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STUDY ON FRP LAMINATES AND FAILURES IN CONCRETE COLUMNS

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Abstract: Retrofitting is one of the most important processes in construction industry. The necessity of retrofitting of existing structures is most desired during the mid life of a structure. In this paper the importance of concrete members retrofitting is analyzed. Retrofitting enhances the strength, serviceability and durability of the structures. The overall life span of the structures can be significantly increased. Retrofitting reduces the vulnerability of damage in an existing structure. In some cases the existing concrete structures undergone failure due to various reasons. Hence, the retrofitting is the primary and effective method to increase the serviceability of the structure. The common retrofitting materials are carbon fibre sheet, basalt fibre, steel fibre and glass fibre sheet. In this study the carbon FRP laminated concrete structure is analyzed. Generally the existing concrete structures strength can be enhanced by wrapping the carbon FRP laminates on it in prescribed method.

***Keywords*:** - Retrofitting, Carbon, FRP Laminate, existing structures.

1. Introduction:

1.1 Cement:

Cement is a binder substance used in construction which hardens and adheres to other materials to bind them together during hydration process. Cement mixed with fine aggregate produces mortar for masonry and with aggregates to produce concrete. Portland cement is the most common type of cement in construction. British masonry worker Joseph Aspdin patented Portland cement in 1824. It was named because of the similarity of its color to Portland limestone, quarried from the English Isle of Portland and used extensively in London architecture. It consists of a mixture of calcium silicates (alite, belite), aluminates and ferrites—compounds which combine calcium, silicon, aluminum and iron in forms which will react with water. Portland cement and similar materials are made by heating limestone (a source of calcium) with clay or shale (a source of silicon, aluminum and iron) and grinding this product (called *clinker*) with a source of sulfate (most commonly gypsum).

1.2 Concrete:

Concrete is mixture of the cement, water, aggregates and other additives if necessary in a proper proportion. It is the most vital component of the construction industry. There are certain guidelines to be followed for the preparation of the concrete. The various properties of the concrete are mechanical properties, durable and serviceability properties of the concrete. The major steps of producing concrete are batching, mixing, casting and curing.

In the process of casting concrete and curing the hydration of the cement undergoes. This hydration process in very important which governs the strength of the concrete. The cement when added with water the hydration process is initiated. The constituent of cement slowly hydrate and hardens the cement paste. The strength of the cement paste was attained by the interlocking of various calcium hydrates present in it. Contrary to popular belief, hydraulic cement does not set by drying out, it requires proper curing and maintaining the appropriate moisture content necessary for the hydration reactions during the setting and the hardening processes. If hydraulic cements dry out during the curing phase, the resulting product will be partially hydrated composite and the properties of the composites decreased accordingly. The minimum temperature of 5 °C is recommended, and no more than 30 °C in curing phase. The concrete at young age must be protected against water evaporation through direct insulation, elevated temperature, low relative humidity and wind.

1.3 Aggregates:

Fine and coarse aggregates make up the bulk of a concrete mixture. Sand, natural gravel and crushed stone are commonly used aggregates in concrete. Recycled aggregates (from construction, demolition, and excavation waste) are increasingly used as partial replacements for natural aggregates, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are also permitted.

The size distribution of the aggregates determines governs the strength of the concrete significantly. Coarse aggregate with a very even size distribution has the biggest gaps whereas the fine aggregate is added to fill the smaller gaps. The binder adheres as paste on the surfaces of the aggregates to bind all the concrete constituents as a homogeneous mixture. Redistribution of aggregates after compaction often creates non-homogeneity due to the influence of vibration. This can lead to strength gradients.

1.4 Reinforcement:

The steel reinforcement is the most commonly used in concrete due to the weak tensile properties of the concrete. Steel reinforcements are the rebars which are manufactured with iron as its major constituent and other materials to enhance the properties of the reinforcement. The steel has the very high tensile strength, ductility which are lacks in concrete. In a building the four major structural components are foundation, columns, beams, and slabs. These structural members undergo both compression and tensile forces in its service. Hence, the application of the Steel reinforcement is provided.

