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4 AUTHORS, INCLUDING:

Hardeep Rai
Guru Nanak Dev Engineering College

Harvinder Singh
Guru Nanak Dev Engineering College

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Health Monitoring and Retrofitting of Structures-A Review

Harpreet Gaba
Assistant Professor, Civil Engineering Department, Guru Nanak Dev Engineering College, Gill Park, Ludhiana-141006, Email: preetgaba@gmail.com
Hardeep Singh Rai
Professor, Civil Engineering Department, Guru Nanak Dev Engineering College, Gill Park, Ludhiana-141006, Email: hs@raiandrai.com
S.P.Singh
Professor, Civil Engineering Department N.I.T., Jallandhar- 144011, Email: spsnitj@gmail.com
Harvinder Singh
Associate Professor, Civil Engineering Department, Guru Nanak Dev Engineering College, Gill Park, Ludhiana-141006, Email: hvs1221@gmail.com

ABSTRACT: The performance of a structural system can be considered as satisfactory if it transfers the applied loads safely, and without causing any distress in its constituent members. However, the deterioration of concrete structures with time due to number of reasons may become responsible for the reduction in the strength of the members. Even a minor reduction in the strength should not be ignored since it carries the potential to cause a major damage and cause failure either leading to a wide scale of loss of life and property, or halting some revenue generating activity or both. It is this possibility which calls for rigorous inspection of structures on a regular basis or in other words structural health monitoring. The concept of structural health monitoring (SHM) helps in identifying the damage at early level of distress, if any and provides warning of the unsafe condition of the structure. Also, retrofitting of structures with laminates has also been progressed and has been used in the construction of structures throughout the world. Laminates like ferrocement, carbon fibers etc. offers advantages such as low labour and construction costs, high stiffness, ease of installation etc. In the present paper, a review of research studies has been presented to provide an outline on structural health monitoring and retrofitting of structures as these concepts have received prominence due to repetitive mal-functioning of several structures.

KEY WORDS: Structural health monitoring, concrete, retrofitting, fibers

INTRODUCTION

A structure is defined as a member that carries the load and transfers this load to the foundation below. The proper function of the structure must be served during its life. The major problem that the today's construction industry is facing is the deterioration of concrete structures. The deterioration starts with passage of time. A structure when damaged has to be inspected and maintained. Even a minor damage should not be ignored since it carries the potential to cause damage and cause failure either leading to a wide scale of loss of life and property, or halting some revenue earning activity or both. It is this possibility which calls for rigorous inspection of structures on a regular basis or in other words structural health monitoring (SHM).

It has become necessary to take a decision whether to demolish a distressed structure or to restore the same. Reconstruction involves a lot of economic interference as compared to the retrofitting. The retrofitting of structures damaged due to various natural or artificial reasons like blasts, fires, earthquakes etc. is a matter of concern these days.

The present paper discusses various studies on structural health monitoring for damage detection and identification and also on methods of retrofitting a damaged structures and its elements.

LITERATURE REVIEW

Structural health monitoring and retrofitting have received prominence due to repetitive mal-functioning of several structures. Some studies to examine SHM and Retrofitting of structures are also viewed. Brief review of various studies has been done so far in the area along with their limitations, if any, is presented in this section.

Damage Detection of Structures

The seismic performance and retrofit of Reinforced Concrete (RC) buildings was studied and it was revealed by (J.M.Bracci et.al 1997) that reliable estimates of story demands versus capacities for use in seismic performance. The capacity spectrum method has been extended and resulting range of demands were compared with inelastic force-deformation capacities for each story level. It was observed that pushover analysis provides a more rational basis for applying lateral force. The method used to damage the entire system was by shaking table-excitations derived from accelerogram.

It was also seen by Simmons et.al (2008) that even the dynamic loadings against the facades of buildings produced catastrophic failures and collapse. A test chamber taken in their study was a steel box with concrete filled end walls. RC beams were anchored to reaction structure to represent floor slabs of the building.

The load was increased uniformly up to failure and load deflection behaviour were monitored and recorded. The ultimate capacity and the load-deflection behaviour of geotextile fabrics were monitored and recorded. A retrofit system of fabrics achieved higher strength values. The major reason of failure of majority of the tests was tearing of fabric at the support. The viability of the concept used was dependent on the tensile strength of geotextile fabric used and anchorage system.

