

The influence of contact type of Composite Bridge Deck pavement on stress in pavement interface

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Abstract. In order to study the stress distribution law of simply-supported bridge deck pavement the finite element software ANSYS is used to building the overall structure model of the composite bridge deck. The huge difference of materials of interface of concrete cushion layer and asphalt pavement layer in composite bridge deck affect the functional performance of the bridge deck pavement dramatically. Analysis shows that the mechanics characteristic of composite bridge deck pavement under different interlayer contact condition appears diversely.

1. Introduction

Bridge deck pavement is a special type of pavement structure, which is paved on deck to prevent bridge deck from the wheels or tracks wearing surface directly. It can not only protect girder from rain, but also to distract concentrated load, bear bending moment and resist deformation along with girder[1-3]. Composite bridge deck pavement structure is an especial structure that the bridge deck is layered and paved by multiple materials. Because of the composite bridge deck pavement structure contains multi-layer materials, when the pavement bears loads and deforms along with girder, different materials show mechanical properties diversely and cause the material nonlinear of structure stiffness. So, calculation and analysis of composite bridge deck pavement structure is more difficult and complex than single material pavement structure. In a nutshell, in-depth theoretical study on the composite bridge deck pavement system is not only great significance but also promising.

2. Basic hypothesis

- (1) Pavement and girder materials are in stage of elastic.
- (2) Pavement layer and girder work together under uncracked condition.
- (3) Bridge deck, pavement layer, and waterproof layer completely continuous contact at the layer interface.
- (4) Bridge deck, pavement layer, and waterproof layer bear vehicle load together.

3. Finite element analysis model and basic parameters

Though building mechanical model of the composite bridge deck pavement, the most unfavorable loading location of pavement under the action of rear tire is found. By numerical calculation, we can get the regularity of pavement surface tensile stress, interface normal tensile stress and interface shear stress with different thickness and elasticity modulus. During research, we take medium and short span hollow slab composite bridge deck as the research object, elastic mechanics as the theoretical basis, through modeling, study internal force of structure under the action of static load. Choose simply supported hollow slab bridge with span of 20 meters and three lanes, the width of bridge is 12.62 meters. In the process of 3-D modeling with the finite element program Ansys, girder, concrete cushion layer, asphalt pavement is simulated by solid45 element which is defined by eight nodes having three degrees of freedom at each node while waterproof layer is simulated by shell element which is a 3-D element having membrane (in-plane)

stiffness but no bending (out-of-plane) stiffness, couple degrees of freedom at the interface between bridge deck, pavement layer, and waterproof layer. The model is made up by three portion, hollow slab, composite pavement and rear tire. The relevant structure size schematic diagrams are shown in figure 1, figure 2.

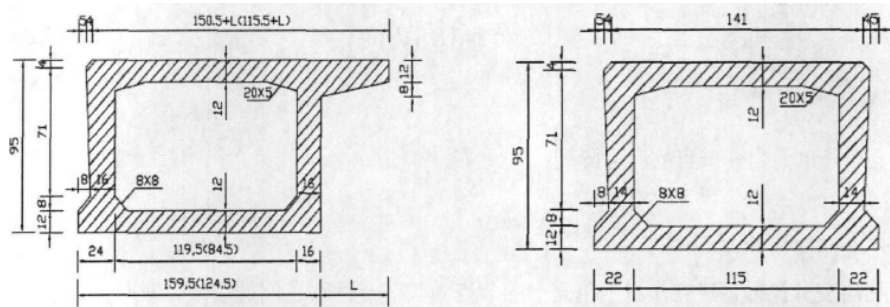


Fig. 1 Hollow slab edge plate structure Fig.2 Hollow slab medium plate structure

The relevant material parameters and element are shown in Table 1 and the finite element mesh of model is show in figure 3.

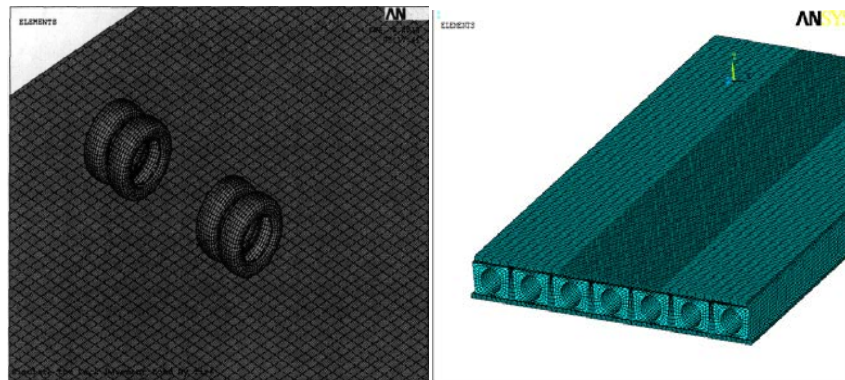


Fig. 3 finite element meshes of model

Table 1. Material Parameters used in Model

Layer	Material	Thickness	Elastic modulus	Poisson's ratio	Material element
Pave ment	The upper asphalt concrete pavement	4 (variable)	2200MPa (variable)	0.25	solid186
	The sub-asphalt concrete pavement	5 (variable)	2000MPa (variable)	0.25	solid186
	Concrete cushion	8 (variable)	35000MPa (variable)	0.15	solid185
Bridg e girder	Hollow slab	—	30000 MPa	0.1667	solid185
	Hinge joints	—	27000 MPa	0.1667	solid185
	Rubber bearing	—	1550 MPa	0.4999	solid186