1.5 Fibre Reinforced Polymer (FRP)

Fibre Reinforced Polymer (FRP) composite is defined as a polymers which are reinforced with fibres. It represents a class of materials that fall into a category referred to as composite materials. Composite materials are made by dispersing particles of one or more materials in another material, which forms a continuous network around them.

FRP composites are different from the traditional construction materials like Steel and Aluminum. FRP composites are anisotropic whereas Steel and Aluminum are isotropic. Therefore, their properties are directional, meaning that the best mechanical properties are in the direction of the fibre placement. These materials have a high strength to density ratio, exceptional corrosion resistance and convenient electrical, magnetic and thermal properties. However, they are brittle and their mechanical properties may be affected by the rate of loading, temperature and environmental conditions. The primary function of fibre reinforcement is to carry the load along the length of the fiber and to provide strength and stiffness in one direction. It replaces metallic materials in many structural applications where load-carrying capacity is important. The use of FRP in engineering applications enables engineers to obtain significant achievements in the functionality, safety and economy of construction because of their mechanical properties.

1.6 Fibres

The choice of fibre frequently controls the properties of composite materials. Carbon, Glass, and Aramid are three major types of fibres which are used in construction. The composite is often named by the reinforcing fibre, for instance, CFRP for Carbon Fibre Reinforced Polymer. The most important properties that differ between the fibre types are stiffness and tensile strain. Figure 1 Shows the types of Fibres.

Fig. 1 Types of Fibres

1.7 Resins

Resins are the adhesive materials which are used in the production of FRP composites and also in in FRP application with the other materials. The matrix of fibres transfer forces between the fibres and protect the fibres which forms detrimental effect. Thermosetting resins (thermosets) are almost exclusively used as a adhesive in fibre application. Vinyl ester and epoxy are the most common matrices. Epoxy is mostly favored above vinyl ester but is also more costly. Epoxy has a pot life around 30 minutes at 20 degrees Celsius but can be changed with different formulations. Epoxies have good strength, bond, creep properties and chemical resistance. Figure 2 shows the FRP manufacturing process.

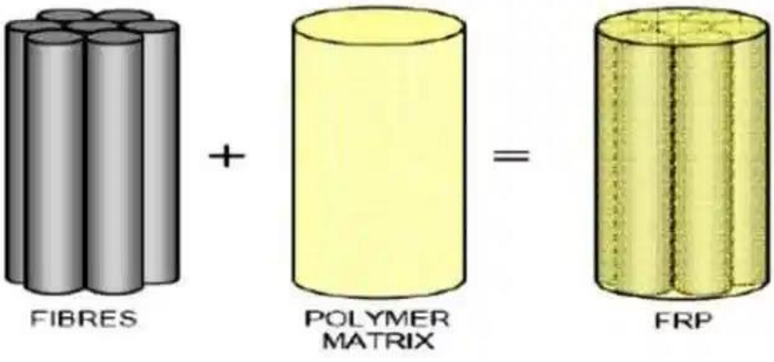

Fig.2 FRP Manufacturing Process

1.8 Types of Fibre Reinforced Polymer (FRP)

1.8.1 Glass Fibre Reinforced Polymer (GFRP)

Glass fibres are basically made by mixing silica sand, limestone, folic acid and other minor ingredients. The mix is heated until it melts at about 1260°C.The molten glass is then allowed to flow through fine holes in a platinum plate. The glass strands are cooled, gathered and wound. The fibres are drawn to increase directional strength. The fibres are then woven into various forms for use in composites. Based on an aluminum lime borosilicate composition, glass produced fibres are considered as the predominant reinforcement for polymer matrix composites due to their high electrical insulating properties, low susceptibility to moisture and high mechanical properties. Glass is generally a good impact resistant fibre but weighs more than carbon or aramid. Glass fibres have excellent characteristics equal to or better than steel in certain forms. Figure 3 Shows the Glass Fibre Reinforced Polymer.

