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Analysis on the deflection and load transfer capacity of a prefabricated airport prestressed concrete pavement

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HIGHLIGHTS

- An indoor deflection test on a prefabricated airport prestressed concrete pavement was carried out.
- Slab corner was the most unfavorable load bearing position for weak load transfer capacity.
- Increasing prestress levels improves the load transfer capacity of the slab edge effectively.

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ABSTRACT

Prefabricated prestressed concrete pavement is a special type of surface that has a broad application in airport engineering. Current research mainly focuses on the performance of small-sized prestressed test pieces, resulting in a lack of structural analysis on full-size prefabricated pavement. By testing the deflection characteristics of an indoor prefabricated airport prestressed concrete pavement, we analyze the deflection characteristics and load transfer capacity of this pavement structure and the influencing factors. Results from our investigation show that the load transfer capacity mainly consists of three aspects: friction action between the slabs; the action of prestressed steel strands as dowel bars; and the load transfer action of the tongue and groove joints. Our findings show that, for the slab edge, increasing the level of prestress provides an effective measure to improve the load transfer capacity. We also identify that the most unfavorable load bearing position is the corner of the slabs as this has a weak load transfer capacity; the optimal load bearing position is in the center of the slabs.

1. Introduction

Prefabricated airport prestressed concrete pavement is characterized by high strength, few joints, quick construction and high durability, and it is widely used in developed countries, such as Europe and America [1,2]. Previous investigations into prefabricated prestressed pavements have shown that this pavement material has important advantages over traditional pavement methods: (1) by virtue of the action of prestress, the strength and failure mode of precast slabs have been improved, and the design thickness has been effectively reduced by 75–100 mm; (2) the durability of airport pavement has been significantly enhanced, providing the pavement with a long life-span (more than 40 years); (3) relying on the relatively large size of prefabricated prestressed concrete pavement slabs, the number of slab joints has been reduced, and both pavement roughness rating and driving comfort have been strengthened; (4) due to the high durability of prestressed concrete pavement slabs, maintenance costs have reduced and the life cycle cost has been effectively lowered [3–6].

Although prestressed precast slab techniques have been widely applied to the construction of highways and airports, design theory about prefabricated airport prestressed concrete pavement has not yet been undertaken. The flexural strength of concrete can be improved in the process of making prefabricated prestressed cement concrete pavement, with effectively reducing its life-cycle cost and actively responding to the need for prefabricated structures; analysis on prefabricated airport prestressed concrete pavement is required to examine its durability and load transfer capacity[10,11]. Analysis on the advantages of prefabricated airport prestressed concrete pavement in airport engineering by Zhao et al. identified that they have a broad developmental potential [7],

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and Yang, investigating the influence of pavement structure parameters on the bearing performance of pavement slabs, concluded that slab thickness exerts the most significant influence on performance. Yang also examined fatigue characteristics of prestressed joists and proposed a fatigue equation that differs from the fatigue equation used for traditional concrete pavements, thus contributing to the rational design of prefabricated airport prestressed concrete pavement [8]. Given that investigations at the joist level cannot directly reflect the structural characteristics of prefabricated prestressed concrete pavement, we used an airport engineering pavement laboratory to undertake tests on deflection and load transfer capacity characteristics of a prefabricated airport prestressed concrete pavement. Through pavement structure analysis based on these tests, we adopted the surface course deflection of concrete pavement slabs as the primary research index, establishing the bidirectional deflection system of the pavement structure, and thus obtaining the deformation and load transfer characteristics of prefabricated prestressed pavement structures. This will provide a reference for the design of future prefabricated airport prestressed concrete pavement.

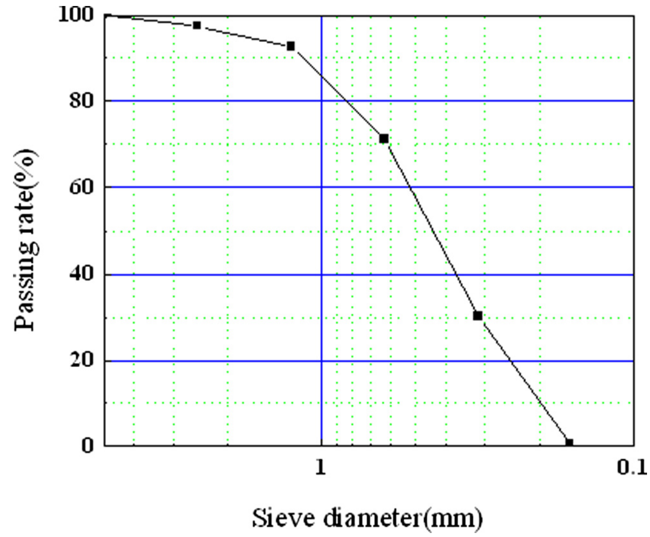

Fig. 1. Grading distribution map of sand.

