Finite element analysis of GFRP reinforced concrete pavement under static load

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Abstract. GFRP was more corrosion resistant than traditional reinforced, it is lightweight, high strength thermal expansion coefficient is more close to the concrete and a poor conductor of electromagnetic. Therefore, the use of GFRP to replace the traditional reinforcement in concrete pavement application has excellent practical value. This paper uses ANSYS to establish delamination and reinforcement of Pavement model and analyzed response of GFRP concrete and ordinary concrete pavement structural mechanics on effects of different factors under the action of static. The results showed that under static load, pavement surface layer presented similar changes on stress of surface layer, vertical and horizontal deformation in two kinds of pavement structure, but indicators of GFRP reinforced concrete pavement were obviously better than that of ordinary concrete pavement.

1. Introduction
CRCP (Continuous Reinforced Concrete Pavement) has been widely used at home and abroad. Pavement seams not set up seams, can inhibit cement concrete pavement transverse joint and expansion, contraction joints pavement weak parts of the formation, it can reduce the weak part of pavement formed by cracks\textsuperscript{[1-4]}.

GFRP reinforcement for reinforcing concrete pavement, Besides with the advantages of steel corrosion in the elimination of CRCP, but also offers the advantages between FRP reinforcement and concrete temperature and stiffness compatibility. In 2002, Chen H.L\textsuperscript{[5]} research on the GFRP-CRCP temperature stress and cracking cases, It found that the use of GFRP bars can reduce the internal stress caused by temperature of the concrete pavement to prevent steel corrosion, reducing pavement cracks, Hung Liang, Roger Chen analyzed the stress situations in moisture loss and shrinkage, and temperature changing environment GFRP reinforced concrete panels. In 1997, Our country began research on bonding properties of GFRP rebar and concrete.

2. GFRP Reinforced Concrete Cube Finite Element Model Validity
Based on plain concrete and GFRP concrete cube on the baswasof uniaxial compression test, application of ANSYS finite element model simulation and verification test results, verify the validity of the model. Combined with the concept of continuously reinforced concrete pavement, arranged GFRP bars in concrete cubes, as shown in Figure 1.
Figure 1: GFRP reinforced concrete specimens layout

According to GFRP volume (laying 4) in ANSYS model establishing intermediate layer. The model was built Figure 2 and the stress-strain curves Figure 3:

![GFRP reinforced concrete cube layered arrangement](image1)
![GFRP reinforced concrete cube single pressure model](image2)

Figure 2: GFRP reinforced concrete cube layered arrangement

Figure 3: GFRP reinforced concrete cube single pressure model

Results: from experiment and ANSYS simulation results, we can see that reach peak stress without failure stage, simulations of the stress-strain curve with the experimental results should stress-strain curve has good consistency, with the increase of strain, stress changes gradually increasing trend; GFRP concrete in ANSYS simulation should be the maximum stress peak must be smaller than the experimental results, it shows that simulation results are relatively safe, can be used to illustrate the concrete failure before the stage of mechanical properties, to concrete project failure to make a favorable judgment.
3. Finite Element Model of Pavement

Structure Parameters and Material Parameters. Pavement structure A was a continuous reinforced concrete pavement, pavement structure B was a common concrete pavement, and the distribution of the two pavement structures follows:

| Layer of structure | Pavement type thickness (cm) | Material parameters |
|--------------------|-------------------------------|---------------------|
|                    | A                | B                | Modulus of elasticity | Poisson ratio |
| Upper layer (C30 concrete) | 12 | 1200 | 0.30 |
| Middle layer (GFRP rebar) | 1 | 25 | 40000 | 0.30 |
| Lower layer (C30 concrete) | 12 | 1200 | 0.30 |
| Base layer (5% water stable gravel) | 25 | 25 | 1550 | 0.20 |
| Subbase layer (Water stable aggregate) | 20 | 20 | 1350 | 0.25 |
| Soil base - - | - | - | 45 | 0.45 |

Pavement Delamination Model. ANSYS with continuous reinforced concrete pavement and ordinary concrete road surface model to simulate the different lies in: the continuous concrete pavement was a continuous FRP reinforcement in the middle part of pavement layer and ordinary concrete pavement was cement mixture, when the model was established, it should pay attention to the attributes of different layers, In the continuous reinforced concrete pavement layer, we should pay attention to the continuous contact between the flexible concrete material and the rigid FRP rebar, two kinds of models such as Figure 5 and Figure 6:

