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Composite Materials: The Present Scenario, Future Trends & Its Applications Focusing on Earthquake Resistant Building Constructions

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Abstract—*Materials play a vital role in the development of human civilization & country's infrastructure. The historians have recognized the importance of materials in early periods of civilization by the name of most extensively used materials, for example, Stone Age, Bronze Age, Iron Edge etc. In recent trends there has been an increasing interest in composites containing low density and low cost materials. Composite materials are combinations of two or more than two materials obtained by artificial combinations of different materials in order to achieve the properties that the individual components cannot attain themselves. The applications of the composite materials start from simple household to heavy industrial purposes including in the Constructions of Earthquake Resistant Building. The present paper emphasizes on some of the important developments in the field of application of textile materials in earthquake resistance constructions. Cement concrete reinforced with steel rods and rings are very popular in ordinary construction material. One of the major drawbacks of using steel is its susceptibility to environmental attack which can severely reduce the strength and life of concrete structures. Recent developments in the field of fiber reinforced cement (FRCs) composites have resulted in the development of highly efficient construction materials. The FRCs are unaffected by electro-mechanical deterioration and can resist corrosive effects of acids, alkalis, salts and similar aggregates under a wide range of temperatures. The fibers used in FRCs along with their properties, various techniques & application on the new and existing masonry structures to protect them from earthquake have been specially discussed here.*

Keywords*: Earthquake, Environmental Attack, Textile Materials, Fiber Reinforced Cement, Masonry Structure, Retrofitting.*

1. INTRODUCTION

In general every construction works in any developing country, such as many of our houses, schools, hospitals, bridges, roads are made from concrete and steel. However, such structures do not make sense in severe earthquake-prone areas such Kashmir, Himachal Pradesh, Uttarakhand, Nepal, Bihar, Delhi, Mumbai etc. Many concrete and steel reinforced masonry structures are widely present around the world. These structures are designed to withstand gravity loads and are not capable to withstand seismic forces during earthquake and caused wide spread damages. To protect the historic structural heritage and monuments of the country, it is essential to develop innovative techniques and technology for rehabilitating deteriorating structures.

After earthquake other than life concern, the removal and transportation of large a mounts of concrete and masonry material causes concentrations of weight, dust, excessive noise, and requires long periods of time to gain strength before the building can be reopened for service. In this paper the focus is given on application of composite materials that enables the new material to resist extreme loads, such as earthquakes and high winds, while remaining functional. In spite of the progress made, it observed that the bridge-building industry is slow to trust new materials. 'Adoption of new materials in bridge engineering is somewhat slow because the profession demands a high level of reliability before new materials find their way into practice.

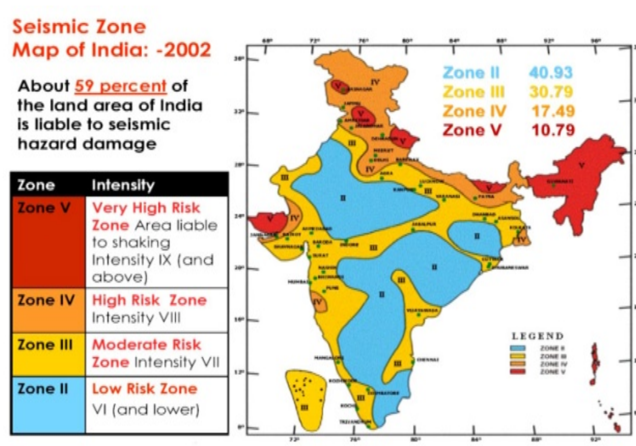


Fig. 1 Seismic zonation and intensity map of India

Repair and reconstructions of these structures with like materials is often complex, expensive, hazardous and disruptive to the operations of the building. Most of these structures requires strengthening or seismic upgrading work in order to ensure their conservation and functional use. Fiber Reinforced Cement (FRC) Composite materials , originally developed for the aerospace indus try, are being considered for application to the repair of buildings due to their low weight, ease of handling and quick implementation. Review of literature indicates that numerous studies were conducted in the pas t to study the behaviour of Fiber Reinforced Cement (FRC) Composite materials. Research and developments are going on to adapt these materials to the repair of buildings and civil structures . suitable configurations of fiber and polymer matrix are being developed to resist the complex and multidirectional stress fields present in building structural members . At the same time , the large volumes of material required for building repair and the low cost of the traditional building materials create a mandate for economy in the selection of FRC materials for construction work.

