Composite Structures 132 (2015) 20–34

Contents lists available at ScienceDirect

Composite Structures

journal homepage: www.elsevier.com/locate/compstruct

Influence of arching action on shear behaviour of laterally restrained concrete slabs reinforced with GFRP bars

Y. Zheng *, C.H. Li, J.B. Yang, C. Sun

Department of Civil Engineering, Dongguan University of Technology, Dongguan, China

ARTICLE INFO

Article history:
Available online 16 May 2015

Keywords:
Arching action
GFRP
Concrete slab
Shear strength

ABSTRACT

This paper reveals the influence of arching action on the shear behaviour of glass fibre reinforced polymer (GFRP) reinforced laterally restrained concrete slabs in bridge decks. A total of seventeen full-size one-way concrete slabs were constructed and tested in this study. Those restrained test slabs represents typical full-scale dimensions of a real bridge deck slab 400 mm wide by 2400 mm long and 200 mm deep. The test variables were lateral restraint stiffness, reinforcement configuration and concrete strength. The behaviour of test slabs was discussed and the influence of those structural parameters on the amount of arching action was evaluated by comparing the results of different specimens. The test results showed that increasing the arching effect resulted in shear failure mode and larger shear strength. The experimental shear strengths of the restrained test slabs were compared with some theoretical predictions in the literatures. The results indicated that those theoretical methods yielded high conservative predictions. A theoretical model that takes into account the effect of arching action in the shear-strength prediction was proposed by the writers. This method provided accurate and slightly conservative predictions.

1. Introduction

It has been evident that corrosion of steel reinforcement constitutes one of major problems that shorten the service lifetime of concrete bridge decks [1,2]. One solution to this corrosion problem is the use of alternative materials to steel reinforcement that do not corrode, such as fibre reinforced polymer (FRP). Since glass fibre reinforced polymer (GFRP) is more economical than other available FRP (CFRP and AFRP), it is more attractive for infrastructure application and has been used as reinforcement in concrete bridge deck slabs for more than twenty years [3].

Currently, it is well established that the concrete bridge deck slabs can fail in shear, including punching shear failure and one-way shear failure, due to the in-plane restraints and the concentrated or distributed loads of large magnitude [4,5]. In addition, it has been recognised that an internal arching effect is induced as the slab deflects due to the horizontal restraints provided by the slab panel boundary conditions such as supporting beams, diaphragms and surrounding slabs [5]. This is known as arching action or compressive membrane action. In previous research, it was shown that this arching phenomenon had a strong effect on failure mode and ultimate capacity of GFRP reinforced concrete bridge deck slabs [5,6]. However, the majority of research on the shear behaviour of FRP reinforced concrete members has been concentrated on the simply supported beams or slabs [7]. The effect of arching action as a result of in-plane restraint was not taken into consideration except in the specimens with small span-to-depth ratio ($\leqslant 2.5$) [8]. Interestingly, the tests by authors showed that the failure mechanism of GFRP reinforced concrete deck slabs with large span-to-depth ratio ($\geqslant 2.5$) could be shear failure due to the significant arching action [5,9]. Therefore, an investigation of the shear behaviour of laterally restrained concrete slabs reinforced with GFRP bars should be carried out by taking into account the effect of arching action.

The aim of this paper is to study the shear behaviour of in-plane restrained GFRP reinforced concrete slabs in bridge deck structures. As shown in Fig. 1, a one-way spanning concrete slab strip with lateral restraints typical of a bridge deck slab is conducted in this study. A series of experimental tests were carried out to investigate the influence from some structural variables on the behaviour of those slabs, which included the degree of external restraints, concrete strengths, reinforcement percentages and reinforcing materials. After comparing the results of different test specimens, the

* Corresponding author at: Department of Civil Engineering, Dongguan University of Technology, Dongguan, Guangdong Province 523808, China. Tel.: +86 15899662977.