2. Test overview

2.1. Test materials

The cement used in this test was the PO-42.5R ordinary Portland cement, the indices of which all meet relevant state standards (Table 1). The sand used in the test was medium sand sourced from the Bahe River, having a fineness modulus of 2.07, a specific gravity of 2.75 and a density of 1.36 g/cm^3. The gradation composition of this sand is shown in Fig. 1. Cobblestones used were derived from continuously-graded crushed limestone, produced in Lantian County of Xi'an (gradation composition is shown in Fig. 2), having a specific gravity of 2.86 and a density of 1.57 g/cm^3.

The mix ratio of the cement concrete was determined by a grade strength of C30 and a flexural-tensile strength of 5.0 MPa. The ratio of water:cement:sand:cobblestone was 0.46:1:1.95:2.56. After the casting of the cement concrete pavement slabs, sand capping and sprinkling was used for curing purposes. Each slab was prepared with six joist test pieces 15 × 15 × 55 cm in size, with the purpose of determining the flexural elasticity modulus, flexural strength and compressive strength of the concrete.

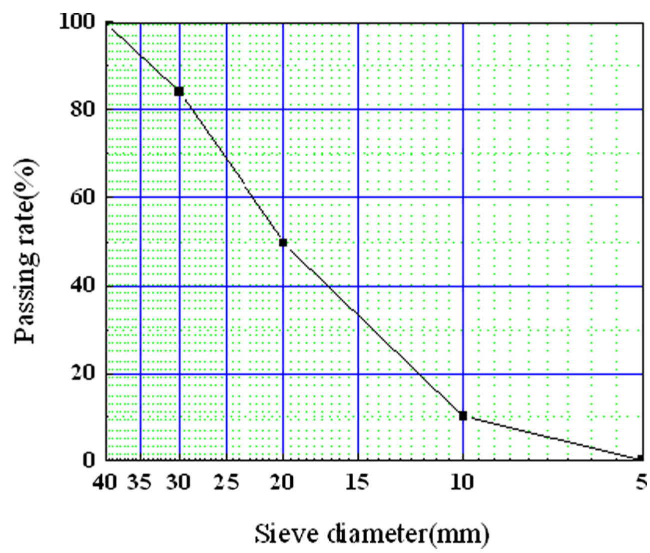

Fig. 2. Grading distribution map of Gravel stones.

2.2. Test equipment

The deflection test installation mainly consisted of three parts: (1) An indoor test pavement slot, being 18 m × 6 m (length × width) in size, and being connected with an undistributed soil base at the bottom. (2) An YX1200 pavement electro-hydraulic servo fatigue test system: this mainly composed of a 200 L double-pump oil source, hydraulic servo console, water circulation tube-type cooling system, hydraulic rubber oil hose, actuator, displacement & force sensor, microcomputer, industrial control computer and control circuit. The YX1200 pavement electro-hydraulic servo fatigue tester is a multi-purpose, automatic fatigue test system, and its actuator has a maximum load of 800 kN, a loading travel of 200 mm and a loading frequency of 0.1–10 Hz. (3) A large-sized composite reaction frame: a single reaction frame can provide a constraint reaction of 100 kN. The columns on both sides of the frame can move along the concave channel on the edge of an 18 m-long test slot, and the actuator of the fatigue tester can be fixed at any position of the reaction frame's girder. In addition, the 6 m-long triangular crossbeam can be accurately positioned using a digital dial gauge, thus measurement data is not influenced by the actuator.

Table 1
Performance parameters of the cement.

Fineness (80 μm weight of screen residue)/%	Water demand of standard consistency/%	Setting time		Soundness	Flexural-tensile strength		Compressive strength	
1.6	27.9	Initial setting 2 h 15 min	Final setting 5 h 35 min	Qualified after boiling	3 d 6.41	28 d 8.94	3 d 29.5	28 d 51.9