Fig. 3 – Glass Fibre Reinforced Polymer

1.8.1.1 Advantages of glass reinforced Polymer

- They can be easily drawn into fibers from molten state
- Glass is cheaper and readily available
- Glass fiber is relatively strong
- Glass is chemically inert with respect to plastic matrix materials

1.8.1.2 Disadvantages of glass reinforced Polymer

- It has poor rigidity and stiffness
- Its application is limited to a temperature below 300-degree Celsius

1.8.1.3 Applications of glass reinforced Polymer

It is used as a manufacturing material in following things.
- Pipes
- Valve bodies
- Pump castings
- Storage containers
- Carbon reinforced plastics

1.8.2 Carbon Fibre Reinforced Polymer (CFRP)

Carbon fibres have a high modulus of elasticity, 200-800 GPa. The ultimate elongation is 0.3-2.5 % where the lower elongation corresponds to the higher stiffness and vice versa. Carbon fibres do not absorb water and are resistant to many chemical solutions. They withstand fatigue excellently and neither corrodes nor show any creep or relaxation. Figure 4 shows the Carbon Fibre Reinforced Polymer.

Fig. 4 – Carbon Fibre Reinforced Polymer

1.8.2.1 Advantages of carbon reinforced Polymer

- It has maximum strength compared to other reinforcing fibers
- It retains its strength at elevated temperatures
- At normal temperature moisture, acids and solvents do not affect carbon fibers
- They are relatively cheap

1.8.2.2 Disadvantages of carbon reinforced Polymer

- There is only one limitation of carbon reinforced plastic. The manufacturing techniques associated with CRP are relatively complicated.

1.8.2.3 Applications of carbon reinforced Polymer

Carbon reinforced plastics are used for the manufacturing of.

- Pressure vessels
- Aircraft components
- Casting of rocket motors

1.9 Applications of FRP

- Carbon FRPs are used in prestressed concrete for applications where high resistance to corrosion and electromagnetic transparency of CFRP are important.
- CFRP composites are employed for underwater piping and structural parts of offshore platform. Added to that, FRP declines the risk of fire.
- Carbon fibre reinforced polymers are used to manufacture underwater pipes for great depth because it
- provides a significantly increased buoyancy (due to its low density) compared to steel.
- The stairways and walkways are also made of composites for weight saving and corrosion resistance.
- It is used in high-performance hybrid structures.
- FRP bars are used as internal reinforcement for concrete structures.
- FRP bars, sheets, and strips are used for strengthening of various structures constructed from concrete, masonry, timber, and even steel.
- FRPs are employed for seismic retrofitting.
- Fibre reinforced polymers are used in the construction of special structures requiring electrical neutrality.
- The high energy absorption of aramid fibre reinforced polymer (AFRP) composites makes them suitable for strengthening engineering structures subjected to dynamic and impact loading.

1.10 Advantages of fiber reinforced Polymer

- It is lightweight
- It has high strength
- It has high modulus of elasticity
- It has high resistance to fatigue failure
- It has good resistance to corrosion
- Disadvantages of fiber reinforced plastic
- Strength of FRP in a direction perpendicular to the fibers is extremely low (up to 5%) compared with the strength along the length of fibers
- The design of components made from FRP is complex
- The manufacturing and testing of FRP components is highly specialized

