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Civil Engineering Application and Research of FRP in India as Compared to China

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ABSTRACT: *To meet up the requirements of advanced infrastructure, new innovative materials and technologies in construction industry has started to make its way. Any technology or material has its limitations. With structures becoming old and the increasing bar corrosion, old buildings have started to demand additional retrofits to increase their durability and life. Engineers throughout the world including India and China have used Fiber Reinforced Plastic (FRP) to solve their structural problems in an efficient and economical manner. In the field of civil engineering, most of the use of FRP is confined to repairing and strengthening of structures.*

Use of FRP for confinement has proved to be effective retrofitting and strengthening application. The confinement in seismically active regions has proved to be one of the early applications of FRP materials in infrastructure applications. Confinement may be beneficial in non-seismic zones too, where, for instance, survivability of explosive attacks is required or the axial load capacity of a column needs to be increased due to higher vertical loads. Hence, FRP composites are finding ways to prove effective. Like other materials, FRP also has its limitations. After presenting a brief review on these dimensions, this paper provides a thorough survey of the application of FRP in civil engineering in India and China.

Keywords: *Fiber Reinforced Plastic (FRP), Retrofitting, Seismic zones.*

I. INTRODUCTION

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 numbers 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 in structural members, these can be repaired and strengthened by several widely used methods.

India and its neighbour China are the two big emerging and developing economies. While they started making use of composites almost simultaneously about more than 30 years ago, the progress made by China is rather Astounding [1]. Fibre reinforced polymer (FRP) in India has taken shape in 1960s with a single resin manufacturer and a lone source of fibre glass. Over the years, the industry has grown steadily, but at a slower pace [2]. FRP materials were developed primarily for aerospace and defence industries in the 1940s and are widely used in many industries today, including aeronautic, marine, automotive and electrical engineering. With the continuing cost reduction in high-performance FRP materials and the growing need for new materials to renovate civil infrastructures, FRP materials are now finding wider acceptance among civil engineers [3]. China may be traced back to the end of 1950s when China was in short supply of steel [4]. Construction is a major part of development plan of developing countries including India. To meet the large demand for infrastructure development, maintenance and life enhancement of existing structures are very important. After many years of use, an existing structure often needs to be repaired or upgraded because of so many reasons like damage due to corrosion or increased load demand etc. There are several methods for retrofitting of structures like- guinting, post tensioning, externally bonded steel plates, steel or concrete jackets etc. Epoxy injection and newly developed methods like advanced techniques for corrosion affected RCC and methods of modifying structural properties using active or passive mass damper for high rise buildings are also there [5]. The technique of externally bonding FRP to reinforced concrete (RC) structures was introduced into China in 1997.[6] In India, field application of FRP for structural strengthening could be traced as early as in 1999. However, FRP is being used for new construction also in many countries; none could be traced in India. The material is still considered relatively new in this part of the world. China is working on use of FRP in new construction in many directions

like FRP bridges, FRP breakwater, FRP space structure, concrete filled FRP tube columns. There exist many FRP footbridges in China.

II. FRP COMPOSITE

A Fiber Reinforced Polymer (FRP) composite is defined as a polymer (plastic) matrix, either thermo set or thermoplastic, that is reinforced (combined) with a fibre or other reinforcing material with a sufficient aspect ratio (length to thickness) to provide a discernable reinforcing function in one or more directions. FRP composites are different from traditional construction materials such as steel or aluminium. FRP composites are anisotropic (properties apparent in the direction of the applied load) whereas steel or aluminium is isotropic (uniform properties in all directions, independent of applied load). Therefore, FRP composite properties are directional, meaning that the best mechanical properties are in the direction of the fiber placement. FRP composites are composed of:

- **Epoxy** - The primary functions of the resin are to transfer stress between the reinforcing fibers, act as a glue to hold the fibers together, and protect the fibers from mechanical and environmental damage. The most common resins used in the production of FRP grating are polyesters.

- **Reinforcements** - The primary function of fibers or reinforcements is to carry load along the length of the fiber to provide strength and stiffness in one direction. Reinforcements can be oriented to provide tailored properties in the direction of the loads imparted on the end product. The largest volume reinforcement is glass fiber.

- **Fillers** - Fillers are used to improve performance and reduce the cost of a composite by lowering compound cost of the significantly more expensive resin and imparting benefits as shrinkage control, surface smoothness, and crack resistance.

- **Additives** - Additives and modifier ingredients expand the usefulness of polymers, enhance their process ability or extend product durability.

