Research and Analysis of Civil Airport Asphalt Concrete Pavement Damage Cause Evaluation and Countermeasure

J Su¹,²*, F Xiao³, Z Liu⁴, L Kong⁵, P Wang¹,² and B Li¹,²
¹China Airport Construction Group Co., Ltd, China
²Beijing Super-Creative Technology Co., Ltd, China
³Chongqing Airport Group co., LTD
⁴Beijing Daxing International Airport of Capital Airport Holding Company
⁵China Airport Planning & Design Institute Co., Ltd.
*E-mail address: 13671346@qq.com

Abstract. Asphalt concrete pavement is characterized by convenient construction and maintenance, ride comfort, low noise, and strong adaptation and coordination deformation. Therefore, it has been gradually used in civil aviation transport airport runway, especially in recent years, the proportion of runways used in large hub airports has increased. However, asphalt concrete pavement also has many issues that is not conducive to the security of airport operation and management under the influence of traffic load, natural environment, and material performance. This paper analyzes and studies the causes and countermeasures of the damages through the investigation of several cases of asphalt concrete pavement damages in China, so as to provide reference for the extensive application and maintenance management of asphalt concrete pavement in airports in the future.

1. Introduction
Civil aviation industry, a national strategic and fundamental industry, has a growing importance in the national development and economic structure. During the 13th Five-Year Plan with macro-oriented policy guidance for a transportation and civil aviation power, the construction of civil airports has been expanded and speeded up. Three world-class airport clusters have basically taken shape in three regions: the Beijing-Tianjin-Hebei region, the Yangtze River Delta region, and the Guangdong-Hong Kong-Macao region. In addition, ten international aviation hubs in cities including Beijing, Shanghai, Guangzhou, and Shenzhen, and 29 regional hubs and non-hub transport airports have jointly formed a comprehensive airport system with wide coverage, reasonable layout and increasingly perfect functions. It is estimated that by the end of 2020[1], the number of transport airports in China will reach 241, with an annual increase of 7.4.

In the plan of the 14th Five-Year Plan for the first and medium to long-term future of the national comprehensive three-dimensional transportation network, it is proposed to strengthen the preventive maintenance of transportation infrastructure and safety assessment, strengthen long-term performance observation, improve data collection, detection and diagnosis, and maintenance and treatment technology system, strengthen disease management efforts, and eliminate safety risks timely. Promote the use of new materials, new technologies and new processes to improve the quality and service life of transportation infrastructure [2].
Civil aviation is an important component of the national comprehensive three-dimensional transportation network. Its infrastructure is also constantly improving and upgrading. In order to support the efficient operation of the airport and meet the special requirements of non-stop flights at the same time, asphalt concrete pavement has been gradually applied to civil airport runway pavement by virtue of its obvious advantages, such as convenient construction and maintenance, ride comfort, low noise, and strong adaptation and coordination deformation. According to incomplete statistics [3], in recent ten years, the number of asphalt concrete runways has been increasing year by year. As shown in Figure 1, asphalt concrete runways accounted for more than 15% of all runways in China, which indicates an increase of more than 130% compared with the number in 2010. Meanwhile, among large hub airports with a throughput of over 20 million, those with asphalt concrete runways account for up to 70%, as shown in Figure 2.

2. Overview of pavement damage condition

The pavement damage condition is one of the most important indicators which can reflect the pavement performance in the process of pavement use. Its low-cost, high operability, and intuitive results have made many countries to treat this method as an important component of the pavement evaluation system. A standardized process for performing this method has been created after decades of development.

Airport Pavement Damage Evaluation System includes two indexes, PCI and SCI. The specific evaluation standards are listed in Table 1 and Table 2 below. This paper focuses mainly on PCI since it is the main index used in reality [4].

| Pavement damage level | Good | Satisfactory | Fair | Poor | Very Poor |
|-----------------------|------|--------------|------|------|-----------|
| PCI range             | PCI ≥ 85 | 85 > PCI ≥70 | 70 > PCI ≥55 | 55 > PCI ≥40 | 40 > PCI |

| Structural bearing capacity | Satisfied | Unsatisfied |
|-----------------------------|-----------|-------------|
| SCI range                   | SCI ≥80   | SCI < 80    |

