Enhancement of Flexural Strength of RC Beam by Using Kevlar Fabric

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Abstract— The use of composite materials in infrastructure repair is still in its infancy. As such, most of the currently available solutions employ relatively dated composites technology and many of the early difficulties experienced in the aerospace, automotive and marine markets have been seen in the early implementation of composites for infrastructure strengthening. This project examines the benefits derived from using aerospace grade materials (Kevlar fabric) in infrastructure repair. It demonstrates that, the use of appropriately engineered repair strategies incorporating high quality pre-impregnated composite materials can provide substantial strength and stiffness improvements to conventional steel reinforced concrete beams.

Keywords: Tensile Strength, Flexural Strength

I. Introduction

The maintenance, rehabilitation and upgrading of structural members is perhaps one of the most crucial problems in civil engineering applications. Moreover, a large number of structures constructed in the past using the older design codes in different parts of the world are structurally unsafe according to the new design codes. Since replacement of such deficient elements of structures incurs a huge amount of public money and time, strengthening has become the acceptable way of improving their load carrying capacity and extending their service lives.

Infrastructure decay caused by premature deterioration of buildings and structures has led to the investigation of several processes for repairing or strengthening purposes. One of the challenges in strengthening of concrete structures is selection of a strengthening method that will enhance the strength and serviceability of the structure while addressing limitations such as constructability, building operations and budget.

- Structural strengthening may be required due to many different situations. Additional strength may be needed to allow for higher loads to be placed on he structure. This is often required when the use of the structure changes and a higher load carrying capacity is needed. This can also occur, if additional mechanical equipment, filing systems, planters, or other items are being added to a structure.
- To allow the structure to resist loads those were not anticipated in the original design. This may be encountered when structural strengthening is required for loads resulting from wind and seismic forces or to improve resistance to blast loading.
- Due to a deficiency in the structure's ability to carry the original design loads. Deficiencies may be the result of deterioration (e.g., corrosion of steel reinforcement and loss of concrete section), structural damage (e.g., vehicular impact, excessive wear, excessive loading, and fire), or errors in the original design or construction When dealing with such circumstances, each project has its own set of restrictions and demands. Whether addressing space restrictions, constructability restrictions, durability demands, or any number of other issues.

Each project requires a great deal of creativity in arriving at a strengthening solution. The majority of structural strengthening involves improving the ability of the structural element to safely resist one or more of the following internal forces caused by loading: flexure, shear, axial, and torsion. Strengthening is accomplished by either reducing the magnitude of these forces or by enhancing the member's resistance to them. Typical strengthening techniques such as section enlargement, externally bonded reinforcement, post-tensioning and supplemental supports may be used to achieve improved strength and serviceability.

Strengthening systems can improve the resistance of the existing structure to internal forces in either a passive or active manner.

- Passive strengthening systems are typically engaged only when additional loads, beyond those existing at the time of installation, are applied to the structure. E.g. Bonding steel plates or adhesive bonded fabric composites on the structural members are examples of passive strengthening systems.
- Active strengthening systems typically engage the structure instantaneously and may be accomplished by introducing external forces to the member that counteract the effects of internal forces. E.g. The use of external post-tensioning systems or by jacking the member to relieve or transfer existing load.

II. Kevlar Fibre

Kevlar (poly-paraphenylene terephthalamide) is the DuPont Company’s brand name for a synthetic material constructed of para-aramid fibers that the company claims is five times stronger than the same weight of steel, while being lightweight, flexible and comfortable. It is also very heat resistant and decomposes above 400 °C without melting.

It was invented by Stephanie Kwolek of DuPont from research into high performance polymers and patented by her in 1966 and first marketed in 1971. Kevlar is a registered trademark of E.I. du Pont de Nemours and Company, originally intended to replace the steel belts in tires, it is probably the most well known name in soft armor (bulletproof vests).

Kevlar is one of the most important man-made organic fibers ever developed. Because of its unique combination of properties, Kevlar is used today in a wide variety of industrial applications. Kevlar para-aramid fiber possesses a remarkable combination of properties that has led to its adoption in a variety of end uses since its commercial introduction in the early 1970s.

Fibers of Kevlar consist of long molecular chains produced from poly-paraphenylene terephthalamide. The chains are highly oriented with strong interchain bonding, which result in a unique combination of properties.

It is also used in extreme sports equipment, high-tension drumhead applications, animal handling protection, composite aircraft construction, fire suits, yacht sails and as an asbestos replacement. When this polymer is spun in the same way that a spider spins a web, the resulting commercial para-aramid fiber has tremendous strength and is heat and cut resistant. Para-aramid fibers do not rust or corrode and their strength is unaffected by immersion in water. When woven together, they form a good material for mooring lines and other underwater objects. However, unless specially waterproofed, para-aramid fiber's ability to stop bullets and other projectiles is degraded when wet.

