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Implementation of Evaluating the Airport Pavement Bearing Strength by ACR-PCR Software in China

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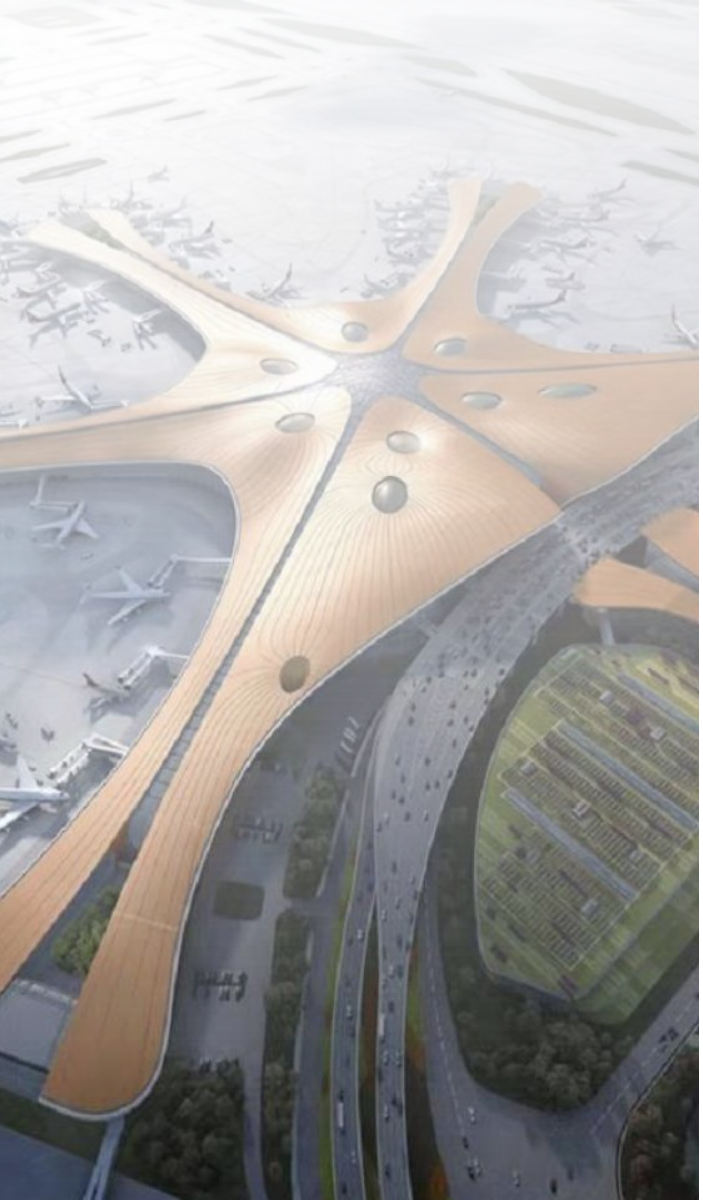


Outline

1. PCR Calculation Method
2. CAAC-PCR Evaluation Software
3. Next Tasks

ACR-PCR Evaluation Method: Strength Reporting

Strength Reporting Format: PCR/Pavement Type/Base Strength Type/Maximum Allowable Tire Pressure Type/Evaluation Method

