Influential Parameter analysis of spread GFRP stay-in-place form deformation

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Abstract. Recently spread GFRP stay-in place forms with T-ribs have been applied to bridge engineering in China. The deformation non-uniformity of spread GFRP plates in the deck transverse direction is more significant than that of narrow GFRP plates. In order to investigate the influential parameters of deformation, a 1.8 m simply supported GFRP plate was analysed using ANSYS. The analysis results show that (1) the maximum deflection of side GFRP plates is larger than that of middle plates; (2) the maximum deflection is affected by rib thickness, plate height, rib spacing and bottom plate thickness; (3) the non-uniformity of deflection is mainly affected by rib spacing and bottom plate thickness; (4) the rib thickness has little effect on the non-uniformity of deflection, and a higher GFRP plate results in a larger non-uniformity of deflection. Based on the analysis results, some measures on improving the flexural stiffness of GFRP plates in the transverse and longitudinal directions are proposed.

1. Introduction

In the past 10 years, considerable attention has been paid to GFRP-concrete composite structures. Among them, GFRP-concrete decks have attracted bridge engineers' interest because of excellent mechanical performance, good durability and convenient construction [1]. The GFRP-concrete deck includes GFRP plates and concrete. In the construction process, the GFRP plate could be used as the formwork to speed up the bridge construction. During the operation period the vehicle load is carried by GFRP plates and concrete. Spread GFRP plates are more convenient for workers than narrow plates, The deformation influential parameter of spread GFRP plates are more complex than that of narrow GFRP plates because of the non-uniformity of deformation. However, the study on the GFRP plate deformation is focused on the narrow plate. Recently, the GFRP-concrete decks with T-ribs has been applied in the steel-concrete composite girder bridge in China [2]. The study on the deformation influential parameter could provide reference for the design of spread GFRP plates with T-ribs.

According to the GFRP plate cross-section, the GFRP-concrete decks could be divided into composite decks with dual cavity system [3], corrugated GFRP-concrete decks [4], composite decks with T-ribs [5], and so on. At present, the mechanical performance of GFRP-concrete decks has been investigated in detail, which includes the static mechanical performance of simply supported decks [6], the static mechanical performance of continuous decks [7], and the dynamic performance of GFRP-concrete decks [8]. Researchers have also study the deformation of narrow GFRP plates [9]. However, there has been little about deformation influential parameter analysis of spread GFRP plates with T-ribs.

In this paper, the deformation influential parameters of spread GFRP plates with T-ribs have been studied by finite element simulation, which include thickness of T-ribs, width of GFRP plates,
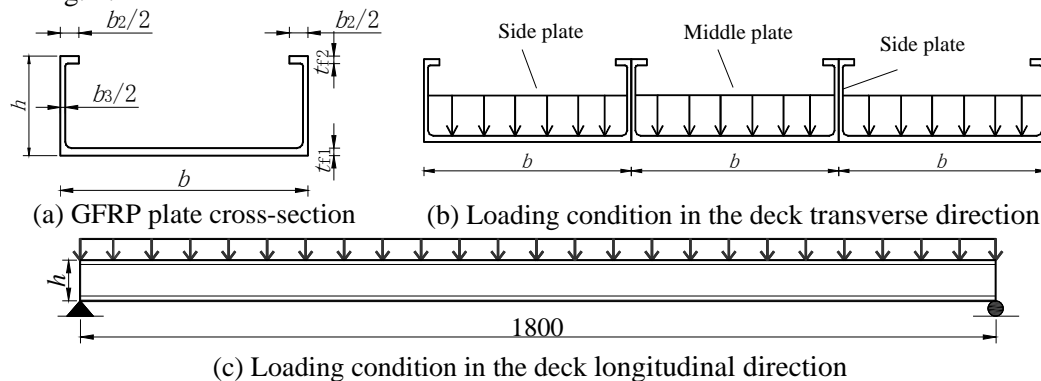
thickness of bottom plates, and height of GFRP plates. The relationships among above parameters, maximum deflection and non-uniformity of deformation have been investigated.

2. An example of GFRP plates and numerical model

According to Chinese standard JTG/T F50-2011, the deformation of GFRP plates cannot exceed 1/400 of the calculated span in the construction process of GFRP-concrete decks. When the adjacent rib spacing is large, the deformation non-uniformity of GFRP-concrete decks in the deck transverse direction is remarkable.