There are 16 different types of concrete pavement damage, as shown in Table 3 below:
| No. | Damage type                                      | Legend        | Levels of damage | No. | Damage type                                      | Legend        | Levels of damage |
|-----|-------------------------------------------------|---------------|------------------|-----|-------------------------------------------------|---------------|------------------|
| 1   | Fatigue Cracks Structural Damage                | Slight        | 9                | 2   | Irregular Cracks Structural Damage              | Slight        | 10               |
|     |                                                 | Medium        |                  |     |                                                 | Serious       |                  |
|     |                                                 | Serious       |                  |     |                                                 | Slight        |                  |
| 3   | Longitudinal and Transverse Cracks Structural   | Slight        | 11               |     | Rutting Structural Damage                       | Slight        |                  |
|     | Damage                                          | Medium        |                  |     |                                                 | Serious       |                  |
| 4   | Reflection Crack Non-structural Damage          | Slight        | 12               |     | Washboard Non-structural Damage                 | Slight        |                  |
|     |                                                 | Medium        |                  |     |                                                 | Serious       |                  |
| 5   | Slipping Crack Non-structural Damage            | ——             | 13               |     | Shoving Non-structural Damage                   | Slight        |                  |
|     |                                                 |               |                  |     |                                                 | Medium        |                  |
| 6   | Loose Aging Non-structural Damage               | Slight        | 14               |     | Jet ablation Non-structural Damage              | ——             |                  |
|     |                                                 | Medium        |                  |     |                                                 |               |                  |
| 7   | Bleed Non-structural Damage                     | ——             | 15               |     | Oil corrosion Non-structural Damage             | ——             |                  |
3. Investigation on damage condition of asphalt concrete runway surface
This paper investigates airport runways from different regions in China, including East China, North China, North-east China, South-west China, Central China, and North-west China. The research content includes the service time of each airport runway, traffic volume, typical damage types, etc., and is evaluated by PCI index, as shown in Figure 3, Figure 4 and Table 4.

| Region            | Airport | Years of Use | Annual Flights | Typical damage type                                      | Runway PCI | Ranking   |
|-------------------|---------|--------------|----------------|----------------------------------------------------------|------------|-----------|
| East China        | HD1     | 12           | 192929         | Subsidence, Upheaval, Rutting, and Cracks                | 79         | Satisfactory |
|                   | HD2     | 9            | 272928         |                                                          | 99         | Good      |
| North China       | HB1     | 17           | 167869         | Longitudinal and Transverse Cracks, Patches, Ablation, Surface Aggregates Polishing | 89         | Good      |
|                   | HB2     | 13           | 19533          | Reflection Cracks, Longitudinal and Transverse Cracks, Irregular Cracks | 75         | Satisfactory |
| North-east China  | DB1     | 14           | 154976         | Reflection Cracks, Longitudinal and Transverse Cracks | 86         | Good      |
|                   | DB2     | 9            | 145350         | Longitudinal and Transverse Cracks, Irregular Cracks, Reflection Cracks, and Surface Loose Peeling | 76         | Satisfactory |
|                   | DB3     | 17           | 147795         | Loose Aging, Temperature Cracks, Longitudinal and Transverse Cracks, Reflection Cracks, Washboard, Rutting, and Patches | 75         | Satisfactory |
|                   | DB4     | 15           | /              | Reflection Cracks, Irregular Cracks, Patches, Loose Aging, and Subsidence | 28         | Poor      |
| Region           | Airport | Years of Use | Annual Flights | Typical damage type                                      | Runway PCI | Ranking |
|------------------|---------|--------------|----------------|----------------------------------------------------------|------------|---------|
| South-west China | XN1     | 9            | 54255          | Loose Aging and Peeling                                   | 95         | Good    |
|                  | XN 2    | 7            | 18160          | Shoving, Upheaval, and Loose Aging                        | 95         | Good    |
|                  | XN 3    | 7            | 43034          | Upheaval, Aggregates Aging, and Shoving                  | 84         | Satisfactory |
|                  | XN 4    | 11           | 10427          | Reflection Cracks and Loose Peeling                       | 74         | Satisfactory |
|                  | XN 5    | 7            | 318398         | Oil Corrosion, Bleed, Longitudinal and Transverse Cracks, and Slight Rutting | 98         | Good    |
| Central China    | HZ1     | 11           | 196213         | Rutting, Cracks, and Loose Aging                         | 79         | Satisfactory |
|                  | HZ2     | 9            | 85596          | Partial Rutting, Upheaval, and Patches                    | 95         | Good    |
| North-west China | XB1     | 6            | 345748         | Patches                                                   | 98         | Good    |
|                  | XB2     | 8            | 61218          | Upheaval                                                  | 95         | Good    |

Research finds that:
1. Over 70% of the main damages to asphalt concrete runways are Cracks (Longitudinal and transverse Cracks/Reflection cracks/Fatigue cracks/Irregular cracks), rutting, loose aging, patches, etc.
2. Runways with damaged surfaces and significantly reduced conditions have typically been in service for more than 10 years.
3. The pavement condition is closely related to the traffic load. The more take-off and landing sorties of the runway, the more obvious the downward trend of the pavement condition is.

4. Research and analysis of methods to deal with pavement damage
To better understand and grasp the domestic asphalt concrete application in civil airport runway pavement, and take targeted countermeasures, this paper analyzes the causes of typical asphalt concrete damage and puts forward appropriate treatment measures by studying the effect and influence of factors such as the area where the asphalt concrete runway is located, the natural environmental conditions, the time when the pavement is put into use, and the traffic load, etc.

