Review Paper on Experimental Study on Freeze & Thaw Resistance of Carbon Fibre Reinforced Concrete

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Abstract:-

Freeze and Thaw resistance is an important durability criterion of concrete in cool areas. To further improvement in freezing and thawing resistance of concrete, carbon Fibre was added into the concrete. Rehashed absorbing water will speed up the freeze-thaw harm of concrete, resulting in the declination in compressive strength of concrete.

Consequently, a repetitive Freeze-Thaw test, in which samples (Specimens) of carbon-Fibre-Reinforced concrete were frozen for 16h followed by 8h of thawing, was completed to gauge the relationship of the carbon Fibre and Freeze-Thaw resistance. The outcomes show that adding Carbon Fibre content upto optimum limit into concrete could diminish the rate of weight loss of the concrete during the Freeze-Thaw investigation. The increment in Fibre content into the concrete resulted in improvement in compressive strength (28 days) of concrete significantly.

The experimental results indicate that the Fibre Reinforced concrete made with carbon Fibre is suitable as construction material in cold regions when the optimal addition of amount of carbon Fibre is 1 % of the weight of the cement.

***Keywords*: Carbon Fibre Reinforced concrete, Carbon Fibre, Durability, Freeze-Thaw Resistance, Compressive strength.**

Introduction

Concrete is a versatile widely utilized construction material. Since concrete has been laid out as a material for construction, investigators have been attempting to work on its quality improvement. As a brittle material, concrete is strong under compression and weak under tension as well as in Flexure. This issue might be lightened by the addition of short carbon Fibres.

Fibre Reinforced Concrete:-

Fibre Reinforced Concrete is concrete containing fibrous material such as steel Fibres, synthetic Fibres, glass Fibres, carbon Fibres and natural Fibres as an additional material in plain concrete. Fibrous material increases the structural integrity of concrete.

Fibrous material is used in concrete to reduce cracking due to drying shrinkage and to plastic shrinkage. It is also helpful in reduction in bleeding of water in concrete and permeability of concrete. Fibres produce higher impact resistance, crack and abrasion resistance in concrete.

Advantages of Fibre Reinforced Concrete:-

- Improve strength of concrete
- Improve frost resistance
- Improve abrasion resistance and impact resistance
- Increase resistance to shrinkage effect
- Increase structural strength
- Improve ductility
- Reduce crack width
- Reduction in steel requirement

Carbon Fibre Reinforced Concrete:

Carbon fibres are fibres about 5 to 10 micrometers in diameter and composed mostly of carbon atoms. Carbon fibres have several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion. Carbon fibres are usually combined with other materials to form a composite. When impregnated with a plastic resin and baked it forms carbon fibre reinforced polymer (often referred to as carbon fibre) which has a very high strength-to-weight ratio, and is extremely rigid although somewhat brittle. Carbon fibres are also composited with other materials, such as graphite, to form reinforced carbon composites, which have a very high heat tolerance.

Advantages of CFRC:

a. High Tensile strength
b. High stiffness
c. High strength to weight ratio
d. Low thermal expansion
e. High temperature tolerance
f. Higher chemical resistance

Literature Review

To improve the quality of concrete, various types of Fibre-reinforced concretes that are made of cement, aggregate, water and scattered Fibres. The extensively used Fibres are steel Fibres, synthetic Fibres, polypropylene Fibres, glass Fibres and carbon Fibres.

Now days, polypropylene Fibres, steel Fibres, carbon Fibres are the most common materials for Fibre Reinforced Concrete.

Karahan et al reported a**dding polypropylene** Fibres into concrete could marginally increment the freeze-thaw durability.

The mixing of polypropylene Fibres in concrete resulted increase in compressive strength, improvement in non-deformability of the concrete, increase the fatigue and impact resistance and increase the toughness. Due to lower elastic modulus of polypropylene Fibres, bonding between concrete and polypropylene Fibre is not strong at all.

Yu et al reported steel Fibres can also be used to improve the frost resistance of concrete.

Steel Fibre Reinforced Concrete has a high compressive strength, crack resistance, and toughness. However steel Fibres can easily rust in humid environment. The mixing of steel Fibres diminishes the flow ability of Fibre Reinforcement Concrete somewhat, resulted in reducing workability of Fibre Reinforced Concrete significantly.

