforcing beams and slabs from below with laminates giving the members extra flexural and shear strength. As discussed earlier by directly bonding we do not use the superior strength of the laminates and much before the laminate reaches its ultimate strength. Hence prestressing these laminates becomes very effective way of using their strengths. The Pre-Stressing gives the
members an active upward force even when no live load is given.

In this method the laminate is adhesively bonded to the concrete. One end of the laminate is kept fixed and the other end is fitted with a Pre-stressing jack. This jack then pushes the clamp which is holding the laminate hence inducing stress in it. It is then kept in the stretched position for a day for the adhesive to get cured. After a day the stress is released slowly and the laminate transfer the stresses to the concrete.

Conclusions

The technique of using pre-stressed FRP composites is simple yet very effective way of strengthening the columns as well as the slabs and beams. It is often not possible to apply steel jackets and pre-stressed concrete to existing concrete. In these cases the pre-stressing of these material gives a effective solution for strengthening as they can be applied in very less working space available. External pre-stressing arrests widening the cracks, and therefore, limit the level of concrete damage at final stages of cyclic loading. In this regard, external prestressing is considered to be a beneficial technique for retrofitting earthquake-damaged columns, where the cracks already appeared.

References

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