In this paper, the deformation of a 1.8 m simply supported GFRP decks with T-ribs was investigated based on finite element simulation. Fig. 1(a) shows the cross-section of the GFRP plate with T-ribs. In Fig. 1(a), b is the width of GFRP plate, t_{f1} is the thickness of GFRP bottom plates, t_{f2} is the thickness of flanges, b_2 is the width of flanges, b_3 is the width of T-ribs, h is the height of GFRP plates. Fig. 1(b) and (c) show the loading condition. The initial cross section parameters are as follows: b is 300 mm, t_{f1} is 6 mm, t_{f2} is 6 mm, b_2 is 60 mm, b_3 is 8 mm, and h is 80 mm. Then the effect of above parameters on deformation is investigated using ANSYS.

Fig. 2 shows the numerical model of GFRP plates. The GFRP plate was simulated by an eight node 3-D orthotropic element SOLID185. According to reference [2], the modulus of GFRP plates in the deck transverse direction is 1.08×10^4 MPa, and the modulus in the deck longitudinal direction is 3.26×10^4 MPa. A uniform load of 0.003952 MPa is applied to the top surface of the bottom plate, which is equal to the weight of concrete decks with the thickness of 15 cm. The numerical model is shown in Fig. 2.

(a) GFRP plate cross-section   (b) Loading condition in the deck transverse direction

(c) Loading condition in the deck longitudinal direction
**Figure 1.** Loading condition of GFRP plates in detail/mm
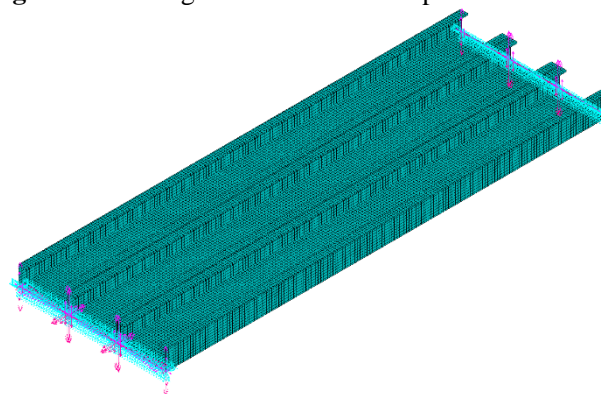
**Figure 2.** Finite element model

3. Parameter analysis

The deformation influential parameters were investigated, which included rib thickness, plate height, bottom plate thickness, and rib spacing. Fig. 3 shows the relationship between deflection and rib thickness. The non-uniformity of deflection under uniform load is impressive. The deflection of side plates is larger than that of middle plates because of the torque carried by side ribs. Moreover, a higher

rib thickness resulted in a lower deflection. However, the non-uniformity of deflection in the deck transverse direction has not been improved.