Fibre reinforced polymer plated beams

Plates and Sheets of Fibre reinforced polymer offer incredibly productive choice to steel plates as external reinforcement for strengthening and rehabilitation applications. Since Fibre Reinforced Polymers were first explored as a plating material in Switzerland in the 1980s (Meier et al. 1992), there has been a lot of examination into their structural behavior. Many of major research studies have been acted in Europe (Deuring 1993; Lane et al. 1997; Meier and Winistorfer 1995; Quantrill et al. 1995; Rostasy et al. 1992; Canada (Alexander and Cheng 1996; Bizindavyi and Neale 1997; Swamy and Mukhopadhyaya 1995; Varastehpour and Hamelin 1995), Heffernan et al. 1996; Shehata et al. 1997), Chaallal et al. 1997; Green et al. 1997; and the United States (An et al. 1991; Arduini and Nanni 1998; Chajes et al. 1996; Malek et al. 1998; Malvar et al. 1995; Nanni 1997; Plevris et al. 1995; Saadatmanesh and Ehsani 1990; Triantafillou 1998). Field applications utilizing FRPs to fortify supported substantial designs have been executed in Europe (Steiner 1996; Nanni 1997), Japan (Ichimasu et al. 1993), and all the more as of late North America (Labossière et al. 1997; Chajes et al. 1996).

To sum up, the general impacts of plating for flexure on a built up concrete beam can be expressed as follows, assuming that premature failure mechanism are avoided:

1. Increased flexural limit under both ultimate and service load conditions. It is reflected in yielding of crack and ultimate moment.
2. Uniformly distributed finer and more evenly cracks in concrete. Reduction in crack width in plated beam.
3. Small amount increment in post cracking flexural stiffness.
4. Reduce ductility. The reduction in ductility might be expected to change from under reinforced section to an over reinforced section.

Cold climate research on fibre reinforced polymer plated beams

By far most of concrete structures that require rehabilitation or strengthening are exposed to extreme environmental conditions.

A significant number of these severe environmental conditions are the result of cold environment conditions for example Freeze-Thaw action, low temperature, and exposure to defrost salts. Due to this, the environmental durability of both the materials and techniques used in rehabilitation applications is of utmost importance, especially in colder climates such as those found in Canada. However, very little research has been performed relating to the environmental durability of Fibre Reinforced Polymer plated members.

Kaiser in 1989 investigated a series of Freeze and Thaw test on beams plated with Carbon Fibre Reinforced Polymer Sheets. He observed that there was no unfavourable impact on the overall structural performance of beam tested after 100 cycles of freeze and thaw from +25 ̊C to -25 ̊C. Baumert et al. in 1996 explored the impact of outrageous cold on the structural performance of Fibre Reinforced Polymer plated beams. That's what these tests showed, for Carbon Fibre reinforced polymer plated (CFRP) beams presented to a temperature distinction of +21°C to - 27°C, there were no unfriendly effects on structural behaviour of beams when subjected to a static load.

Green et al. in 1997 also conducted a series of tests to observe the freeze & thaw durability of beams strengthened with CFRP sheets. The beams were subjected to 50 freeze & thaw cycles from -18°C to +15°C. It was observed that freeze & thaw cycling didn't impact the strength of the concrete beams, the FRP sheets, or the FRP to concrete bond (although no specific effort was made to study bond behaviour).

Tysl et al. (1998) studied the effect of surface deterioration on the freeze–thaw durability of CFRP plated reinforced concrete beams. It was found that neither freeze-thaw cycling nor partial surface deterioration had a diminishing effect on the overall load deflection response of the plated beams.

Very little researches been done on the effects of freeze - thaw cycling specifically on Fibre Reinforced Polymers. Daniel and Ishai in 1994 express that, since the fibres in Fibre Reinforced Polymers are generally least sensitive to the climate conditions, thermal effects are most observable in framework overwhelmed properties, such as compressive strength and transverse tensile strength, and in-plane shear. Longitudinal rigidity isn't thought of as essentially impacted by temperature impacts.