2. LITERATURE REVIEW:

Shrikant 2014 studied the behaviour of the various natural fibres reinforced in the polymer composites. The various natural fibres such as bamboo fibres are studied. The properties and their behaviours in the FRP also studied. The various properties such as mechanical strength, durability, advantages and disadvantages are discussed in the study conducted by Chris 2009. The various properties of the fibre reinforced composites are discussed in the study conducted by the Shivakumar 2011. Ashik 2015 studied the various natural fibre reinforced polymers and its properties. The tensile properties of the natural fibres are discussed in the research conducted by Ku. The general properties, merits and demerits of the studied by Marston 2007. Bongarde 2014 Studied the properties of the various natural fibres. Saleel 2016 studied the behaviour of the carbon fibre reinforced polymers in very elaborate manner. It states the varies advantages and disadvantages in the carbon fibre reinforced polymers. It also studied the properties of the carbon reinforced polymer. Norazman 2013 studied the Carbon fibre reinforced polymer in the concrete beams. This study showed the various merits ad demerits in using CFRP as reinforcement in concrete members. Karam 2016 studied the shear strength of the concrete beams reinforced with GFRP reinforcements.

3. RETROFITTING OF COLUMN BY USING FRP

In recent years, the repair of un-strengthened and damaged reinforced concrete member by externally bonding of FRP laminates has established considerable attention. Use of fiber reinforced polymer has increasing popularity in structural retrofitting field due to advantages such as lightweight, high strength and simplicity of application. One of the most attractive applications of FRP is wrapping existing reinforced concrete (RC) columns or bridge piers to enhance their deformation capacity especially at the potential plastic hinge regions and the retrofit of existing concrete columns by the provision of FRP jackets. Such jackets are commonly formed in a wet layup process, with the fibers being present only or predominantly in the hoop direction. Column is the most vulnerable load carrying element of structure but due to Minimum cross section size and lack of steel reinforcement in under designed columns leads to a weak column construction. It is very important to strengthen the columns so that the plastic hinges are formed in the beams. The role of FRP for strengthening of existing or new reinforced concrete structures is growing an extremely rapid speed of construction and the possibility of application without disturbing the existing functionality of the structure. During an earthquake, three modes of RC column failures that can take place due to cyclic axial and lateral loads are shear failure. Hybrid construction with FRP and concrete combine mass, stiffness, damper and low cost of concrete with the speed of construction, light weight, strength and durability of FRP. CFRP & GFRP wrapping can enhance the strength of concrete columns under axial loading Compressive Strength of the Concrete Columns increases with increase in the number of layer of GFRP Confinement by GFRP enhances the performance of rectangular concrete columns.

3.1 Resins

There are totally two types of resins are available. They are Thermoset Resins and Thermoplastic Resins.

3.1.1 Thermoset Resins

They are mostly used for common for structural applications. These reins are mostly in liquid state at room temperature prior to curing. They are impregnated into reinforcing fibers prior to heating. In this resins the chemical reaction occurs only during heating/curing. It will become solid after heating/curing. These resins cannot be reversed/ reformed once heated or cured.

3.1.2 Thermoplastic Resins

These resins are manufactured from recycled plastic pellets. These resins are in solid state at room temperature. It is heated to liquid state and pressurized to impregnate reinforcing fibers and cooled under pressure. This resin can be reversed /reformed.

3.1.3 Common Thermoset Resin Types and its features

Types of Resin	Advantages	Disadvantages
Polyester	Lowest Cost resin , Easy to use	Sensitive to UV degradation and only moderate mechanical properties
Polyurethane	Higher strength and flexibility than vinyl esters, Very high chemical/environmental resistance & Higher mechanical properties than vinyl esters	
Vinyl ester	Very high chemical/environmental resistance & Higher mechanical properties than polyesters	Sensitive to heat & Higher cost than polyesters
Epoxy	Highest Cost & used in aerospace applications	Higher cost than vinyl esters (about 1.5 x)

