Study on Application of Steel Fibre Reinforced Self-stressing Concrete in Transforming Old Simply Supported Bridges into Continuous System

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Summary

Steel Fibre Reinforced Self-stressing Concrete (SFRSSC) is a new type of fibre reinforced composite with self-expansive performance and high tensile resistance. It can be used in the old bridge reinforcement because when SFRSSC is restrained by steel bars or other terminal conditions, it can create some values of pre-stressing force to enhance the cracking moments of the continuous beams. The primary goal of this research is to apply SFRSSC to strengthen the old bridges for simply supported beams transformed into continuous system. Firstly, the computer analysis of the internal force of continuous T-beams with 5 spans is carried out. Secondly, based on the model experiments of 8 continuous T-beams with 2 spans, flexural performance of the beams reinforced by SFRSSC layers is investigated. It is concluded that flexural performance of continuous T-beams strengthened by SFRSSC is more greatly improved than that strengthened by conventional concrete.

Keywords: steel fibre; self-stressing concrete; bridge strengthening; composite concrete beam

1. Introduction

The exceptional properties of SFRSSC, including self-expansive performance, high strength, and uniaxial tensile strain-hardening make SFRSSC a promising material for application in the rehabilitation field. However, their composite structural behaviour with conventional reinforced concrete is not yet known. This paper presents computer analysis and model experiments that validate the potential of SFRSSC for rehabilitation applications.

Firstly, the computer analysis of the internal force of continuous T-beams with 5 spans is carried out. The results of the computer analysis show that the expansive action of SFRSSC can effectively decrease the internal force in negative bending moment area. Secondly, based on the model experiments of 8 continuous T-beams with 2 spans, flexural performance of the beams reinforced by SFRSSC layers is investigated. Owing to enhancement of steel fibres and self-stress induced by steel bars, the layers greatly improve the first-crack strength and stiffness of the beams. Furthermore, SFRSSC can help cancel out the relative deformation and stress due to new concrete shrinkage between new and existing concrete during the process transforming simply supported beams into continuous beams.

2. Computer analysis of the internal force of continuous T-beams

The moment in the mid-span is reduced after transforming the old simply supported bridge into continuous system, but the negative bending moment on the support is increased largely. Thereafter, the concrete at the joint is easy to crack under the large negative bending moment. In this research, SFRSSC is used to connect the two simply supported T-beams and the crack resistance of the joint concrete is enhanced considerably because of the self-stress restrained by the bars and steel fibres.

The positive bending moments on the supports, formed by the expansive performance of the SFRSSC, are quite beneficial to improve the crack resistance of the concrete in the negative bending moment areas. The moment values of the service phase on the supports can be

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approximately 10.4% reduced compared with the design values in the negative bending moment areas, owing to the positive bending moments produced by the SFRSSC.

3. Results and discussion of the test

Tab.1 Description of specimens

Name	Concrete of the layers	M_1/M_{1u}	Reinforcement of the layers
PL20-0.55	RC	0.55	1.48%
ZL20-0	SFRSSC	0	1.48%
ZL20-0.55	SFRSSC	0.55	1.48%
ZL20-0.8	SFRSSC	0.80	1.48%
PL14-0.55	RC	0.55	0.97%
ZL14-0	SFRSSC	0	0.97%
ZL14-0.55	SFRSSC	0.55	0.97%
ZL14-0.8	SFRSSC	0.80	0.97%

The variable parameters of the test were the material of the new layers (conventional concrete and SFRSSC), the presence of reinforcement in the new layers (0.97% and 1.48%) and the pre-cracked grade (0, 0.55 and 0.80). During these tests, the load was measured with inductive load sensors. The deflections of the beams were followed by the inductive deformation sensors at six places of the beams. The curve of the load-deflection can be plotted automatically by computer.

The general appearance of the crack resistance during the flexural beam tests is traced in Tab.2. It shows that the first-crack strength in negative bending moment area of the continuous composite SFRSSC-RC beams can be 51.4% (with 0.97% ratio of reinforcement and 0.55 pre-cracked grade) and 121.0% (with 1.48% ratio of reinforcement and 0.55 pre-cracked grade) increased compared with that of the continuous composite RC-RC beams respectively. The crack resistance in negative bending moment area of the continuous beams enhanced significantly, owing to the presence of the steel fibres and chemical pre-stressing created by the bars' restraint.

Tab.2 Cracking loading resistance of tested beams

Name	first-crack strength M_{cr} (kN·m)	$M_{cr} /f_c^{0.55}$
PL20-0.55	13.05	1.540
ZL20-0	31.10	3.275
ZL20-0.55	28.84	3.037
ZL20-0.8	26.59	2.800
PL14-0.55	17.56	2.072
ZL14-0	31.10	3.275
ZL14-0.55	26.59	2.800
ZL14-0.8	22.07	2.324

4. Conclusion

(1). The results of the computer analysis show that the expansive action of SFRSSC can effectively decrease the internal force in negative bending moment area and increase the crack resistance of the concrete in negative bending moment area. The test results obviously indicates that the composite SFRSSC-RC continuous beams enhance the crack moment 51.4%～121.0% more than conventional concrete continuous beams;

(2). Steel fibre reinforced self-stressing concrete in transforming old simply supported bridges into continuous system can be a feasible way to strengthen the old bridge. Many construction problems can be avoided by this method such as anchorage difficulty of pre-stressing bars and too dense collocation of bars in negative bending moment area.