Study on the Panel Size Selection of Precast Concrete Pavement in Airport

Jinxing Cheng[1,a], Qicheng Ren[1,b], Lifang Zhang[2,c,*], Haoqiang Ye[2,d]

[1]Civil Aviation Engineering Consulting Company of China. No.9 Capital Airport West Road, Shunyi District, Beijing, China.
[2]College of Civil Aviation, Nanjing University of Aeronautics and Astronautics. No29 Jiangjun Avenue Jiangning District Nanjing, Jiangsu, China.

[a]305838056@qq.com, [b]714041237@qq.com
[c]Corresponding author:zlf.zj@nuaa.edu.cn,
[d]2219634118@qq.com

Abstract. Precast concrete pavement (PCP) is newly developed for airport pavement repairing and rapid runway construction in China which allows for faster construction and lower maintenance frequency. The PCP panel structure design and analysis is stated in this paper related to usage stage. Taking into accounting the requirements in usage stage, four panels are analyzed in this paper and a 2.5m×5.0m panel is recommended. It is shown that the maximum tensile stress generated by certain aircraft is greatly influenced by the ratio of panel length to width, with a maximum variation of exceeding 20%. For panels of different sizes, the panel with width equaling to length can gain the best bearing performance. The suggestions can be reference in airport PCP design and construction.

Keywords: Structure design and analysis, precast concrete pavement, airport pavement, plate size, maximum tensile stress, ratio of panel length to width

1 INTRODUCTION

Precast concrete pavement (PCP) is an effective method for repairing and replacing concrete road surfaces, as well as constructing new roads with heavy traffic. It is also suitable for airport runway and taxiway maintenance, construction, and emergency runway construction. Compared to cast in place cement concrete pavement, PCP allows for faster construction and lower maintenance frequency, while maintaining high adaptability and excellent quality [1-4]. Countries such as the United States, Japan, Russia, and France have used PCP for airport pavements, with significant variations in panel sizes. For instance, Japan adopts PCP panel size of 15m×2.5m[5]. Extensive research on the construction, connections, and construction techniques of PCP has been conducted in the United States [6-7]. It has been applied to partial repairs of highways, with panel sizes ranging from 1.6m to 4.6m, depending on the region of defects. In new construction projects, single-lane widths (3.6m to 4.0m) or double-lane widths (7.3m) can be selected, with a consideration that the size in one direction should be smaller than

© The Author(s) 2024
B. Yuan et al. (eds.), *Proceedings of the 2024 8th International Conference on Civil Architecture and Structural Engineering (ICCASE 2024)*, Atlantis Highlights in Engineering 33,
https://doi.org/10.2991/978-94-6463-449-5_57

3.65m, taking into account overload restrictions. In a study by Hong[8], the stress on the bottom surface of PCP panels was analyzed for various sizes (0.5m × 0.5m, 1m × 1m, 1.5m × 1.5m, 2m × 2m) and thicknesses (10cm to 40cm) using the load of the Su-30 aircraft. It was concluded that smaller panels exhibited better stress distribution. Chai [9] analyzed 5m × 5m panels, as well as half-sized panels (2.5m × 5m) and quarter-sized panels (2.5m × 2.5m), using the B737-800 aircraft and investigated the maximum principal stress under critical loads. It was recommended that the size of prefabricated panels should not be smaller than half the size of the original pavement panels. Vaitkus [10] analyzed the relationship between the dimensions and thickness of panels ranging from 3.5m × 4.2m to 4.0m × 4.6m, but the aspect ratios of these panels were all smaller than 1.2. Ameen Syed [1] analyzed panel sizes of 2.5m × 3.0m, 3.5m × 4.0m, and 3.75m × 4.50m, and recommended that panel sizes should not exceed 3.5m × 4.5m. In summary, research on the panel dimensions of PCP is mostly based on highway requirements, with a focus on smaller aspect ratios. There are few researches considering the transportation and large panels in airport pavement. This study investigates the panel dimensions of PCP in airport pavement, considering the requirements of usage scene and bearing performance. The aim is to provide references for designing more suitable prefabricated panels.