E-mail address: zhengy@dgut.edu.cn (Y. Zheng).

http://dx.doi.org/10.1016/j.compstruct.2015.05.028
0263-8223/

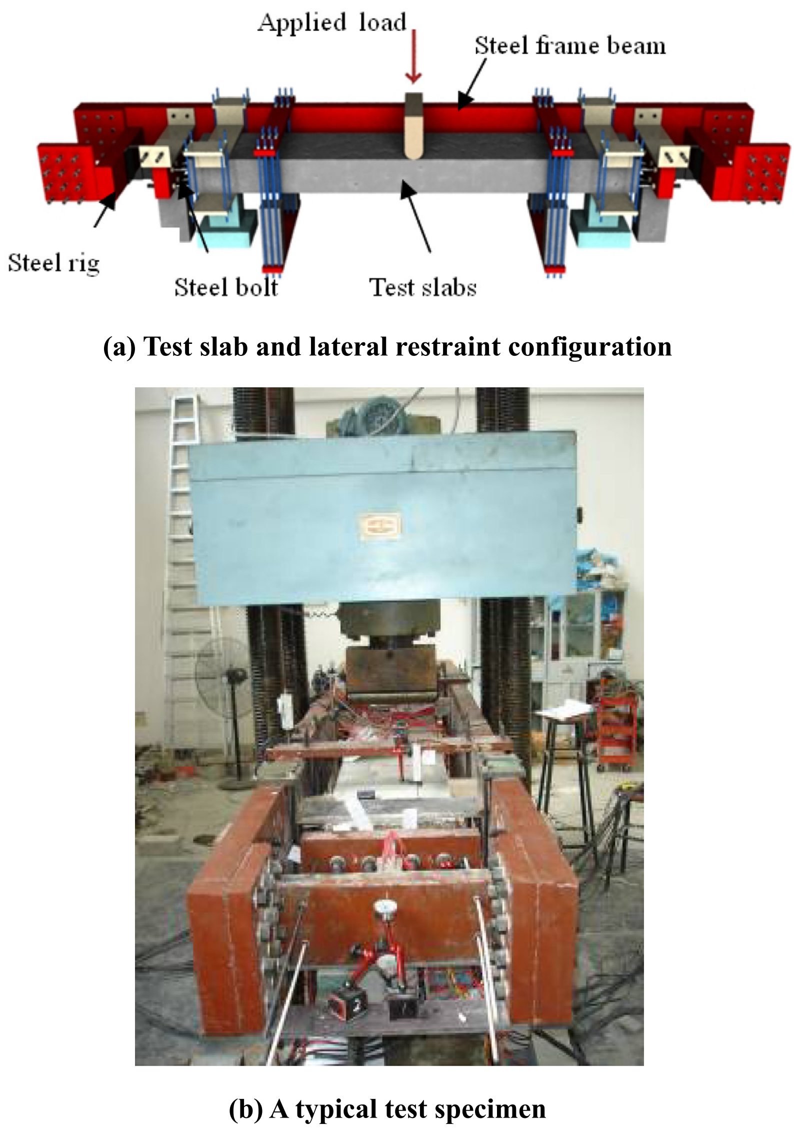

Fig. 1. Test model.

influence of arching action on shear-strength and failure mode was discussed and presented. A understanding of the nature of shear behaviour of concrete deck slabs reinforced with GFRP bars can be extended. Subsequently, the shear-strengths from the test were compared to the theoretical predictions provided by some published shear-strength design methods and a model proposed by authors. It was shown that the theoretical method taking into consideration the effect of arching action proposed in this study gave reasonable agreement with the test results.

2. Background to shear behaviour of FRP reinforced concrete members

It is well known that the cracked reinforced concrete flexural member without shear reinforcement, such as concrete slabs, resists the applied shear stress by means of five structural mechanisms: (i) shear resistance of uncracked concrete; (ii) aggregate interlock; (iii) dowel action of the longitudinal reinforcement; (iv) residual tensile stress across the inclined crack; and (v) arching action [10]. As similar to the behaviour of steel reinforced concrete members, those five mechanisms are expected in FRP reinforced concrete members. Due to the relatively low modulus of elasticity of the FRP composite material, FRP reinforced concrete structures generally develop wider and deeper cracks compared to those reinforced with steel. Those cracks decrease the contribution to shear strength from the uncracked concrete due to the low depth of concrete in compression. The contribution of aggregate interlock and residual tensile stress can also be reduced by the large crack widths. Additionally, due to the relatively small transverse strength of FRP bars and relatively wider cracks, the contribution of dowel action may be negligible. Finally, the shear capacity of FRP reinforced concrete members is smaller than those reinforced with the same amount of steel bars. This is well reported by the findings from the experimental investigations [11]. In addition, the shear behaviour of FRP reinforced concrete slabs without shear reinforcement is potentially the dangerous case in shear prone applications due to the brittle nature of concrete and FRP reinforcing bars [10].

Since most research of the shear behaviour of FRP reinforced concrete members is carried out based on the simply supported