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Deficient RC slabs strengthened with combined FRP layer and high-performance fiber-reinforced cementitious composite

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Abstract: Today, strengthening of concrete structures in order to withstand excessive loads and increase the ductility of the structure, etc., using high-performance fiber-reinforced cementitious composite (HPFRCC) and fiber-reinforced polymer composite (FRP) is very common. In this study, a reinforced concrete (RC) slab under vertical load with different strengthening methods is investigated using the finite element method (FEM). If the quality of the slab is poor and 60% of the concrete strength is lower than the standard design status, the flexural stiffness of the slab is reduced by 75%, and the need for reinforcement is felt. By changing the width of the FRP layer with a strip arrangement from 50 to 100 cm and changing the thickness from 2 to 7 mm per slab with a width of 4 m, the maximum stiffness and bearing capacity are experienced with an increase of 23% and 10%. Also, by changing the width of the FRP layers in the checkered arrangement from 50 to 100 cm and changing the thickness from 2 to 7 mm, the maximum hardness and bearing capacity are experienced with an increase of 22% and 25%. It can be concluded that the use of the checkered arrangement is more effective in increasing the bearing capacity.

Keywords: concrete slab, strengthening method, FRP layer, HPFRCC, crack

1. Introduction

At present, various methods are used to repair and strengthen the members and connection of reinforced concrete (RC) structures. The new fiber reinforced polymer (FRP) material, in addition to being resistant to corrosive environments and having a tensile stiffness equal to or even higher than steel, is lightweight and easy to apply. For this reason, strengthening RC members with FRP sheets is an important issue. In recent years, the use of FRP sheets in the strengthening of the existing structures has received much attention, and therefore scientific studies on this issue seem necessary. Also, the weakness of concrete in the tensile zone and its replacement with HPFRCC concrete can eliminate the tensile weakness of concrete. Despite the fact that this method can be very effective in various fields such as repair and reinforcement of concrete members, but the study and finite element analysis on the strengthening of RC slabs compared to other concrete members is less investigated. One of the applications of FRP is to place the layers on the replacement part of ordinary concrete with HPFRCC concrete to strengthen the flexibility of concrete slabs in long openings. In these cases, if the initial design of the member is unsuitable, its stiffness and flexural strength can be increased by using FRP sheets. Therefore, in this study, the effect of FRP sheets located on HPFRCC concrete on the flexural strength of reinforced concrete slabs is investigated. For this purpose, the deficient RC slab of a bridge with two reduced levels of compressive strength of concrete is strengthened with the use of carbon fiber reinforced polymer (CFRP) sheets, and the validity of numerical studies is checked using the available test results.

2. Results and Discussion

Loading is done in the case of a slab with a span of 4 m according to the passage of the 700 kN tank and a slab with a span of 5 m according to the loading pattern of the train. The compressive strength of concrete in the initial state is 30 MPa. Initially, a 4 m concrete slab is placed under the tank load by reducing the compressive strength by 30% (the compressive strength of concrete, in this case, is equal to 21 MPa), and then with a further drop, the compressive strength of 30 MPa is decreased to 12 MPa to evaluate the behaviour of the system and simulate the state of damage or weakness in the concrete mix at the time of construction. Based on the result, it is determined that with a 30% decrease in concrete strength, the flexural stiffness of the slab by 89%, and with a 60% decrease in concrete strength, the initial flexural stiffness of the model is only 9% compared to the damaged model. By reducing the strength by 30% of the initial strength of concrete, tensile cracks were not observed in the model despite the displacement of 5 mm. However, with a further reduction of the resistance from 21 to 12 MPa, it was observed that the system underwent nonlinear behaviour, and tensile cracks were observed in the edges of the slab and the lower surface of the slab. If three layers of CFRP are used as a strip next to each other with a distance of half the width of each layer and different thicknesses, it is observed that by increasing the width from 50 to 100 cm in a fixed thickness (2 mm), the flexural stiffness increases by only 5%. By changing the thickness from 2 to 7 mm by keeping the width of the CFRP constant, it is observed that the bending stiffness is increased by 15% and the bearing capacity is increased by up to 8%. By changing the width from 50 to 100 cm and changing the thickness from 2 to 7 mm, the maximum stiffness and bearing capacity are experienced with an increase of 23% and 10%, respectively. In the case of using three layers of CFRP layers in a checkered pattern next to each other with a distance of half the width of each CFRP layer and different thicknesses, it is observed that by increasing the width from 50 to 100 cm in constant thickness (2 mm), bending stiffness increases by only 4% and bearing capacity increases by more than strip model (8%). By changing the thickness from 2 to 7 mm by keeping the width of the CFRP constant, it is observed that the bending stiffness has increased by 17% and the bearing capacity has increased by 21%. By changing the width from 50 to 100 cm and changing the thickness from 2 to 7 mm, the maximum hardness and bearing capacity are experienced with an increase of 22% and 25%. It can be concluded that the use of the checkered pattern is more effective in increasing the bearing capacity.

3. Concluding Remarks

Based on the results, it is determined that with a 30% decrease in concrete strength, the flexural stiffness of the slab decreased by 89%, and with a 60% decrease in concrete strength, the initial flexural stiffness of the specimen is only 9% compared to the damaged specimen. By reducing the strength by 30% of the initial strength of concrete, tensile cracks were not observed in the model in the displacement of 5 mm.

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