Evolution of engineering materials

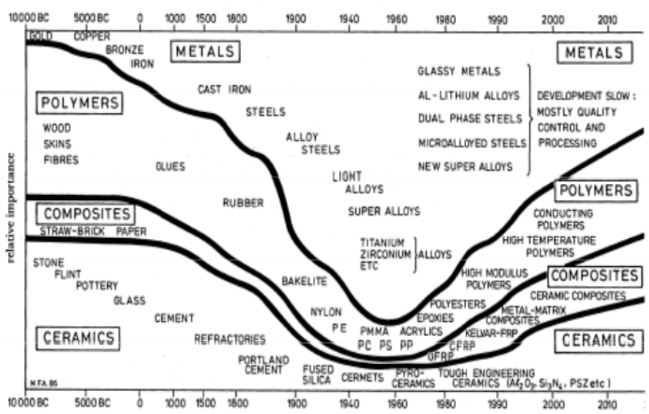


Fig. 2: Evolution of Engineering Materials

Characteristics of composite materials:

Composite material is a material composed of two or more distinct phases (matrix phase and dispersed phase/ reinforced phase) and having bulk properties significantly different from those of any of the constituents.

Matrix phase: The primary phase, having a continuous character, is called matrix. Matrix is usually more ductile and less hard phase. It holds the dispersed phase and shares a load with it.

What are the functions of a matrix?

1. Holds the fibres together
2. Protects the fibres from environment
3. Protects the fibres from abrasion
4. Helps to maintain the distribution of fibres
5. Distributes the loads evenly between fibres
6. Enhances some of the properties of the resulting material and structural component such as that fibre alone is not able to impart.
7. Provides better finish to final product.

Dispersed (reinforcing) phase

The second phase (or phases) is embedded in the matrix in a discontinuous form. This secondary phase is called dispersed phase. Dispersed phase is usually stronger than the matrix, therefore it is sometimes called reinforcing phase.

What are the functions of reinforcement?

1. Contribute desired properties
2. Load carrying
3. Transfer the strength to matrix

Classification of composite materials

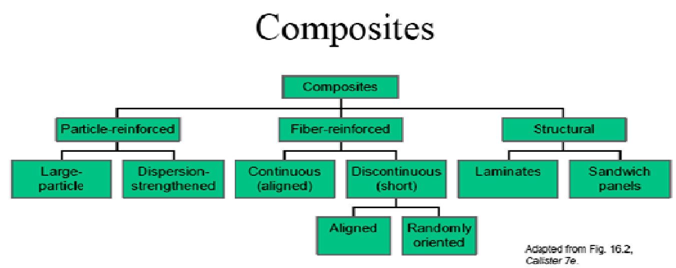


Fig. 3: Classification of composite materials

(i) Based on matrix materials:

(a) Metal Matrix Composites (MMC): Metal Matrix Composites are composed of a metallic matrix (aluminum, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase. It increases Yield Strss, Tensile Strength and Creep Resistance.

(b)Ceramic Matrix Composites (CMC): Ceramic Matrix Composites are composed of a ceramic matrix and embedded fibers of other ceramic material (dispersed phase). . It increases fracture toughness.

(c)Polymer Matrix Composites (PMC): Polymer Matrix Composites are composed of a matrix from thermoset (Unsaturated Polyester (UP), Epoxiy (EP)) or thermoplastic (Polycarbonate (PC), Polyvinylchloride, Nylon, Polysterene) and embedded glass, carbon, steel or Kevlar fibers. . It increases modulus, Yield Stress, Tensile Strength and Creep Resistance.

(Ii) Based On Reinforcing Material Structure:

(a) Particulate Composites: Particulate Composites consist of a matrix reinforced by a dispersed phase in form of particles.

(I) Composites with random orientation of particles.