**Figure 5:** GFRP continuous reinforced concrete pavement delamination  
**Figure 6:** layered concrete pavement delamination

4. Mechanical analysis of pavement under static loading

In order to analyze the vehicle axle load on pavement structural mechanics, to design specification standard axle load 100kN (wheel 50kN) as a benchmark, using finite element analysis, considering the wheel loads load condition of the reference wheel load of 50%, 100%, 200% and 300%, respectively, corresponding wheel as 25, 50, 100, 150KN load (axle load for 50, 100, 200, 300KN), for simplicity, in the study think tire width unchanged, only tire contact length along with the change of the wheel size.
Analysis of Pavement Wheel loads Under Different Stress.

Table 2: A surface layer within the pavement structure stress calculation results

| Structure Load (kN) | 25     | 50     | 100    | 150    | 200    | 250    | 300    | 350    | 400    | 450    | 500    |
|--------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Maximum peak of shear stress (KPa) | 108.849 | 139.4032 | 235.31088 | 414.48024 |
| Appearance position | X (cm) | 15.93375 | 16.996 | 15.6366 | 14.3244 |
| Y (cm) | 0 | 0 | 0 | 0 |
| Z (cm) | 1.125 | 2 | 3.78 | 5.98 |
| Maximum shear stress of a layer (KPa) | 85.7055 | 112.2656 | 191.84928 | 327.35716 |
| Appearance position | X (cm) | 6.4875 | 6.92 | 4.3596 | 1.5916 |
| Y (cm) | 0 | 0 | 0 | 0 |
| Z (cm) | 0 | 0 | 0 | 0 |
| Maximum shear stress of bottom layer (KPa) | 69.3255 | 95.6128 | 151.44612 | 268.1202 |
| Appearance position | X (cm) | 13.96125 | 14.892 | 13.0788 | 14.3244 |
| Y (cm) | 0 | 0 | 0 | 0 |
| Z (cm) | 11.25 | 12 | 12.6 | 13.8 |
| Maximum tensile stress of bottom layer | 97.224 | 115.484 | 169.9932 | 251.30904 |
| Maximum vertical compressive stress | 189.18975 | 222.7008 | 312.70764 | 446.94888 |

Figure 7: A surface layer of pavement all the stress and wheel load curve
Figure 8: Pavement Structure B surface stress and wheel load of each curve

It can be seen from table 2 and figure Figure 7~Figure 8. Vertical maximum compressive stress in surface layer in the pavement structure. The maximum shear stress peak, surface layer upon layer table and maximum shear stress layer bottom, layer bottom maximum tensile stress appeared on the X-axis section, with acting on the pavement structure of the wheel load increases nonlinearly increases, Pavement structure A, B as the wheel load increases, the maximum shear stress surface layer and the layer table peak maximum shear stress increases significantly greater than the surface layers of the bottom layer of the maximum shear stress and maximum tensile stress increased dramatically bottom, among them, surface maximum shear stress dramatically increases the maximum, especially when the wheel load was large, this law was more obvious, This shows, under conditions of heavy axle load, maximum shear stress in the surface layer of the peak size of the wheel load sensitive, wheel load increases, it will cause the maximum shear stress in the surface layer of a sharp increase in peak, surface layer was more prone to shear deformation.

5. Conclusions
(1) As the wheel load increasing from a small gradual, the maximum shear stress peak will move gradually from the outside of the wheel to the outer edge of the mobile, and the surface layer depth will gradually increase. At all levels under the wheel loads, GFRP reinforced concrete pavement structure was smaller than the ordinary concrete pavement structure layer within the maximum shear stress and peak stress, and the maximum shear stress peak depth was small.

(2) At the different wheel load, with the increase of modulus, the surface layer within the maximum transverse shear strain and the maximum vertical compressive strain decay rapidly. With the increase of the thickness of the surface layer, the surface layer within the maximum transverse shear strain decrease gradually, but the attenuation amplitude smaller. With the increase of base modulus, the surface layer within the maximum transverse shear strain decreases and the amplitude was very small, but pavement structure vertical compressive strain with the base modulus increases gradually.

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