3.1.4 Epoxy adhesive

Epoxy is a commonly used for strong adhesives which are required to be used for bonding – two materials or surface together. Epoxy adhesives are usually two component systems i.e., two compounds (resins) that need to be mixed together and cured either at room temperature or at elevated temperatures. Epoxies are created by polymerizing admixture of two starting compounds, the resin and the hardener. When resin is mixed with a specified catalyst, curing chains react at chemically active sites, resulting in an exothermic reaction. Covalent bond between the epoxy groups of the resin and the amine groups of the hardener (catalyst) that arise from this combination afford for the cross- linkage of the polymer, and thereby dictate the rigidity and strength of the epoxy. Epoxy adhesive generally used for coating; excocting of FRP on column or beams, now a day's a wide range of epoxy resins are produced initially. Epoxy provides the use of the strongest bond epoxies are known for their excellent adhesion, chemical and heat resistance and have very good structural insulting properties.

3.1.4.1 Advantages of Epoxy Adhesives

- High mechanical and thermal properties
- High moisture resistance
- Long working times available
- High temperature resistance

3.1.4.2 Disadvantages of Epoxy Adhesives

- More expensive than polyurethanes
- Critical mixing/Consistency
- Corrosive handling

3.2 Fibre Reinforced Polymer (FRP) Laminates

To overcome the above shortcomings, a new form of FRP laminate has been developed (Ehsani, 2010). During the manufacturing process, one or more layers of carbon or glass fabric are saturated with resin and subjected to heat and pressure to construct pre-cured laminate sheets as thin as 0.01 inches. The precision required to produce such a thin laminate was one that was finally achieved after an extended R&D process. The laminates are 4 to 5 feet wide and are supplied in rolls as long as 300 feet. The tensile strength of these laminates ranges between 60,000 and 155,000 psi depending on the number of layers of fabrics and the orientation of the fibers.

Unlike the wet layup system, the laminates are stiff enough to stand on their own. In the field, an appropriate length of the laminate is cut and wrapped around the deteriorated column to create a structural shell that is not bonded to the host column. A thin layer of epoxy is brushed over the overlapping portion of the laminate to create a two- or three-ply shell in the field – similar to a sonotube. The annular space between the shell and the host column is filled with resin or grout to make the host column and the shell work compositely. Figure 5 Shows the various FRP laminates.

Fig. 5 FRP Laminates

3.2.1 Manufacturing Process of Fibre Reinforced Polymer (FRP) Laminates

The process of manufacturing of FRP laminates is explained in step by step manner. There are mainly eight important steps involved in the manufacturing process. They are

3.2.1.1 Melting

Once the batch is prepared, it is fed into a furnace for melting. The furnace may be heated by electricity, fossil fuel, or a combination of the two. Temperature must be precisely controlled to maintain a smooth, steady flow of glass. The molten glass must be kept at a higher temperature (about 1371 °C) than other types of glass in order to be formed into fiber. Once the glass becomes molten, it is transferred to the forming equipment via a channel (fore hearth) located at the end of the furnace.

3.2.1.2. Forming into fibers

Several different processes are used to form fibers, depending on the type of fiber. Textile fibers may be formed from molten glass directly from the furnace, or the molten glass may be fed first to a machine that forms glass marbles of about 0.62 inch (1.6 cm) in diameter. These marbles allow the glass to be inspected visually for impurities. In both the direct melt and marble melt process, the glass or glass marbles are fed through electrically heated bushings (also called spinnerets). The bushing is made of platinum or metal alloy, with anywhere from 200 to 3,000 very fine orifices. The molten glass passes through the orifices and comes out as fine filaments.

3.2.1.3 Continuous-filament process

A long, continuous fiber can be produced through the continuous-filament process. After the glass flows through the holes in the bushing, multiple strands are caught up on a high-speed winder. The winder revolves at about 3 km a minute, much faster than the rate of flow from the bushings. The tension pulls out the filaments while still molten, forming strands a fraction of the diameter of the openings in the bushing. A chemical binder is applied, which helps keep the fiber from breaking during later processing. The filament is then wound onto tubes. It can now be twisted and plied into yarn.