4.1. Causes of pavement damage

The research results of this paper show that the damages and downswing of asphalt concrete runways in the north-east and south-west region are more obvious. The main performances are Cracks (longitudinal and transverse/reflection/fatigue cracks/Irregular cracks), rutting, and loose aging. The damages are mainly concentrated in the main grounding zone, load turbine zone, and the junction where aircrafts slowly turn away from the runway, as shown in Figure 5. Based on a comprehensive survey of the geology, natural environment conditions, year of use, traffic load and other conditions of the airport site, the causes of the damages [5] are analyzed as follows:
1. Causes of longitudinal and transverse cracks: Mainly affected by temperature and construction, specifically including 1) Cracks in the base layer reflecting to the pavement surface; 2) Improper handling of the construction process; 3) Shrinkage of asphalt pavement due to low temperature.
2. Causes of fatigue cracks and irregular cracks: Mainly affected by raw materials, traffic load and structural layer deformation, including 1) Raw materials, especially asphalt binder performance is insufficient or construction quality problems; 2) damping deformation of soil base or reflection of
damaged base; 3) the pavement structure layer does not meet the designed strength requirements or is caused by overload operation.

3. Causes of rutting: Mainly affected by the properties of raw materials and mixtures, and traffic loads, specifically including 1) Low softening point of asphalt or poor grading of mixture under special loads; 2) poor grading of mixing material causes deformation under the action of load.

4. Causes of loose aging: Mainly affected by mixture performance, long service cycle and natural environment, specifically including 1) Uneven mix ratio of asphalt mixture, excess mixing temperature, insufficient rolling forming temperature, deterioration of asphalt and poor quality of rolling forming; 2) long service cycle of asphalt concrete; 3) in cold areas, the surface is damaged by ice crystals due to the intrusion of rain and snow into the surface.

Combined with the above analysis of the causes of asphalt pavement damages, the main influencing factors can be summarized as follows: (1) Environmental effects such as frozen snow in winter and heavy rain in summer; (2) poor selection of raw materials and poor quality of mixing materials and spreading on site; (3) effects of long-term frequent load.

4.2. Research and analysis of methods to deal with pavement damage

According to the international common experience and practice, it is recommended that once the PCI value is lower than 70 (the minimum maintenance value recommended by FAA), the damage degree of the pavement will decrease sharply, and the maintenance cost will also increase sharply. Therefore, when the PCI value of the airport pavement damage is about 70, it is the best time to maintain the pavement, as shown in Figure 6 [6].

![Figure 6 Pavement PCI, life cycle, and maintenance occasion diagram](image)

In view of the damage situation of asphalt concrete pavement and the treatment measures taken by various airports over the years, the damage treatment measures [7] are summarized as follows through investigation, analysis and summary:

1. Grouting: Based on the size and degree of cracks, paving or grouting can be used. Choose heating type modified rubber asphalt materials or modified emulsified asphalt materials with good durability, strong bonding and strong temperature stability.

2. Fog sealing layer: When the pavement surface is in good condition and there is no obvious damage or the damage is slight, it is advisable to use solvent-based materials to utilize fog sealing or micro-surface treatments.

3. Patches: Based on the range, depth and degree of the damage, choose the hot mix asphalt mixture with hard aggregate texture, good grading and good modifier to carry out certain layer thickness repair or full thickness repair.
4. Pavement coverage includes functional coverage and structural coverage, 1) Functional coverage: Used when there are large number of wide-spread asphalt surface damages that greatly reduce pavement function or affect the safety of operation; 2) Structural coverage: It shall be applied if the original pavement structure fails to meet the pavement grade requirements of the aircraft type used according to the airport operation requirements.

5. Thermal regeneration technology: Utilize thermal regeneration technology based on the asphalt concrete runway surface structure, the degree of damage, raw asphalt material performance and other comprehensive situations.

Asphalt concrete pavement damages are mainly formed during operation. Although it is closely related to the use, maintenance and management of pavement, it is also inseparable from pavement design and construction. Solving the damages include several steps (1) Design: Design the strength and thickness of pavement based on the airport site, environmental conditions and application needs, and select high-quality materials; (2) construction: Effective paving treatment, mixture temperature control, rolling, joint treatment, etc.; (3) maintenance: After put into use, combine routine maintenance, regular pre-maintenance, timely treatment of damages and other means.

5. Conclusions
To sum up, with the development trend of civil airport construction in China, the broad prospect of asphalt concrete pavement application and its comprehensive efficiency should be actively utilized to improve the quality of construction projects and the level of operation and management. The key tasks should be summarized as follows:

1. In the construction phase, a comprehensive, detailed and dynamic grasp of the status and development trend of the pavement should be achieved through scientific, reasonable and effective testing and evaluation methods, so as to provide basis and support for the decision-making of the transportation management and construction.

2. The formation, application and maintenance of pavement structure is an organic and unified whole. Asphalt concrete pavement structure also conforms to the rules. In order to reduce or even cure the pavement damages, the construction unit should pay attention to design, construction and maintenance.

3. The construction unit should comprehensively consider technology, materials, funds, time and other multi-dimensional factors to achieve comprehensive and long-term input-output benefits.

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