2 PRELIMINARY DIMENSIONS DESIGN

Airport runways are typically multiples of 100m in length, with widths of 30m, 45m, or 60m. Military airport runways also have lengths that are multiples of 100 m, with widths of 40m, 45 m, or 50m. All these dimensions are multiples of 5m. The runway slope is generally a double-sided slope, and to meet the slope requirements, prefabricated concrete panels should be laid on both sides of the runway centerline. The width of half of the runway is 15m, 22.5m, 25m, or 30m, all of which are multiples of 2.5m.

According to the specifications for airport cement concrete pavement design [11], rectangular concrete panels are recommended, with a maximum length of 5m and a width-to-length ratio of 1:1 to 1:1.25. According to the overall dimensions of the runway and transportation regulations, PCP panels with length of 5m can be selected. The width of the prefabricated concrete panels is advised as 2.5m. If there are no restrictions related to highway transportation, other sizes such as 5m × 5m can be used.

3 COMPARATIVE ANALYSIS OF SIZE INFLUENCE IN USE STAGE

3.1 Modeling Overview

The service aircraft in Chinese transport airports are mainly B737, A320, A330. However, the load effects of A320 are relatively small. Therefore, A330 and B737, representing the same series, were chosen to analyze the influence of panel size and study the stress and deflection of the panels under factors such as critical load, reinforcement, and base reaction modulus [12]. A model was established using 3×3 pieces of panels, with panel sizes ranging from 2.5m×5.0m, 3.0m×5.0m, 4.0m×5.0m, and 5.0m×5.0m, all with a thickness of 0.3m. Two sets of 32 finite element models were created, totaling 192 different working conditions, to analyze the differences in stress and deflection of the pavement panels under various conditions and summarize the influencing factors. The prefabricated panels were simplified as single-layer panels on a Winkler foundation [13,14]. Elastic foundation was used, and the lateral edges of the outer panels were restrained with U1 and U2 to limit their horizontal displacement. Z-direction shear springs (Spring2) were placed between the panels to represent joint load transfer. The reinforcement was modeled using beam elements and embedded within the pavement panel.

3.2 Aircraft Load and Critical Load Position Arrangement

To simplify the calculations, the representative aircraft load was converted into a rectangular load [15]. The aircraft parameters and corresponding rectangular wheel contact area are shown in Table 1. The length and width of the cement concrete pavement design specification were approximately equal, with the edge of the panel being the most critical load position. Due to transportation and installation requirements, the aspect ratios of prefabricated panels varied, resulting in more complex load conditions compared to traditional pavement. Referring to the Westergaard theory solution, the deflection and stress at the middle of the edge and the corner of the pavement panels are larger than those in the middle of the panel. Therefore, the critical load locations were arranged at the corners, the middle of the long side, and the middle of the short side.

Table 1. Model calculation parameters and wheel print dimensions

Aircraft	Main landing gear tire pressure /(MPa)	Rectangular wheel contact size	
		Length/(m)	Width (m)
B737-800	1.47	0.43	0.30
A330-200	1.42	0.53	0.37

3.3 Plate Stress and Deflection

The subgrade reaction modulus has an impact on the deformation and stress of the pavement panels [16,17]. The subgrade reaction modulus are set as 80 MPa, 100 MPa, 120 MPa, and 140 MPa. The maximum tensile stress and deflection for each condition, considering as plain concrete, are shown in Fig.1 to Fig.4.

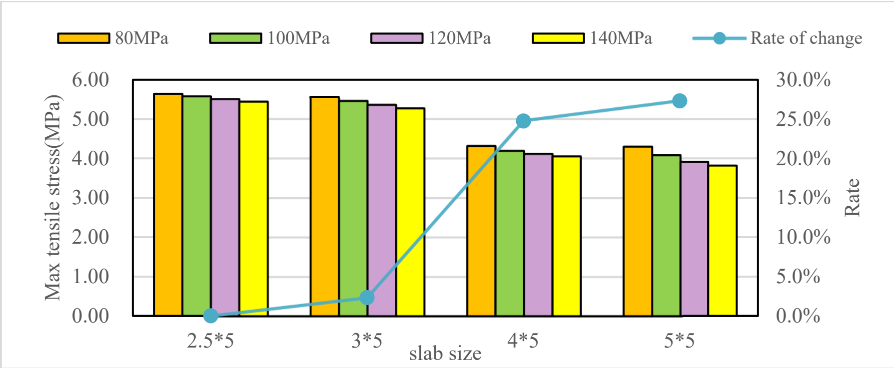

Fig. 1. Maximum tensile stress of slab under A330 aircraft load (plain concrete)