3.2.1.4 Staple-fiber process

An alternative method is the staple fiber process. As the molten glass flows through the bushings, jets of air rapidly cool the filaments. The turbulent bursts of air also break the filaments into lengths of 20-38 cm. These filaments fall through a spray of lubricant onto a revolving drum, where they form a thin web. The web is drawn from the drum and pulled into a continuous strand of loosely assembled fibers. This strand can be processed into yarn by the same processes used for wool and cotton.

3.2.1.5 Chopped fiber

Instead of being formed into yarn, the continuous or long-staple strand may be chopped into short lengths. The strand is mounted on a set of bobbins, called a creel, and pulled through a machine which chops it into short pieces. The chopped fiber is formed into mats to which a binder is added. After curing in an oven, the mat is rolled up. Various weights and thicknesses give products for shingles, built-up roofing, or decorative mats.

3.2.1.6 Glass wool

The rotary or spinner process is used to make glass wool. In this process, molten glass from the furnace flows into a cylindrical container having small holes. As the container spins rapidly, horizontal streams of glass flow out of the holes. The molten glass streams are converted into fibers by a downward blast of air, hot gas, or both. The fibers fall onto a conveyor belt, where they interlace with each other in a fleecy mass. This can be used for insulation, or the wool can be sprayed with a binder, compressed into the desired thickness, and cured in an oven. The heat sets the binder, and the resulting product may be a rigid or semi-rigid board, or a flexible bat.

3.2.1.7 Protective coatings

In addition to binders, other coatings are required for fiberglass products. Lubricants are used to reduce fiber abrasion and are either directly sprayed on the fiber or added into the binder. An anti-static composition is also sometimes sprayed onto the surface of fiberglass insulation mats during the cooling step. Cooling air drawn through the mat causes the anti-static agent to penetrate the entire thickness of the mat. The anti-static agent consists of two ingredients a material that minimizes the generation of static electricity, and a material that serves as a corrosion inhibitor and stabilizer.

Sizing is any coating applied to textile fibers in the forming operation, and may contain one or more components (lubricants, binders, or coupling agents). Coupling agents are used on strands that will be used for reinforcing plastics, to strengthen the bond to the reinforced material. Sometimes a finishing operation is required to remove these coatings, or to add another coating. For plastic reinforcements, sizings may be removed with heat or chemicals and a coupling agent applied. For decorative applications, fabrics must be heat treated to remove sizings and to set the weave. Dye base coatings are then applied before dying or printing.

3.2.1.8 Forming into shapes

Fiberglass products come in a wide variety of shapes, made using several processes. For example, fiberglass pipe insulation is wound onto rod-like forms called mandrels directly from the forming units, prior to curing. The mold forms, in lengths of 91 cm or less, are then cured in an oven. The cured lengths are then de-molded lengthwise, and sawn into specified dimensions. Facings are applied if required, and the product is packaged for shipment.

4. FAILURES IN R.C COLUMN

The common failures occurs in the concrete columns are listed below. They are

1. Pure Compression Failures
2. Buckling Failure
3. Shear Failure
4. Torsional Failures
5. Combined Stress Failure
6. Failure due to the Errors in the Construction
7. Failure due to Construction Defects

4.1. Pure Compression Failures

The column is an element that transfers the weight of a structure as axial stress to the foundation or supporting element. Concrete is capable of carrying the compressive load is dominant in carrying loads whereas in other elements such as beams compressive stress is taken only by part of the section.

Reinforcement is also provided to columns where it is not possible concrete to carry the whole load or as nominal reinforcements. The column can fail in compress due to the increase of the axial stress than its capacity. These types of failure could be due to the following reasons. The fig. 6 shows the compression failure in columns.