4. Contact analysis between pavement layer

Short and medium span bridge pavement in Guangdong province generally divided into two forms [5-6]: one is double-deck pavement and thickness is often 9-12cm, another is single-deck pavement and thickness is generally 4-5cm. When the vehicle load loads in the middle of girder, the deflection of structure is maximal, so choose middle of bridge as the most unfavorable position lengthways. By calculating and comparative analysis, the most unfavorable position crosswise is 3.65m away from the left edge of bridge. Take AC-13 as the upper layer material of asphalt concrete pavement, and AC-16 as sub-layer material. The material of leveling layer is C40 reinforce concrete. The thickness of pavement structure is 5cm+6cm+10cm. According to "General Code for Design of Highway Bridges and Culverts" in China [7], Class I Highway-vehicle load is chosen, the weight of rear axle is 140KN while tire press is 0.85MPa. The huge difference of materials of interface of concrete cushion layer and asphalt pavement layer in composite bridge deck affect the functional performance of the bridge deck pavement dramatically. In daily engineering application, interlayer is processed by galling, thicken interfacial bond layer and so on. But theoretical analysis of interface is insufficient. In this paper, the relationship between using performance of composite bridge pavement and interlayer contact condition is discussed to provide theoretical data for interlayer combination processing.

Contact algorithm is highly nonlinear, it requires high quality of computer hardware for a large model calculating. So model is simplified to save calculating cost, the width of calculating model is half of whole bridge. Because the extreme values of contact stress appear in the scope of tire contact area, the longitudinal length is set to 3m.

It can be seen from Fig.4 and Fig.5 that the tensile stress of upper AC layer reduce a little with the increment of friction coefficient of AC-PCC interface, while the shear stress increase slightly. Compared with ideal combination state, under the contact condition, the shear stress of upper AC layer increase dramatically, the extreme values of crosswise shear stress comes to 0.771MPa, larger nearly by 51.3% than 0.47MPa under ideal condition. So we can conclude that if the bond property of AC-PCC interface is deficient, the force situation of upper AC pavement would worsen.

Nether AC pavement is a transition zone between AC and PCC, it contact with PCC layer directly, and it will lead to stiffness mutation in the interface. In mechanics analysis, stiffness mutation is likely to cause stresses concentrating. So the stress in nether AC pavement directly matters working stability of upper AC layer.

From fig.6 we can conclude that with friction coefficient rising, stress in upper AC layer decrease, that is to say rougher the interface is, the lower AC stress diffusion effect is.

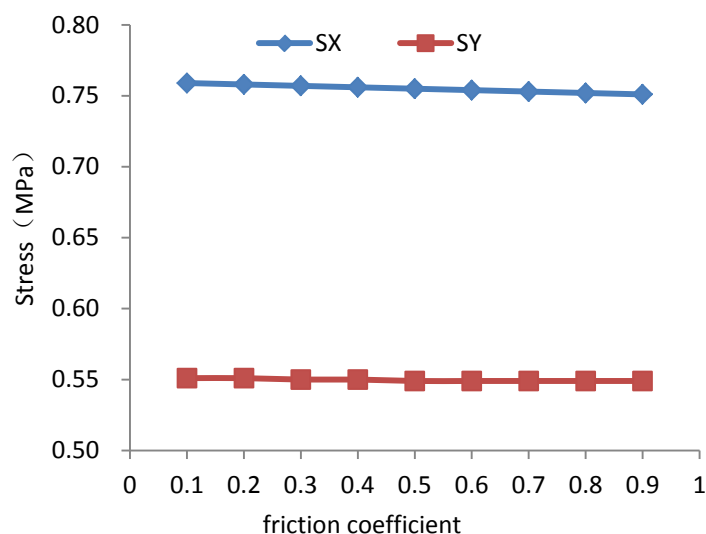


Fig.4 The relationship between friction coefficient and tensile stress of upper AC