(II) Composites with preferred orientation of particles. Dispersed phase of these materials consists of two-dimensional flat platelets (flakes), laid parallel to each other.

(b)Fibrous Composites:

(I)Short-fiber reinforced composites. Short-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of discontinuous fibers (length < 100*diameter).

(a) Composites with random orientation of fibers.

(b) Composites with preferred orientation of fibers.

(II) Long-fiber reinforced composites. Long-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of continuous fibers.
(a) Unidirectional orientation of fibers.
(b) Bidirectional orientation of fibers (woven).
(c)Laminate Composites:
When a fiber reinforced composite consists of several layers with different fiber orientations, it is called multilayer (angle-ply) composite.
(I)Laminar Composites: Sheets (panels) with different orientation of high strength directions are stacked and glued together, producing a material with more isotropic strength in the plane. Examples are plywood and modern skis.
(II)Sandwich Panels: Strong, stiff end sheets are bonded to lightweight core structure, for instance honeycomb.which provides strength to shear. It is used in roofs, walls, and aircraft structures.

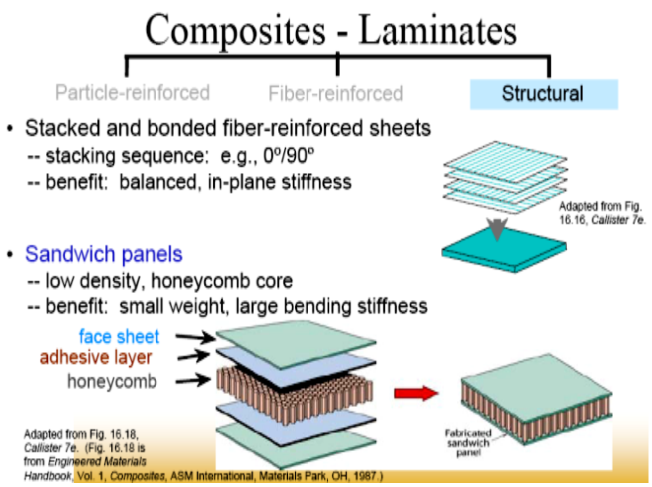


Fig. 4: Structural Composite

Why composites? The biggest advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application. Composites also provide design flexibility because many of them can be moulded into complex shapes. The downside is often the cost. Although the resulting product is more efficient, the raw materials are often expensive.

Damages due to Earthquake: The Indian subcontinent has a history of devastating earthquakes. The major reason for the high frequency and intensity of the earthquakes is that the Indian plate is driving into Asia at a rate of approximately 47 mm/year. Geographical statistics of India show that almost 54% of the land is vulnerable to earthquakes. Most earthquake-related deaths are caused by the collapse of structures and the construction practices play a tremendous role in the death toll of an earthquake. In southern Italy in 1909 more than 100,000 people perished in an earthquake that struck the region. A larger earthquake that struck San Francisco in 1906 killed fewer people (about 700) because building construction practices were different type (predominantly wood).

Survival rates in the San Francisco earthquake were about 98% and that of southern Italy was between 33% and 45%). Building practices can make all the difference in earthquakes, even a moderate rupture beneath a city with structures unprepared for shaking can produce tens of thousands of casualties.

Although probably the most important, direct shaking effects are not the only hazard associated with earthquakes, other effects such as landslides, liquefaction, and tsunamis have also played important part in destruction produced by earthquakes.

Earthquake is defined as the seismic vibration which generates ground motion both in horizontal and vertical directions. Due to the inertia of the structure this ground motion generates shear stress and bending moment in the structural framework. The level of damage done to a structure depends on the amplitude and the duration of shaking. In earthquake resistant design it is important to ensure ductility i.e. the structure should be able to deform without causing failure. Strength and ductility of structures depend mainly on proper detailing of the reinforcement in beam-column joints. The flow of forces within a beam-column joint may be interrupted if the shear strength of the joint is not adequately provided.