Tests directed by Dutta in 1988, where FRPs were exposed to 150 freeze-defrost cycles from +23°C to -40°C, however, showed that the rigidity (Tensile Strength) of glass-Epoxy fibre reinforced polymer was decreased by about 10% due to Freeze-Thaw cycling. Thermal Cycling produce significant degradation of off-axis properties for carbon fibre reinforced polymer.

For concrete, crumbling because of freeze-defrost is brought about by freezing of pore water inside the concrete. If the pores are too little, the extension brought about by freezing can apply stresses on the concrete that break the concrete and subsequently cause crumbling.

Air entraining agent of 7% to 8% depending on the size of aggregate can essentially dispense with this Freeze-Thaw damage (Neville in 1995).

Results & Conclusions

The slump value was in decreasing order with increasing in amount of carbon fibre. The addition of carbon fibre in concrete in larger amount reduces the workability of concrete while it is also responsible to knotting of the fibres.

Effect of Carbon Fibre on compressive strength of concrete:

Mechanical Properties of concrete decreases with increases in Freeze-Thaw Cycles in which the compressive strength is the most delegated parameter.

When a small quantity of carbon fibre was considered the compressive strength of the Carbon Fibre Reinforced Concrete (CFRC) was lower than that of Plain Cement Concrete and when the quantity added more than 0.5% by weight of cement, the compressive strength of Carbon Fibre Reinforced Concrete (CFRC) was more than that of Plain Cement Concrete. Thus optimum value of Carbon Fibre Resins is 1% by Weight of Cement. the compressive strength decline from the beginning and afterward an increment with the increment of carbon fibre resins in concrete.

There are several types of micro cracks develop in concrete which can be classified in to two categories according to the age of concrete, first one is plastic shrinkage cracks and second one is cracks developed due to concrete hardening. Carbon fibre resins have greater effect on plastic shrinkage as compare to crack developed due to hardening of concrete.

Concrete have smaller tensile strength before hardening stage (Plastic Deformation Stage). When it comes under hardening stage many micro cracks develops in the interior of concrete due to evaporation of moisture content from the concrete. Fibre reinforcement mechanism is mainly deals with the improvement of crack resistance. Fibre resins would be distributed in the concrete as fine reinforcement which can be resist the tensile stresses develops through the deformation and also can control the shrinkage of concrete that reduces the development of cracks resulting in better performance of concrete in all aspects.

However fibre resins instigates the interface defects in to the composite material that may be harmful for the mechanical properties of the concrete. The impact of carbon fibre resins in concrete can be control by some factor such as Amount of Fibre Content provided, distance between fibres, bond between fibre resins and concrete material.

According to this experimental study, at first the Carbon fibre content was not adequate to oppose plastic shrinkage resulting in development of cracks planes at higher rate that compressive strength. When the amount of carbon fibre content increased an enormous number of plastic shrinkage cracks were eliminated that formed in concrete and the constructive outcome was prominent than the presented feeble area. The concept of adding carbon fibre content in concrete makes the compressive strength increase rapidly and showing approximate linearly growth of compressive strength. Increment in carbon fibre content reduces the strength significantly resulted in declination in compressive strength.

Freeze-Thaw Resistance of Carbon Fibre Reinforced Concrete:

The frost resistance mark displayed on concrete cube in increasing pattern with increase in carbon fibre content before 1 % by weight of cement. When carbon fibre content increase more than 1% then, it shown not any further improvement in frost resistance in concrete. When the water present in pores experienced frost resistance its volume increased and which would cause of tensile stress development and micro cracks forms. The improvement in frost resistance by using carbon fibre in concrete prevented the formation of micro cracks. Therefore the addition of optimum carbon fibre content that is 1 % by weight of cement used can improve the frost resistance in concrete.

Conclusions:

- By increasing Carbon Fibre Content from 0% to 1.25% by weight of cement showing a decrease pattern in workability. Slump value decreases from 146mm to 78mm.
- The mixing of Carbon fibre into concrete could compressive strength decrease first and cause increase after that, the value of maximum compressive strength after 50 cycles reported is 47.26MPa which is just only 0.381% lower than its 28 days strength.
- The mixing of carbon fibre content into concrete can decrease the weight loss of the concrete.

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