Compressive Membrane Action in FRP-strengthened Concrete Beams

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Summary

A comparison of compressive membrane action (CMA) between standard reinforced concrete (RC) members and RC members strengthened with Fibre Reinforced Polymer (FRP) is performed. Results indicate that the CMA effect decreases with increasing steel reinforcement for RC beams whereas this conclusion only holds for the effect of top steel reinforcement in case of FRP-strengthened RC beams. Results also show that the CMA effect increases with increasing concrete strength and is not significantly affected by the span-to-depth ratio for both RC and FRP-strengthened beam systems.

Keywords: Compressive membrane action; reinforced concrete; fibre reinforced polymers.

1. Introduction

Since compressive membrane action (CMA) has been recognized for laterally restrained members, research results have shown that CMA is beneficial in strength enhancement. With regard to the investigation of CMA in concrete members, a commonly applied method proposed by Park and Gamble [1], is applied here using plastic theory to consider CMA by expressing the strain compatibility and the force equilibrium. With the increased application of Fibre Reinforced Polymer (FRP) to strengthen concrete structures, it is desirable to conduct a comparison of CMA between standard concrete members and FRP-strengthened concrete members. The aim of this study is to investigate the differences of CMA between these two beam systems.

2. Results and Conclusion

After the extension of Park and Gamble's model to consider CMA for FRP-strengthened RC beams based on assumptions including those adopted in [2], the model was validated by a RC beam (A1) from [3] and a FRP-strengthened RC beam (FR-1) from [4]. The results show the applicability of the extended model. Then, the comparison of CMA between standard RC beams and FRP-strengthened RC beams is carried out by defining an enhancement factor α_{P} defined as $\alpha_{P,CMA,RC} = P_{CMA,RC}/P_0$ and $\alpha_{P,CMA,FRP} = P_{CMA,FRP}/P_{0,FRP}$, where $\alpha_{P,CMA,RC}$ and $\alpha_{P,CMA,FRP}$ are enhancement factors, $P_{CMA,RC}$ and $P_{CMA,FRP}$ are the peak resistances considering CMA, P_0 and $P_{0,FRP}$ are the peak resistances based on [2], respectively for RC beams and FRP-strengthened RC beams. A beam with configuration similar to the test specimen in [5] is adopted as the benchmark beam for a parameter study. The parameters consist of the steel reinforcement, concrete strength and span-to-depth ratio.
Fig. 1 shows that CMA is very significant in improving the beam strength. For example, a strength increase of 40% can be obtained, compared to the benchmark beam, when CMA is considered for a standard RC beam. Obviously $\alpha_{P,CMA,RC}$ decreases with increasing steel bars whereas $\alpha_{P,CMA,FRP}$ only decreases with increasing top steel bars but increases with increasing bottom steel bars. Also, the decrease of the enhancement factor due to the increase of top steel reinforcement in standard RC beams is more significant that in FRP-strengthened RC beams.

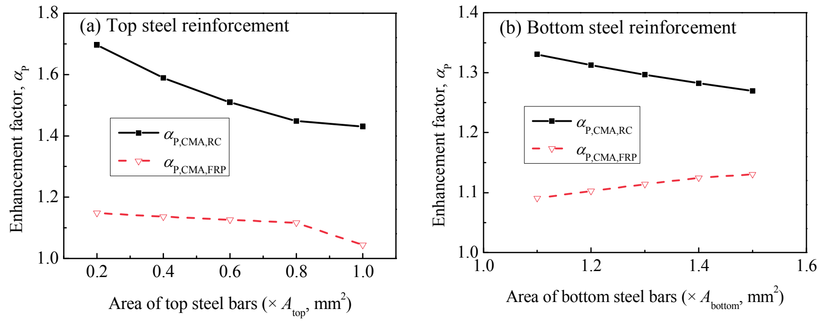

Fig. 1 Effect of steel reinforcement

Fig. 2 and Fig. 3 show the effects of concrete strength and span-to-depth ratio on CMA, respectively. It can be seen that the enhancement factor increases with increasing concrete strength ($f_{ck} \leq 50$ MPa) for both RC and FRP-strengthened RC beam systems. However, the span-to-depth ratio does not significantly influence the development of the enhancement factor, as shown in Fig. 3.

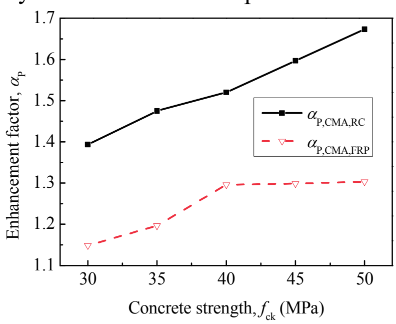

Fig. 2 Effect of concrete strength

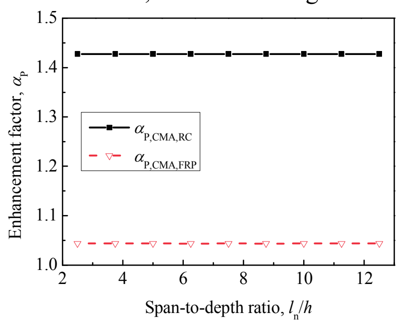

Fig. 3 Effect of span-to-depth ratio

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