- Reinforcement and concrete have certain capacity based on their amount and area of the section. If axial stress is greater than that capacity column will fail in compression.
- Further, the reinforcement and concrete have their own stain that they can bear. As per the British standards, concrete is capable of carrying a strain up to 0.0035 and steel starts yielding at a strain of 0.002 and it can increase greater than the concrete. When the axial stress exceeds a certain amount resulting in concrete strain greater than 0.0035 concrete will fail suddenly. It will be a sudden crushing of concrete.
- If the section is sufficiently reinforced, it will provide warnings before these types of column failure. The article published as ***structural cracks in concrete*** could also be referred more information on cracking.

Fig. 6 Compression Failure in Column

4.2 Buckling Failure

Mainly, the buckling failure can be identified as a failure of the design as we consider the buckling effect in the design. If the designer aware of these types of column failures, he could attend this. The additional bending moment of the column slenderness of the column is considered in the design. Further, the effective height of the column is considered based on its pattern of bucking. Buckling failure, the name itself provides the idea about the mode of failure. Therefore, we consider it in the design. Buckling failure is the other basic mode of failure of columns in addition to crushing failure of columns. We provide links to columns to avoid buckling. It is the basic idea for providing links to the columns other than for as shear reinforcements. Figure 7 shows the bulking failure of column.

Fig. 7 Bulking Failure in Column

4.3 Shear Failure

Lateral loads in a structure are carrying by vertical elements such as columns and shear walls. When there are no shear walls, columns carry these lateral loads. If no adequate shear links these types of column failure could occur. Lateral loads are generated by winds, earthquake loads, from retaining structures, etc. Shear links are provided to columns based on the shear forces excreted on them. Further, the size of the columns is increased in the direction of shear to increase the shear capacity. In general, failure of columns due to shear can be identified as the failure of design. Designers should have provided adequate shear links or sections to carry the shear forces. Figure 8 shows the shear failure in columns.

Fig. 8 Shear Failure in Column

4.4 Torsional Failures

There is a probability of columns subjecting to torsional moments. Usually, columns are designed for axial, bending, and shear forces. However, due to the irregularities in the structure, the torsional behavior of the column can be observed. Columns are torsionally rigid when they are compared with the beam as they have reinforcement around the section and links are provided at closer spacings. However, if the torque exceeds the limiting values, columns could be failed in torsion. The article published as 6 causes of beam failures discuss the torsional failure of beams and their cracking patterns.

4.5 Combined Stress Failure

Concrete columns are subjected to bending moments in addition to the axial forces due to the eccentric moment generated due to the unbalance loads.
Bending stress and axial compression stress are added together to get the final stress in the section.
It will not be uniform stress. However, failure of the column will be based on the above criteria discussed under the pure compression failure.
The most important thing that the designer should consider in the design is the possible load combination and alternative loading effects. When there are significant deviations in the spans, we need to be alert about the design.

4.7 Failure due to the Errors in the Construction

There may be many errors that could happen in construction and they also can categorize under types of column failure. Employing qualified engineer to the project and close supervision of construction work will minimize these types of column failure.

- Mistakenly reduce the bar diameter
- Construct an incorrect column in the location
- Changes in the grade of concrete
- Lack of strength in the concrete due to the failure of the concrete supplier.

4.8 Failure due to Construction Defects

Columns could fail due to the construction defects. For example, improperly treated honeycomb in a column could lead to a failure when the loads are applied. These types of column failure can be avoided if attended with much care. Cavities inside the column that were not filled properly with construction ground reduce the compressive area of the column. As a result, its axial capacity will be reduced. Similar instances could cause failure.

5. CONCLUSION

In this paper an understanding of the properties and performances of fiber reinforced polymers (FRP) has been developed through the study of their different applications for structural retrofitting. Design guidelines and recommendations should be made more readily available to ensure more rapid and effective applications of FRP as a seismic material. This innovative technique shows a great potential when disruption of traffic or activity of the building is not possible or only for a limited time. Indeed, applying fiber reinforced polymers (FRP) layers is very quick and does not require specialized equipment's (crane,etc.). With increasing acceptance by the industry over the past years, FRP have become commonly used in different types of structural retrofitting.

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