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Strengthening of RC beams using lightweight self-compacting cementitious composite

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Abstract

Repair and strengthening of reinforced concrete (RC) members in existing structures are very important to extend their service life. In this study, steel fiber reinforced high strength lightweight self-compacting concrete (SHLSCC) developed by the authors is applied for the strengthening of RC beams to improve their bending moment capacities. There are significant improvements in stiffness of strengthened beams as well as 14 - 58 % improvements in peak load when strengthened with 40 mm, 50 mm and 60 mm layers of SHLSCC. Application of SHLSCC in lower half (tension zone) of the beam increased its peak load by 33.1 %. Results indicate that the material may effectively be utilized for strengthening of bending members in existing structures.

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Keywords: lightweight concrete; micro fibers; strain hardening material; flexural strength; RC beam strengthening.

1. Introduction

Repair and strengthening of reinforced concrete (RC) members in existing structures are very important to extend their service life, otherwise the structure has to be demolished and reconstructed. Mostly, strengthening/repair of structures is more economical compared to its demolition and reconstruction [1]. Additional advantages are better sustainability and resource as well as energy saving. Strengthening requirements may arise due to:

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- The deterioration of the members, change in material properties or corrosion of reinforcement steel, reducing their load carrying capacities.
- Change in normative regulations with higher load and safety demands.
- Change in usage of the structure with higher load requirements.

In every case, the load carrying members need to be strengthened to enhance their capacities. Among these load carrying elements, flexural members have their own importance as they are always present in the buildings. This research study is conducted to improve the bending moment capacities of the flexural members. Different techniques have been used recently for the strengthening of flexural RC members. Most common of which is the use of FRP composites because of the advantages associated with this material like high strength to weight ratio, resistance to corrosion, easy and speedy application and minimum changes in the geometry of the strengthened members [2]. Hawelih et al. reported an increase of 30 - 98 % in the load capacities of RC beams strengthened in flexure using glass and carbon FRP [3]. In another study Akbarzadeh and Maghsoudi investigated behavior of reinforced high strength concrete continuous beams strengthened with carbon and glass FRP sheets and reported increase in load carrying capacities of tested specimens with increase in number of carbon FRP sheets, however, stiffness of the beams strengthened with glass FRP was less than those reinforced with carbon FRP [4]. Tahsiri et al. used RC jacketing and carbon FRP for strengthening of beams and noticed significant improvements in flexural and shear strengths of the beams [5]. Spadea et al. demonstrated good improvement in the load carrying capacities of the beams tested in bending, strengthened with carbon FRP compared to control beams [6]. However, there are some serious disadvantages associated with FRP like high cost of epoxy, inability of its application on wet surfaces and at low temperatures, lack of vapor permeability which may be harmful for concrete structure and difficulty in conducting post-earthquake assessment of damaged reinforced concrete members hidden under the undamaged FRP jackets. To cater for these problems, cement based mortars may be used [7].

For this reason textile fiber reinforced mortar (TRM) jacketing is being used for the strengthening of RC members. Elsanadedy et al. in 2013 demonstrated around 39 - 91 % increase in flexural capacity of RC beams using basalt textile reinforced mortar layers. TRM jacketing has also been applied to improve the shear capacities of RC beams [7]. Escrig et al. used different type of TRM in combination, for strengthening of RC beams and reported significant increase in flexural toughness and shear resistance as well as changing the failure mode from brittle to ductile [8].

Due to the established fact that fiber reinforced concrete has good tensile and flexural properties and its ease of application, it may also be used to enhance the load carrying capacities of flexural members by strengthening them. Therefore, recently by adding fibers to concrete, another strengthening material known as ductile fiber reinforced cementitious composites or strain hardening cementitious composites (SHCC) have been developed by different researchers and used for repair/strengthening of RC members [9-13]. According to a previous research, at failure the maximum load increased by 9.5 % while the displacement increased by 34.4 % for the beams strengthened using ductile fiber reinforced cementitious composite [11]. Exhibiting strain hardening behavior with increase in peak load deflection of 17.6 and 18.6 times and load carrying capacity of 2.5 - 3.5 times have been demonstrated, using 30 mm and 50 mm SHCC layers in tension zones, compared to the deflections and peak loads of plane concrete [14].

In strengthening the existing RC members, the aim would be to strengthen them with minimum addition of self-weight and avoiding vibrations in the structure, which may be unwanted for the existing structures and the surrounding ones. In such case, a strengthening concrete composite which is lightweight and self-compacting may be ideal for application. Therefore, a new concrete SHLSCC has been recently developed by the authors in the earlier phase of the research, which is lightweight, self-compacting and possesses good flexural strength [15]. In the current research, this SHLSCC is applied for the strengthening of RC beams to improve their bending moment capacities, investigate material effectiveness in strengthening and develop models to calculate the enhanced bending moment capacities of these strengthened RC beams.

2. Objectives and scope

The reason for the current research is to check the effectiveness of the newly developed self-compacting and lightweight strengthening material [15]. The strengthening layers of SHLSCC have been applied to the beams in