Kevlar is a type of aramid that consists of long polymeric chains with a parallel orientation. Kevlar derives its strength from inter-molecular hydrogen bonds and aromatic stacking interactions between aromatic groups in neighboring strands. These interactions are much stronger than the Vander Waals interaction found in other synthetic polymers and fibers like Dyneema. The presence of salts and certain other impurities, especially calcium, would interfere with the strand interactions and has to be avoided in the production process. Kevlar consists of relatively rigid molecules, which form a planar sheet-like structure similar to silk protein. These properties result in its high mechanical strength and its remarkable heat resistance. Because it is highly unsaturated, i.e. the ratio of carbon to hydrogen atoms is quite high, it has a low flammability. Kevlar molecules have polar groups accessible for hydrogen bonding.

Water that enters the interior of the fiber can take the place of bonding between molecules and reduce the material's strength, while the available groups at the surface lead to good wetting properties. This is important for bonding the fibers to other types of polymer, forming a fiber reinforced plastic. This same property also makes the fibers feel more natural and "sticky" compared to non-polar polymers like polyethylene. In structural applications, Kevlar fibers can be bonded to one another or to other materials to form a composite.

A. *Properties of fabric:*

Property(unit)	Type
Material	Kevlar fabric
Structure of fabric	Biaxial 0 º /90 º
Weight (g/m^2)	105
Nominal thickness per layer (mm)	0.6
Maximum tensile stress (N/mm^2)	1812.53
Cost (Rs./ m^2)	1000

III. METHODOLOGY:

A. *Casting of beams*

1) *Introduction*

As per previously mentioned concrete mix design, nine beams of size 150mm x 230mm x 2000mm as casted for study. The reinforcement details of which are as shown in fig.1.

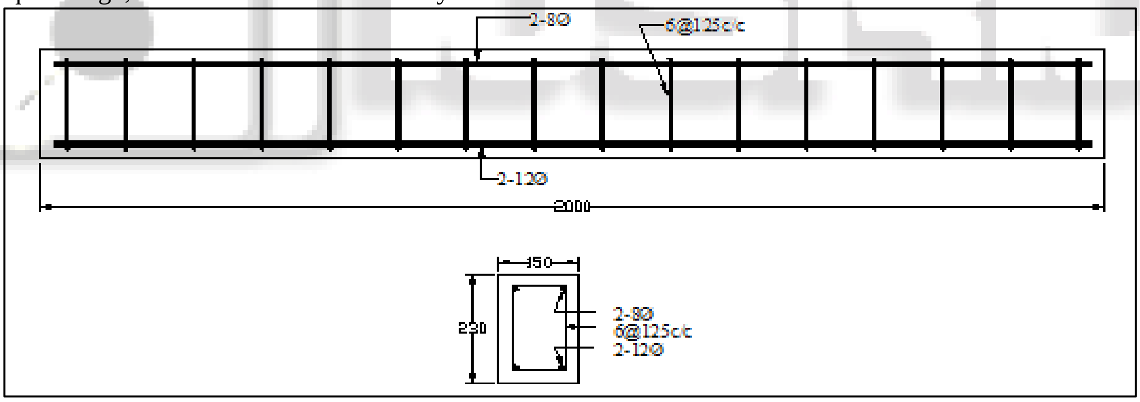

Fig. 1.1: Reinforcement details of beams

2) *Form work*

Fresh concrete, being plastic requires some kind of form work to mould it to the required shape and also to hold it till it sets. Therefore the form work has to be suitably designed. It should be strong enough to take the dead load and live load, during construction and also it must be rigid enough so that any bulging, twisting or sagging due to the load is minimized. Wooden beams, mild steel sheets and several other materials can be used. Formwork should be capable of supporting all vertical and lateral loads safely that might be applied to it.

Dead loads on formwork consist of the weight of the forms and the weight of freshly placed concrete. Live loads include weights of workers, equipment, material storage, accelerating and braking forces from buggies and other placement equipment. Impact from concrete placement also should be considered in formwork design. Horizontal or slightly inclined forms often are supported on vertical or inclined support members, called shores, which must be left in place until the concrete placed in the forms has gained sufficient strength to be self-supporting. The form work used for casting of the entire specimen consists of mould prepared with plywood panels. The form work was thoroughly cleaned and all the corners and junctions were properly sealed to avoid leakage of concrete through small openings. Shuttering oil was then applied to the inner face of the form work. The reinforcement cage was then placed in position inside the form work carefully keeping in view a clear cover of 25 mm for the top and bottom bars.