(a) Deflection distribution

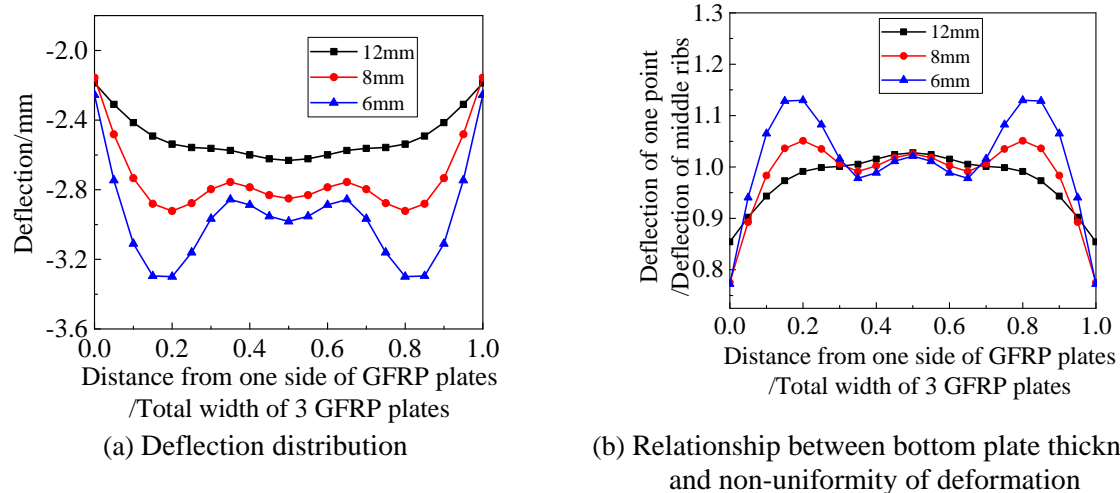(b) Relationship between rib thickness and non-uniformity of deformation
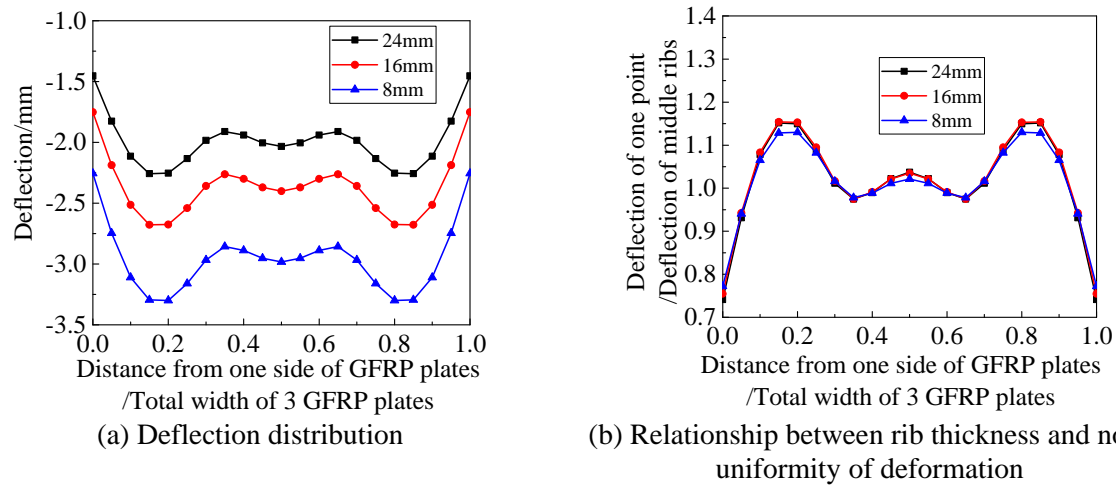
Figure 3. Relationship between deflection and rib thickness

Fig. 4 shows the relationship between deflection and plate height. It could be seen from Fig. 4(a) that the maximum deflection of GFRP plates with the height of 90 mm is lower than that of GFRP plates with the height of 70 mm. A higher plate could reduce the deflection of GFRP plates. However, the deformation non-uniformity of GFRP plates increases with the increase of GFRP plate height. The increase of plate height is detrimental to the deformation uniformity.

(a) Deflection distribution

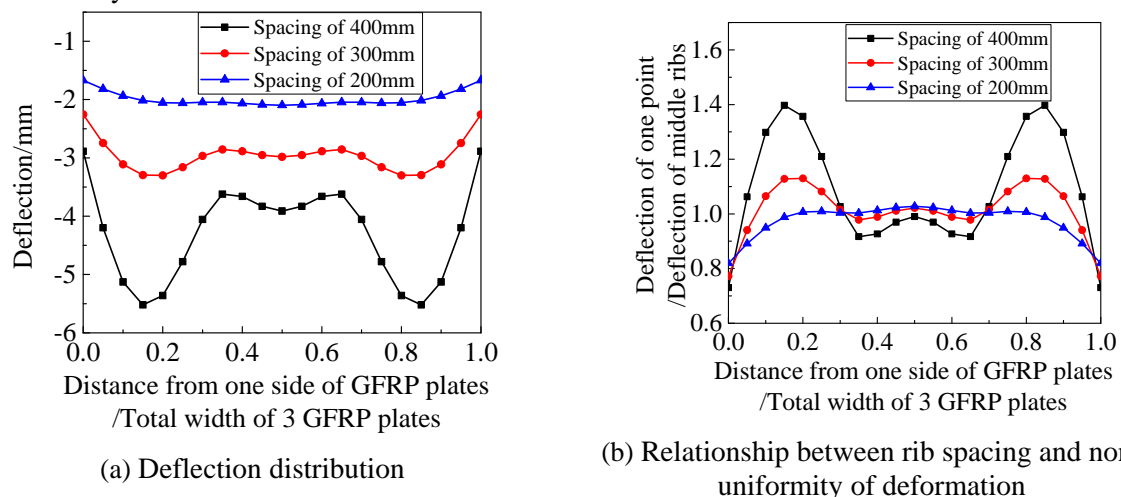(b) Relationship between plate height and non-uniformity of deformation
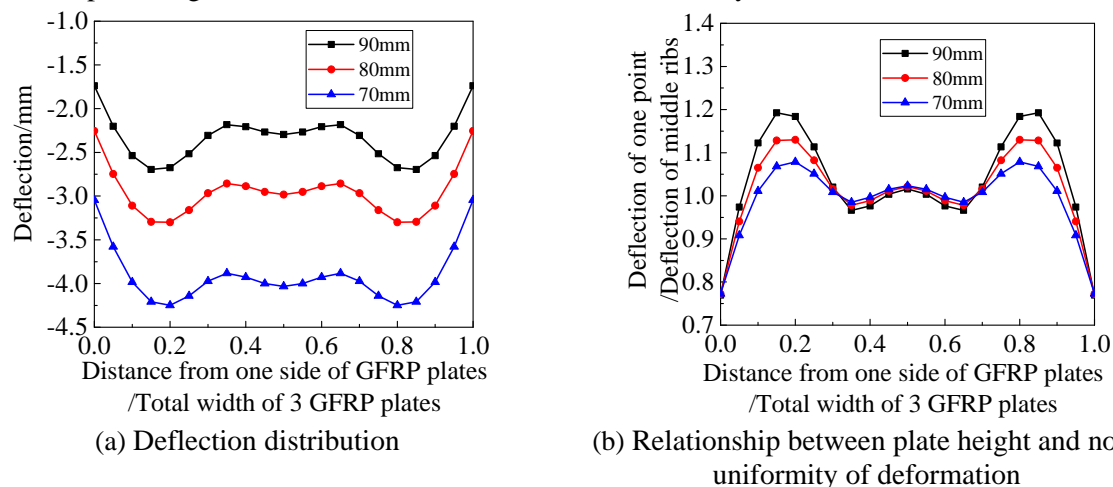
Figure 4. Relationship between deflection and plate height