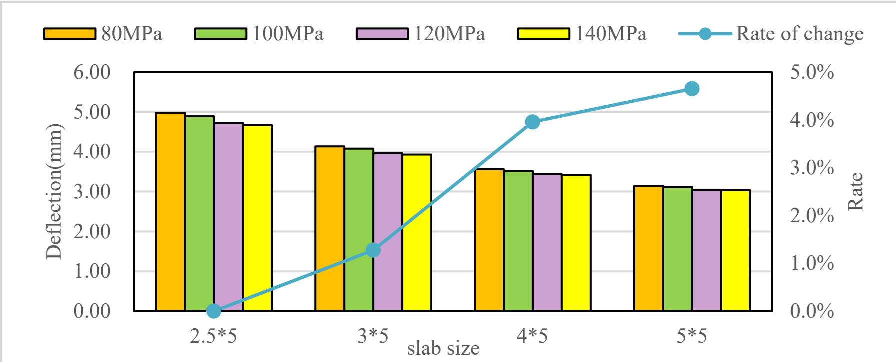

Fig. 2. Maximum deflection of slab under A330 aircraft load (plain concrete)

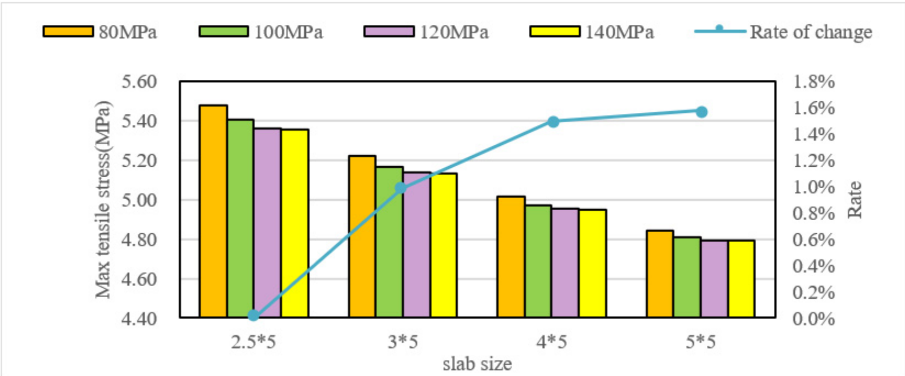

Fig. 3. Maximum tensile stress of slab under load of B737 aircraft (plain concrete)

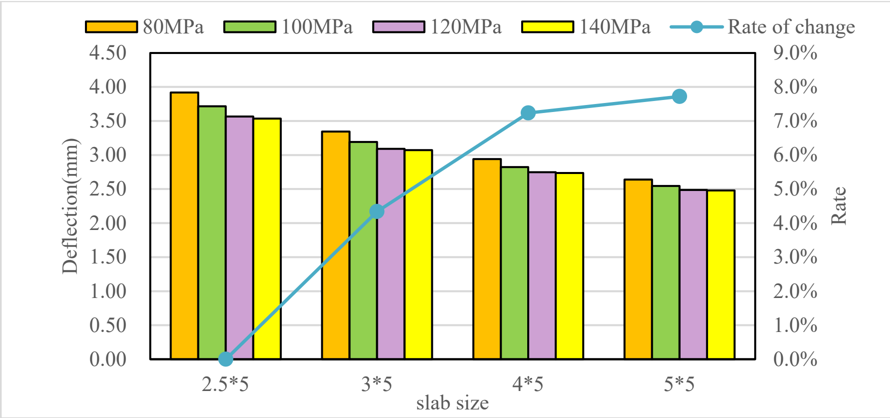

Fig. 4. Maximum deflection of slab under load of B737 aircraft (plain concrete)

The stresses for different load location of A330 in plain concrete and reinforced concrete with subgrade reaction modulus 80MPa are shown in Fig.5.