3) *Mixing of concrete*

Mixing of concrete should be done thoroughly to ensure that concrete of uniform quantity is obtained. Hand mixing is done in small works, while machine mixing is done for all big and important works. Although a machine generally does the mixing, hand mixing sometimes may be necessary.

The dry materials are mixed at least three times until the color of the mixture is uniform. Water is then added slowly while the mixture obtains the proper consistency.

4) Compaction

All specimens were compacted by using needle vibrator for good compaction of concrete. Sufficient care was taken to avoid displacement of the reinforcement cage inside the form work. Finally the surface of the concrete was leveled and finished and smoothened by metal trowel and wooden float.

5) Curing of Concrete Beams

The concrete is cured to prevent or replenish the loss of water which is essential for the process of hydration and hence for hardening. Also curing prevents the exposure of concrete to a hot atmosphere and to drying winds which may lead to quick drying out of moisture in the concrete and thereby subject it to contraction stresses at a stage when the concrete would not be strong enough to resists them.

Concrete is usually cured by water although scaling compounds are also used. It makes the concrete stronger, more durable, more impermeable and more resistant to abrasion and to frost. Curing is done by spraying water or by spending wet hessian cloth over the surface. Usually, curing starts as soon as the concrete is sufficiently hard. More than 14 days of curing. However, the rate of hardening of concrete is very much reduced with the reduction of ambient temperature.

B. Procedure for Bonding of Fabric to Beam

The concrete surface is made rough by wire brush and it is thoroughly cleaned to remove all dirt and debris. The epoxy resin and hardener are weighed in the ratio of 1:1 and mixed thoroughly and applied over the concrete surface. The fabric is then placed on the top of epoxy resin coating such that the warp direction of the fabric is kept along the longitudinal reinforcement of the beam. During hardening of the epoxy, a constant uniform pressure is applied to ensure good contact between the epoxy resin-hardener, the concrete and the fabric. Concrete beams with fabric are cured for 7 days at normal temperature before testing.

C. Testing of Beams

All the specimens will be tested in the loading frame of the “strength of materials” Laboratory of DYPSOET, Lohegoan, Pune. The testing procedure for the entire specimen will same. After the curing period of 28 days was over, the beam surface was cleaned and white washed for clear visibility of cracks. Before testing the member was checked dimensionally, and a detailed visual inspection made with all information carefully recorded.

1) Procedure

After setting and reading all gauges, the load was increased incrementally up to the calculated working load, with loads and deflections recorded at each stage. Loads will then normally be increased again in similar increments up to failure, with deflection gauges replaced by a suitably mounted scale as failure approaches. This is necessary to avoid damage to gauges, and although accuracy is reduced, the deflections at this stage will usually be large and easily measured from a distance. Similarly, cracking and manual strain observations must be suspended as failure approaches unless special safety precautions are taken. If it is essential that precise deflection readings are taken up to collapse. Cracking and failure mode was checked visually, and a load/deflection plot was prepared.

The most commonly used load arrangement for testing of beams will consist of two-point loading. Loading was done by universal testing machine of capacity 100 KN. A dial gauge was used for recording the central deflection of the beams. This has the advantage of a substantial region of nearly uniform moment coupled with very small shears, enabling the bending capacity of the central portion to be assessed. If the shear capacity of the member is to be assessed, the load will normally be concentrated at a suitable shorter distance from a support. Two-point loading can be conveniently provided by the arrangement. The load is transmitted through a load cell and spherical seating on to a spreader beam. This beam bears on rollers seated on steel plates. The test member is supported on roller bearings acting on similar spreader plates. The loading frame must be capable of carrying the expected test loads without significant distortion. Ease of access to the middle third for crack observations, deflection readings and strain measurements is an important consideration, when failure occurs.

IV. CONCLUSION

The project demonstrates that, the use of appropriately engineered repair strategies incorporating high quality pre-impregnated composite materials can provide substantial strength and stiffness improvements to conventional steel reinforced concrete beams. In this experimental investigation the flexural behaviour of reinforced concrete beams strengthened by Kevlar fabric was studied. From the test results and calculated strength values. In the range of service loads the Kevlar fabric reinforcement yields to lower crack widths and crack intervals. By strengthening the beam, performance of a weakened structure can be improved and it will protect many lives from sudden failure. This method of strengthening does not reduce the headroom and prevents corrosion of the reinforcement effectively.

With this study carried out, it can be concluded that, this method of strengthening the flexural members in existing buildings is a better option for repair and maintenance.

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