Under seismic forces, the beam-column joint region is subjected to horizontal and vertical shear forces whose magnitudes are many times higher than those within the adjacent beams and columns. Conventional concrete loses its tensile resistance after the formation of multiple cracks. So, the joints need to be more ductile to efficiently bear or dissipate the seismic forces. Most failures in earthquake-affected structures are observed at the joint. A construction joint is placed in the column very close to the beam-column joint. This leads to shear or bending failure at or very close to the joint. The high compressive stress in concrete may also cause crushing of concrete. All concrete structures create a hinge at the joint and more the number of hinge higher will be the probability of collapse of concrete.

In many structures these details have not been followed due to various difficulties occurred at the constructional site. The most common cause of failure of structures is lack of confinement. Rehabilitation and retrofitting strategy must be alleviated to protect these structures.

Shaking of Building Structures due to earthquakes

Shaking of the ground caused by the passage of seismic waves, especially the surface waves near the epicentre of the earthquake are responsible for the most damage during an earthquake.

The intensity of ground shaking depends on:

- Conditions of the local geology influence events:
- Duration and intensity of the earthquake

- The distance from the epicentre.

When the ground shakes, buildings respond to the accelerations transmitted from the ground through the structure's foundation. The inertia of the building can cause shearing of the structure which can concentrate stresses on the weak walls or joints in the structure resulting in failure or total collapse. The type of shaking and the frequency of shaking depends on the structure. Tall buildings tend to amplify the motions of longer period motions when compared with small buildings. Each structure has a resonance frequency that is characteristic of the building. Predicting the precise behaviour of buildings is complicated, a rule of thumb is that the period of resonance is about equal to 0.1 times the number of stories in the structure. Thus Macelwane Hall resonates at about 0.3 seconds period, and Griesedeck at about 1.4 seconds. Taller buildings also tend to shake longer than short buildings, which can make them relatively more susceptible to damage. Fortunately many tall buildings are constructed to withstand strong winds and some precautions have been taken to reduce their tendency to shake. And they can be made resistant to earthquake vibrations. In many regions of limited resources and/or old structures, the structures are not very well suited to earthquake induced strains and collapse of adobe-style construction has caused thousands of deaths in the last decade. The worst possible structure for earthquake regions is the unreinforced masonry.

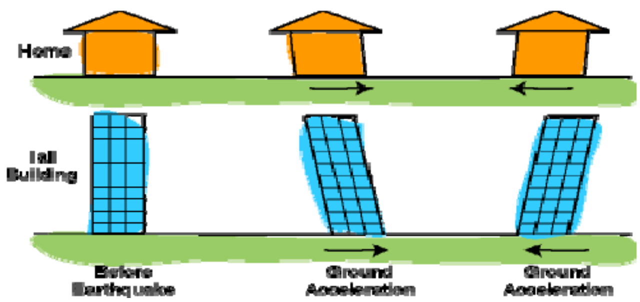


Fig. 5: Shaking of Building Structures

Application of Composite Materials in Earthquake Resistant Building Construction:

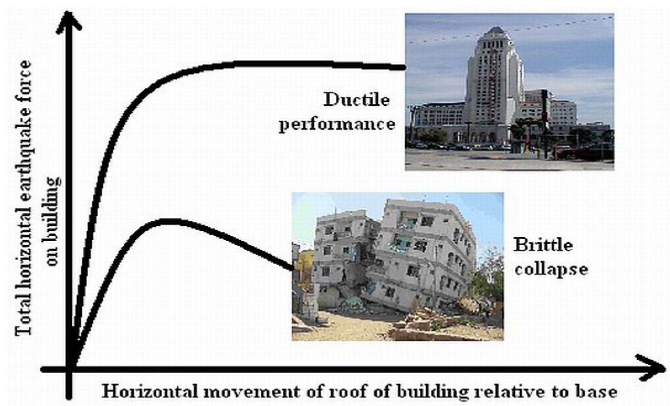
Earthquake-resistant structures are structures designed to withstand earthquakes. While no structure can be entirely immune to damage from earthquakes, the goal of earthquake-resistant construction is to erect structures that are fare better during seismic activity than their conventional counterparts. According to building codes, earthquake-resistant structures are intended to withstand the largest earthquake of a certain probability that is likely to occur at their location. This means the loss of life should be minimized by preventing collapse of the buildings for rare earthquakes while the loss of functionality should be limited for more frequent ones. To fight with earthquake destruction, the only method available to ancient architects was to build their landmark structures to last, often by making them excessively stiff and strong.

