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Review

Repair and rehabilitation of concrete structures using confinement: A review

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HIGHLIGHTS

- Research findings on design and applications of repair techniques using confinement are discussed.
- FRP confinement has significant potential in repairing applications.
- The lacking in the current research development is discussed.
- Issues that hindered the widespread use of confinement are critically analysed.

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ABSTRACT

Repair and rehabilitation of existing damaged concrete structures have emerged as one of the most important construction activities globally. Money used on repairing damaged structures has exceeded that of the money used on building new structures. The earthquake strikes recently in Asian countries such as Japan and Borneo Malaysia have attracted the attention of structural engineers and scholars on the research and development of rapid repairing techniques. Confinement is one of the rapid repairing techniques that is popular and proven to be efficient in restoring the original capacities of damaged concrete. Although many research investigations have been done to confirm the suitability of these techniques in repairing damaged concrete structures, there are several barriers that hindered the widespread use in practical. These barriers include the lack of design and installation guidelines and long-term durability studies. This paper reviewed the use of confinement as a repairing technique and the design and installation processes involved in order to facilitate the research development in this field. The findings have reached a consensus that confinement repair techniques are effective as they can restore the original capacities of damaged concrete members. More investigations are still required to establish sufficient design guidelines and lastly, the confinement pressure loss over a service period should be tested to ensure the durability of the repaired concrete members.

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Abbreviations: FRP, fibre-reinforced polymer; CFRP, carbon fibre-reinforced polymer; GFRP, glass fibre-reinforced polymer; AFRP, aramid fibre-reinforced polymer; SCC, self-compacting concrete.

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1. Introduction

The integrity and stability of a concrete structure are compromised when it is damaged, be it due to seismic, impact or excessive loads. Actions are immediately required to be taken to arrest the damage and prevent the ultimate failure of the whole structure [1]. Various strategies are available to address the damage, such as downgrading the structure function, demolition, reconstruction of a part or the whole structure or arrest further damaging using rapid repair techniques [2]. Due to the time and economic considerations, the option to immediately repair the damaged part is the most favourable. Past research works have proven that repairing damaged concrete using external confinement is effective in restoring the original load carrying capacity of the concrete columns [3–7]. Besides, it was also reported that the confinement can restore the ductility of damaged concrete elements as well [8–11]. Despite extensive research being done in this area, concrete repair using confinement has not yet gained worldwide acceptance as a reliable method. This can be mainly due to the reasons as follows:

(1) The installation of confinement needs to be more economically competitive.
(2) More reliable data is required to be tested on practical on a long term basis.
(3) The design of such repair works need to be further developed.

The current study is aimed to provide an all-encompassing review and assessment of the existing confining methods that have been proposed to repair damaged concrete. To this end, extensive literature are first reviewed and classified according to their particular types. The variables and parameters as well as the reliability of the existing database are then carefully assessed. In the last part of this paper, a critical discussion is presented on the important factors that influence the effectiveness of these methods. It is believed that this paper can aid in closing the gap between research and large-scale industry adoption.

2. Types of confining methods

2.1. Concrete jacketing

Among many confining methods, concrete jacketing can be considered as the first method that has been attempted to repair damaged concrete columns. It is a technique to cover the damaged concrete with a new layer of reinforcement and concrete. Hence, this technique is also known as reinforced concrete jacketing (Fig. 1). The normal procedure to perform concrete jacketing is as shown in Fig. 2. It is generally acknowledged that the effectiveness of concrete jacketing is directly attributed from the monolithic behaviour of the composite element. Hence, the treatment of the interface must be handled with extra care. Roughening the concrete surface and the use of epoxy resin can increase the bonding of the new concrete layer with the old surface. Steel connectors might be used to replace dowel bars (Fig. 2). To reduce the thickness of the jacket, higher strength concrete might be used. As the compaction of the new concrete layer is difficult to be performed, self-compacting concrete (SCC) is used to replace the conventional concrete.

In 1988, Bett et al. [14] investigated the effectiveness of concrete jacketing in restoring the lateral load capacity of damaged columns. Lateral load and constant axial load were applied for all specimens. They reported that the columns repaired with concrete jacketing demonstrated higher stiffness and lateral load capacity than control columns. This clearly indicated the effectiveness of concrete jacketing in repairing damaged concrete structures. A few years after that, Ersoy et al. [15] extended the study in concrete jacketing by studying the behaviour of jacketed columns subjected to uniaxial load and the combination of uniaxial load and cyclic lateral load. As expected, they concluded that the jacketed

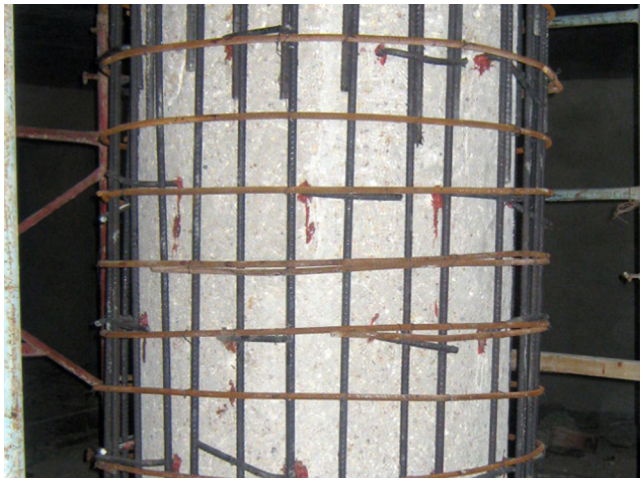

Fig. 1. Installation of dowel bars and new steel cage for concreting (Source: www.coreandcut.com [12]).