Composite materials are made by combining at least two different constituent materials with one or more materials as reinforcements, and one or more materials as the matrix. FRP composite is similar to RC, with a fiber (such as glass, carbon or aramid) as the reinforcement and a polymer (polymer resin matrix such as epoxy, polyester) as the matrix. The fiber reinforcement carries load in pre-designed directions and the polymer matrix serves as a binder, a medium to transfer loads between adjacent fibers and to provide protection for the fiber. Current FRP composite materials typically have highstrength and high-stiffness structural fibers embedded in lightweight, low-cost, and environmentally resistant polymers; which have better mechanical and durability properties than either of the constituents alone. [3] FRP products produced for use in structural engineering can comprise significantly more ingredients than just the primary constituents: fiber and polymer resins.

III. ADVANTAGES AND LIMITATIONS OF FRP

FRP has tremendous potential and has great advantages over conventional materials and techniques of retrofitting of RC structures. The increase in use of FRP for retrofitting of RC structure may be attributed to their advantageous properties mainly - high corrosion resistance, light weight, extremely high strength to weight ratio, ease of handling and installation (hence substantially reduced working time). However, there are some factors limiting its frequent use such as very high material cost, lack of design codes on FRP in many countries like India, unawareness of or reluctance to accept existing reports, guidelines and technical publications currently being used worldwide [7, 8].The following are major pros and cons of using Composites:

Advantages

- Corrosion proof.
- Higher UTS and young's modulus.
- Easy in transportation, can be installed easily.
- Light weight. Hence, very high strength to weight ratio.
- High fatigue resistance.
- Joints can be easily avoided as they are available in desired length.

Limitations

- Low ductility value and fickly plastic behaviour
- Susceptible to local unevenness.
- High cost.

- Low shear strength.

FRP's can be used in the concrete structures in following forms:

- Plates- at the face to improve the tension capacity.
- Laminates- below beams and slabs to improve load taking capacity.
- Bars- as reinforcements in beams and slabs replacing the steel bars
- Cables- can be used as tendons and post- tension members in suspension and bridge girders.
- Wraps- around concrete members i.e. columns, beams, slabs etc for confinement.

IV. FRP IN CIVIL ENGINEERING INDIA VERSUS CHINA

The overall composites market in India is relatively small, compared to per capita consumption in other parts of the world. A few years ago consumption level of composites in India was only about 30,000 MT, as compared to about 2,00,000 MT in China [1]. There is enormous scope of use of FRP in India, because of seismically deficient buildings, long coast line and long monsoon season pressing the use of non-corrosive FRP. Traditional materials, such as wood, are in short supply. There are a few examples of FRP application for retrofitting before Gujarat earthquake (2001) and after this earthquake only, the technique is gaining attention in India. However, the same is not to the extent warranted by potential of the FRP that exist. As the material is still considered relatively new in this part of the world, most of the works had been carried out in accordance to available guidelines and published literature like ACI 440.2R-02. The composite market in China is developing rapidly with construction as the largest end-use market. . The technique of externally bonding FRP composite plates or sheets to RC Structures was introduced into China in 1997. After extensive research and promotion since then, it has now become a major method for retrofitting concrete structures; and consequently, the first specification for FRP in civil engineering in China, "Technical specification for strengthening concrete structure with carbon fibre reinforced polymer laminate CECS-146" (CECS-146 2003), was published in 2003. A national standard, "Standard for FRP in Civil Engineering", is also being developed [6, 9]**.**

FRP: Research and Application in India and China

In India, in the field of education and research related to FRP in construction, Structural Engineering Research Center (SERC) Chennai, FRP institute Chennai, Indian Society for Advancement of Materials and Process Engineering (ISAMPE) (headquarter- Bangalore), Research Design and Standards Organization (RDSO) under the Ministry of Railways at Lucknow, Technology Information Forecasting and Assessment Council (TIFAC) a unit of DST, Composites Technology Centre (at IITM) are among others, participating actively. For the composites industry a monthly magazine 'FRP Today' is being published in India since the year 2000. The Department of Science and Technology, Government of India, in collaboration with the universities, is developing standards for FRP in construction. Focus is placed on the rate of degradation of glass FRP in view of the South Asian environment and the concrete mix typically used in India. The application is targeted at corrosion damaged structures and seismic retrofitting [10]. Composites Technology Centre (formerly -Fibre Reinforced Plastics research Centre) was established in 1974 at IITM as an interdisciplinary centre for carrying out teaching, research, design and development in the field of composite materials and their applications. The centre was renamed as Composites Technology Centre in 1997 [11].

In china, various educational and other bodies involved in education and research on FRP include-Dalian University of Technology. Fuzhou University, Guangdong University of Technology, Hong Kong Polytechnic University, Hong Kong, Southeast University, Nanjing , Tsinghua university, *Beijing* Tongji University, Shanghai, Association of Chinese Civil Engineering (ACCE), National Engineering Technique Research Center of Industrial Building (NETRCIB)., the Chinese Science and Technology Ministry and the Chinese National Science Foundation., Natural Science Foundation of China , Royal Society, The China Association for Engineering Construction Standardization in China, Chinese Science and Technology Bureau, Beijing FRP institute, Nanjing GFRP institute, Shanghai Research Institute of Building Sciences, Shanghai.