The pushover analysis for RC framed structures was studied by Lakshamanan (2006) and it was found that the strength decreases with the number and amplitude of cycles and that some deficiencies in the detailing of beam-column joints is reflected even after repair. As it was observed, there was a significant load drop in the post-peak load behaviour because of inherent detailing deficiency in the beam-column junction. These incoherent deficiencies in the detailing of beam-column joints get reflected even after repair. There was a need to evolve suitable performance factors when the system shows a negative stiffness.

The repair of slab-column connections using carbon fibre reinforced polymer (CFRP) sheets was also studied by Ian Robertson et.al (2004). Epoxy repairs of cracks in slab-column connection were able to restore lateral load capacity.

Concrete slab subjected to a blast load was also experimentally checked by Luccioni et.al (2008).The charge of 5kg Gelamon produced crushing of concrete in the circular zone of about 250mm diameter while it was about 300mm diameter for 12.5kg Gelamon.

Eight cylindrical specimens were extracted by Antonaci et.al (2010) from a concrete slab and evaluated under damage. For each specimen, rupture load was reached through a number of loading steps at increasing intensity.

The experimental and theoretical studies on the effect of structural topping on shear capacity of hollow core slaba was done by Girhammar et.al (2008). The testing program included construction of composite slabs 950mm in width, 6400mm in length and 280mm in thickness. Plain concrete and steel fiber reinforced concrete were used as topping material. The beams were cast at both ends of slabs to prevent cracking during transport. Pull-off test for tensile strength and compression strength test was done. Fiber reinforcement increased compressive strength of concrete topping by 20% whereas there was a slight increase in tensile/bond strength of fiber-reinforced concrete. When analytical evaluation of failure modes and ultimate load carrying capacities was made, it was seen that the predicted failure mode was shear tension failure in all cases. .The observed load bearing capacities were on an average 30% and 37% higher than from analytical results of Eurocode 2 method and Yang's method.

Results of analysis made from the use of rubbercrete were reported by Mohammad (2011). It was observed that there was a decrease in unit weight and increase in air content with an increase in crumb rubber replacement.

Strengthening of Structures

Various methods for the retrofitting of structures or structural elements are being used these days depending upon the economic study of a problem, Sometimes, if problem requires a retrofit instead of new construction, it become more important to review and employ best possible technique for this purpose. The brief literature in this case is listed below.

The results of an experimental study of the feasibility of strengthening a deficient RC cantilever slabs by bonding glass FRP (GFRP) strips/sheets were presented by Yeng et. al (2000). The results demonstrated significant increase in the ultimate load.

An emergency retrofit technique utilizing pre-tensioned high steel bars (PC bars) and steel plates was experimentally investigated and analytically evaluated by Miyagi, et.al (2004), that recovered lateral capacity and improved ductility.

The performances of a reactive powder concrete, RPC, as a new repair and retrofitting material was assessed for durability by Lee et.al (2006). The materials for cement-repair were Regular Concrete (RC) and High Strength Mortar (HSM) with 10% silica fume. RPC was used as a retrofitting material. Freeze-thaw cycle acceleration deterioration test was used to evaluate bond durability. Blocks were subjected to Freeze-thaw cycles at a rate of one cycle per 185 minutes as per with ASTM C666 (1997). For flexural and compressive strengthening test, flexural beams and cylinders were cast. For the rebar pull out tests, a total of 24 concrete cylinders were used. The effects of Flexural strengthening with bonding RPC of 10 mm and 20 mm thickness are about 150% and 200% more than those of normal strength concrete. The effects of compressive strengthening with bonding RPC of 10 mm and 20 mm thickness are about 200% and 300% more than those of normal strength concrete.

The research was also carried out by Sundarraja et.al (2009) by strengthening the RC beams by using GFRP sheets. The load carrying capacity of the retrofitted beams was more than control beams.

The effect of FRP on slabs was reported by Smith et.al (2009). The use of line loading affected the development of cracking as well as location of deboning initiation.

CONCLUSIONS

The concept of structural health monitoring and retrofitting helps to identify a damage detection of structural system and consequently their strength restoration. Their safe performance is necessary for ensuring safety to the human and economic activities thereby, it has become important to monitor the damage for its existence, location and extent and retrofit the same to enhance its performance features.

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