Seismic Constructions Design: Using Fiber Reinforced Cement (FRC) Composite

The objectives of this paper is to develop seismic

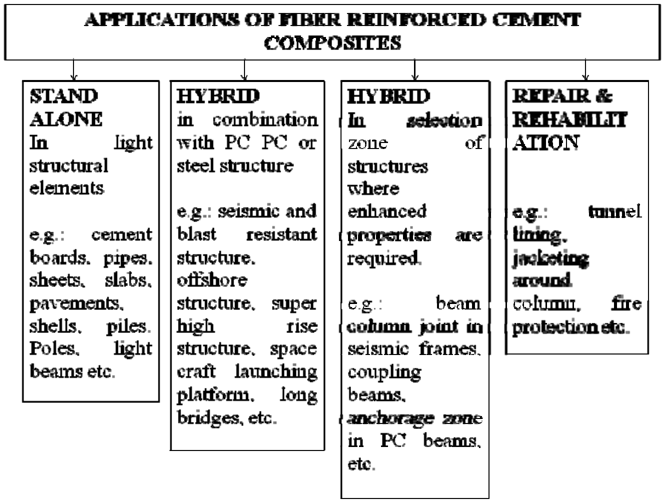
Constructions design guidance using composite materials, which is compatible with the conventional construction design technique. Concepts and technique may be summarized as follows:

Fiber Reinforced Cement (FRC) Composite materials are widely used in many structural applications where their mechanical performances are of primary importance. The stiffness and the strength of composites are dependent upon the mechanical properties of the constituents, but also upon the stress transfer processes occurring at the fibermatrix interface. Fiber Reinforced Cement (FRC) or Concrete composites are generally defined as composites with two main components, the fiber and the matrix.



Fiber reinforced cement based composites have made striking advances and gained enormous momentum over the past four decades. This is due in particular to several developments involving the matrix, the fiber, the fiber-matrix interface, the composite production process, a better understanding of the fundamental mechanisms controlling their particular behaviour, and a continually improving cost performance ratio. The FRCs are unaffected by electro-mechanical deterioration and can resist corrosive effects of acids, alkalis, salts and similar aggregates under a wide range of temperatures. FRCs thus holds a very distinct advantage over steel as an external reinforcing device. Moreover, FRCs are available in the form of laminas and different thickness and orientation can be given to different layers to tailor its strength according to specific requirements. Again, FRCs as post-reinforcements possess high specific strength (strength/weight ratio) as well as they are very light and easy to handle. The FRCs are available as unidirectional fibers of a huge length. Therefore, joints in the reinforcement can be avoided very easily. Moreover, the corrosion of the reinforcements can be avoided completely. Research work is gaining momentum on the application of composite materials as post- reinforcement.

Some potential applications of FRCs in Earthquake resistant construction:



The Historic Dharahara Tower at Nepal, Before And After Collapse DueTo The Devastating Seismic Effect (It Could Have Been Avoided if the Application Of Our Research Technique Could Have Been Commercialised) occurred on 25 April 2015 at 11:56 a.m.

FRCs can be used in the concrete structures in the following forms:

- Plates- at a face to improve the tension capacity.
- Bars - as reinforcement in beams and slabs replacing the steel bars.
- Cables- as tendons and post tension members in suspension and bridge girders.
- Wraps - around concrete members to confine concrete and improve the compressive strength

2. CONCLUSION

From the concept of composite materials, it is understood that composite materials can be used as a viable alternative for conventional reinforced concrete frames in earthquake prone regions. Fiber reinforced cement composites are found effective in construction and rehabilitation of masonry structures. Fibers used are high performance fibers such as aramid, carbon or glass. These fibers are judged more efficient than steel. Prefabrication and reduced member sizes are clear advantages of the composite frame as compared to reinforced concrete frames. Moreover the composite frame - which was designed for a fire resistance - was virtually automatically capable to withstand also severe earthquake loads. However, proper earthquake-resistant detailing of connections and critical regions is of paramount necessity.

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