The first research of FRP in civil engineering in China was conducted in Tsinghua University in 1958. The test was intended to use GFRP bars instead of steel bars as there was limited amount of steel in that time in China. But the beam failed in very brittle style with a sudden rupture of GFRP bars, so that the research was not continued. From 1970s, there were some research institutes in China began the research on the GFRP bridge and there were some GFRP bridges were built. Besides, there some researches and application of GFRP water tanks for buildings [9]. Systematic research on FRP in construction was begun in 1997, when the external bonded CFRP sheets strengthening technique for RC structures was introduced in China. The first test to demonstrate the effectiveness of this new strengthening method was conducted in 1997 by NETRCIB. In 1998, a subcommittee of FRP in construction was founded under the Chinese Civil Engineering Association. After that, there has been more and more research on FRP strengthening of structures [4]. From 1997 to 1999, the researches were mainly to demonstrate the effectiveness of the strengthening method. Under the support of

Chinese Science and Technology Bureau, a series of experimental researches on flexural strengthening of RC beams and slab, shear and seismic strengthening of RC columns were conducted in Tsinghua University and NETRCIB to establish the design method for the RC structure strengthening with CFRP sheets and plates [9].

The research of GFRP bridges in China began since 1970s; consequently 1982 witnessed the first trial in Miyun, Beijing. Since 1998, more than 40 concrete filled GFRP tube columns were tested to determine the static and seismic behaviours in Tongji University. After the first test demonstrating the effectiveness of the strengthening method using external bonded FRP, in 1999, research on RC structures using FRP bars began, at South east University, Nanjing, followed by Tongji University, Shanghai. Since 2000, series of experimental researches on steel structure strengthening with CFRP were conducted by NETRCIB. A test was done in Tsingua University in 2000, demonstrating use of CFRP in self structure monitoring. Beijing FRP institute developed a FRP sandwich panel breakwater. NETRCIB also conducted a test on a containment shell structure of a nuclear power station strengthened with CFRP sheets. To use FRP to make super large span space structure, the CFRP tubes were developed for the research of space truss structure in Tsinghua University. Southeast University studied RC beams pre-stressed with FRP tendons and developed some anchorage devices for pre-stressed FRP tendons. The basic compressive behaviours of confined concrete by FRP and hybrid FRP jackets, including round, square and rectangular sections were researched in several universities in China. There were also research reports and publications about strengthening with FRP sheets and plates for two-way slabs, torsion members and beam-column joints. The four universities researched on the seismic strengthening of masonry wall using FRP, under cyclic lateral load in the wall plane [9]. There are many specific research for example a new form of hybrid FRP concrete- steel double skin (FCSDS) columns has recently been proposed by Prof. J.G. Teng. The column consists of an outer FRP tube, an inner steel tube and concrete in the annular space between the two tubes. They have many advantages over simple concrete-filled steel or FRP tubes [12].

To evaluate the current trends in the FRP education, a survey of universities around the world was carried out between November 2001 and February 2002. The Editorial Board of the American Society of Civil Engineers Journal of Composites for Construction (Lawrence C. Bank, Editor) sponsored the survey of the civil/structural engineering programs. Among others, 35 universities from Asia were included in the survey, out of 35 only 12 participated in the survey including 4 from China, 3 from Japan, and 2 from Thailand, 1 each from Korea and Singapore and 1 from India i.e.-IIT Bombay. In the survey participants from People's Republic of China were, Dalian University of Technology, Fuzhou University, Guangdong University of Technology, and Hong Kong Polytechnic University, Hong Kong [13]. According to the survey, despite a significant number of field applications and laboratory research on FRP, the research results have not yet been fully translated into teaching curricula, and civil engineering graduates for the most part are not sufficiently trained to design or specify FRPs for construction projects [13]. This situation is improving now, however at a very slow pace.

V. CONCLUSION

India is the second fastest growing economy after China. In spite of all the potential of India, .rapid use of FRP in civil infrastructure is difficult because of local code restrictions There is an urgent need to develop Indian standards for use of FRP and more production facilities. For use of FRP, China has Technical specification CECS-146, and a National Standard is also underway. China is far ahead of India in the field. With less than 5% of the Asian FRP market, there is plenty of room for growth in India [9].

The application of FRP in civil engineering is showing upward trend in India and China, however, FRP is still a specialty item. To improve this situation, civil engineering and their extension programs must provide sufficient training on unique features of FRPs so that engineers could design or specify them in construction. At this juncture, there is a need of Government- Industry-Institute partnership to exploit full potential of FRP. The increase in use of FRP for retrofitting is inevitable because of its potential.

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