Fig. 5 shows the relationship between deflection and thickness of bottom plates. With the increase of bottom plate thickness, the maximum deflection and the deformation non-uniformity are effectively reduced. When the bottom plate thickness is 12 mm, the maximum deformation of middle plates is close to that of side plates. A thicker bottom plate enhances the flexural stiffness in the longitudinal and transverse direction. Therefore, the maximum deflection and the non-uniformity of deformation are reduced.

(a) Deflection distribution

(b) Relationship between bottom plate thickness and non-uniformity of deformation

Figure 5. Relationship between deflection and thickness of bottom plates

Fig. 6 shows the relationship between deflection and rib spacing. The spacing between ribs has a significant effect on maximum deformation and deformation non-uniformity. As the average flexural stiffness of GFRP plates is increased with the decrease of rib spacing, the maximum deflection decreases. In addition, it can be seen from Fig. 6(b), the non-uniformity of spread GFRP plates is more significant than that of narrow GFRP plates, and the reduction of rib spacing could effectively improve the uniformity of deflection.

(a) Deflection distribution

(b) Relationship between rib spacing and non-uniformity of deformation

Figure 6. Relationship between deflection and rib spacing

In general, the deflection non-uniformity of GFRP plates with a wider rib spacing is more remarkable than that of narrow GFRP plates. Although the increase of rib thickness, plate height, bottom plate thickness and the decrease of rib spacing could reduce the maximum deformation, different parameters have different effects on the deformation uniformity. The deformation uniformity is mainly affected by bottom plate thickness and rib spacing.

Based on the previous analysis, the following measures could be considered in the design and construction to improve the longitudinal and transverse stiffness of GFRP plates: 1) The side edge of GFRP plates could be placed on the top surface of cross beams. The side support could reduce the deformation of side plates. 2) The deformation uniformity in the deck transverse direction could be increased by increasing the thickness of GFRP bottom plates or reducing the spacing between GFRP ribs. 3) These methods could reduce the maximum deformation of GFRP plates, which include the increase of rib thickness, plate height, bottom plate thickness and the decrease of rib spacing.

4. Conclusions

1. The maximum deflection of side GFRP plates is larger than that of middle plates. A higher GFRP plate is beneficial to the total flexural stiffness, but it is detrimental to uniformity of deformation in the deck transverse direction.

2. The rib thickness, plate height, bottom plate thickness, and rib spacing have an significant influence on the maximum deflection of GFRP plates in the construction stage. The deflection could be reduced by increasing the rib thickness, plate height, and bottom plate thickness. In addition, a narrower GFRP plate results in a lower deflection.

3. The deflection non-uniformity of spread GFRP plates is more remarkable than that of narrow GFRP plates. The non-uniformity of deflection in the deck transverse direction is mainly affected by the bottom plate thickness and the spacing between T-ribs.

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