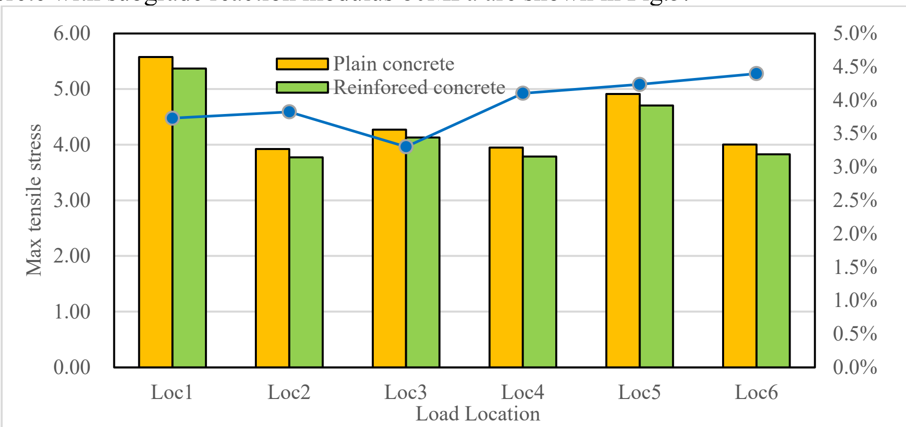

Fig. 5. Comparison of stress in plain concrete slab and reinforced concrete slab

3.4 Analysis

To analyze the influence of panel size, it can be found that under the A330 load, the variation in panel size causes a significant change in the maximum tensile stress, with a maximum variation of up to 27.3%. However, under the loading of a B737 aircraft, this variation has a less impact, with a variation of less than 2%. When the slab size is set as 5.0m×5.0m, with a length-to-width ratio close to 1:1, the stress is minimized. When the size is set at 2.5m×5.0m, the maximum tensile stress is the highest among the four panel sizes. However, the impact of size variation on the panel deflection is relatively small. In terms of relative variation, the stress variation is not significant for the 2.5m × 5.0m and 3.0m × 5.0m panels. When transitioning from 3.0m×5.0m (length/width ratio of 1.67) to 4.0m×5.0m (length/width ratio of 1.25) under A330 loading, there is a noticeable decrease in stress. However, the stress variation is not significant when transitioning from 4.0m×5.0m to 5.0m×5.0m.

Increasing the modulus of subgrade reaction has a significant effect on reducing the deflection of the panel. Comparing the effects of considering reinforcement and not considering reinforcement, the maximum stress is slightly reduced after adding reinforcement, the reduction is small, within 5%. Taking the example of a 2.5m×5.0m panel under the load of an A330 aircraft, the stress reduction magnitude is between 3.3% and 4.4%. So at elastic stress stage, the reinforcement contribute little to reducing stress.

4 CONCLUSION AND DESIGN SUGGESTION

Based on the analysis above, the following conclusions and recommendations can be drawn regarding the selection of panel dimensions from the perspectives of transportation, lifting, and usage:

(1)Considering the usage scenario of airport pavement and the convenience of transportation and installation, it is recommended to adopt a PCP panel dimension of 2.5m×5.0m, which is beneficial for transportation and installation.

(2)At the usage stage perspective, the maximum tensile stress generated by certain aircraft is greatly influenced by the ratio of panel length to width, with a maximum variation of up to 27.3%. In general, when the ratio of panel length to width is close to 1, the maximum tensile stress under aircraft loading is smaller. Therefore, when the conditions cannot meet a ratio of 1 to 1.25, selecting a larger length-to-width ratio considering other factors does not have a significant impact.

ACKNOWLEDGEMENTS

This work was supported by National Key Research and Development Program of China(No. 2021YFB2601205).

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