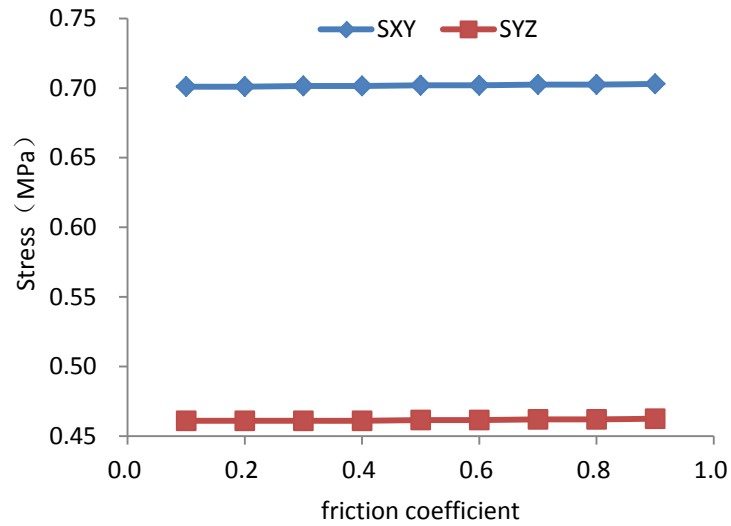


Fig.5 The relationship between friction coefficient and shear stress of upper AC

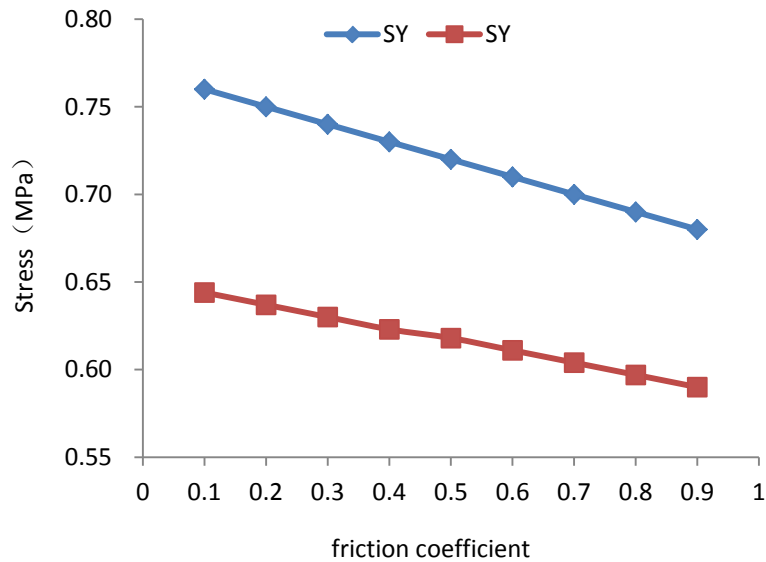


Fig.6 The relationship between friction coefficient and tensile stress of nether AC

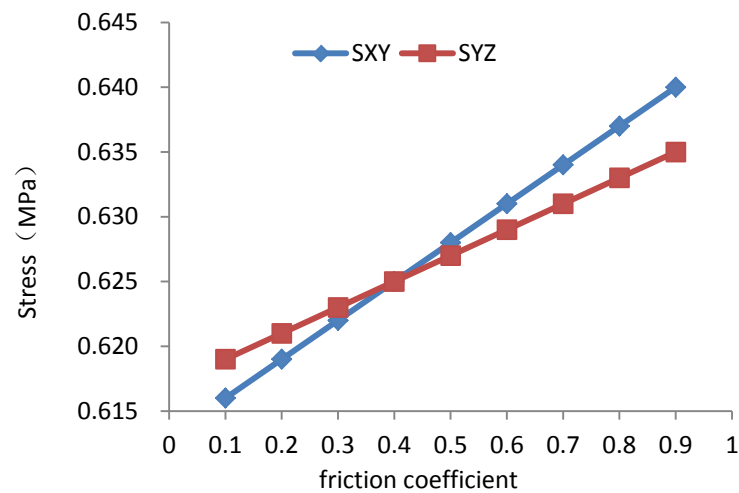


Fig.7 The relationship between friction coefficient and shear stress of nether AC

Aiming to analyze force situation of each layer under condition of regular contact, four contact condition- friction coefficient, totally rough, binding and coherent-is supposed. Table.2 shows stress

of upper AC at four contact status.

Table.2 Stress of upper AC of each contact status

Contact status	Crosswise tensile Stress (MPa)	Longitudinal tensile stress(MPa)	Crosswise shear Stress (MPa)	Longitudinal shear stress(MPa)
Average value	0.75	0.545	0.709	0.469
Complete rough	0.737	0.542	0.712	0.470
binding	0.648	0.463	0.717	0.486
Coherent	0.766	0.756	0.528	0.292

5. Conclusions

In this paper, the finite element software ANSYS is used to building the overall structure model of the composite bridge deck, though detailed statics analysis of model, we can conclude that:

(1) The force situation of the two layer of asphalt pavement is different, the upper layer mainly bears tensile stress and the nether bear shear stress.

(2) Thicken the thickness of upper AC can reduce its tensile stress efficiently, but it should not be too thick. The best thickness of upper AC of highway composite bridge deck pavement under the condition of overloading should be 7-8cm.

(3) It is uneconomic to increase nether layer thickness to reduce stress of upper layer.

(4) Analysis shows that the mechanics characteristic of composite bridge deck pavement under different interlayer contact condition appears diversely, if the bond property of interface is deficient, the force situation of pavement would worsen. So, the bond property of interface should be strengthen, especially the AC-PCC interface.

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