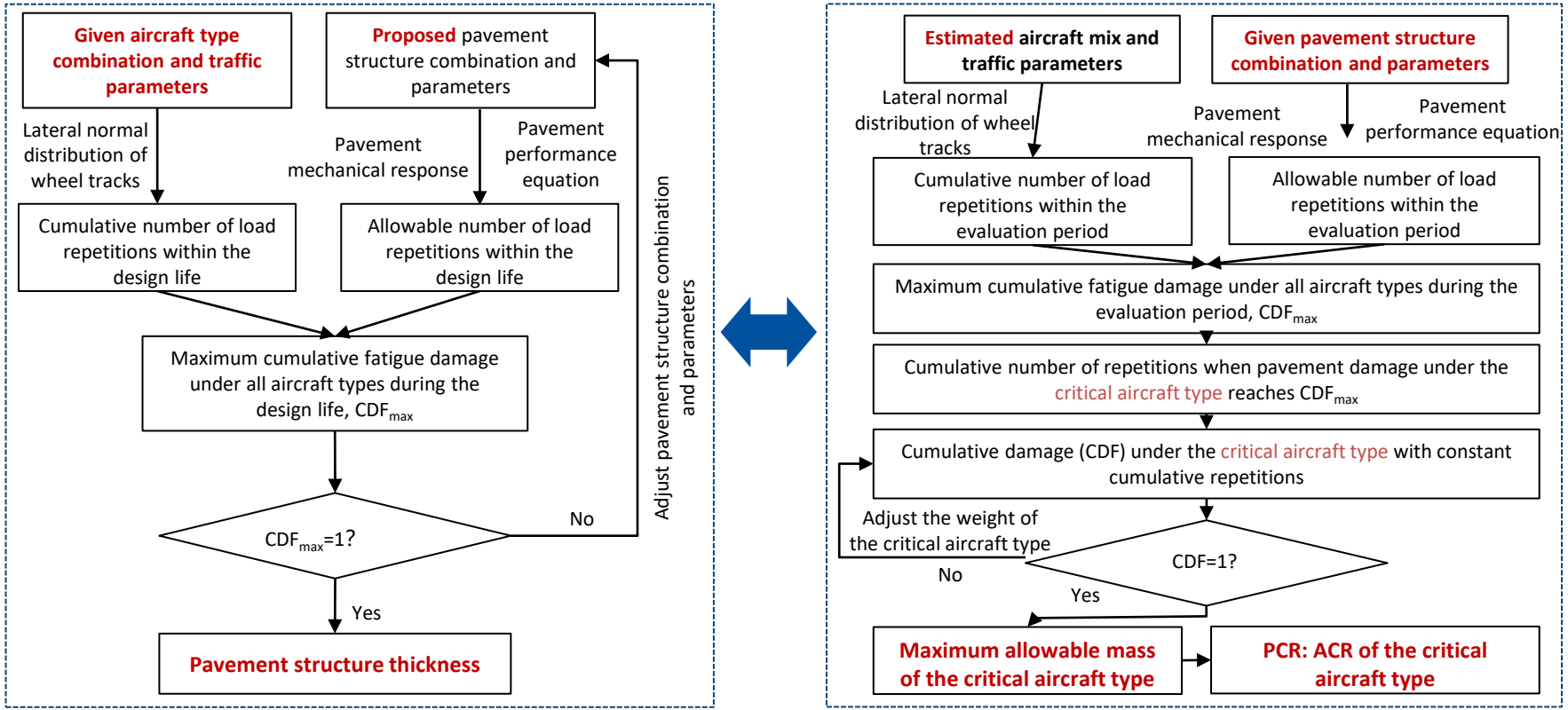
Category			Code	Definition	Remarks
1	Pavement Type	Rigid Pavement	R	If the pavement structure is composite or non-standard, annotations should be added.	No Change
		Flexible Pavement	F		
2	Base Strength Type	High Strength	A	Base E = 200 MPa, representing E values greater than 150 MPa.	PCN base strength uses CBR and k.
		Medium Strength	B	Base E = 120 MPa, representing E values between 100 MPa and 150 MPa.	
		Low Strength	C	Base E = 80 MPa, representing E values between 60 MPa and 100 MPa.	
		Very Low Strength	D	Base E = 50 MPa, representing E values less than 60 MPa.	
3	Maximum Allowable Tire Pressure	No Limit	W	Unrestricted tire pressure.	No Change
		High	X	Tire pressure limit up to 1.75 MPa.	
		Medium	Y	Tire pressure limit up to 1.25 MPa.	
		Low	Z	Tire pressure limit up to 0.50 MPa.	
4	Evaluation Method	Technical Evaluation	T	Indicates the evaluation of pavement characteristics through testing or theoretical assessment.	No Change
		Empirical Evaluation	U	Indicates the evaluation of pavement characteristics based on empirical experience.	

ACR-PCR Evaluation Method: Evaluation Standards

Item	Pavement Classification	Overload Operation Assessment
ACR ≤ PCR	Rigid Pavement	Unrestricted operation under specified tire pressure and maximum takeoff weight conditions.
	Flexible Pavement	
ACR > PCR	Flexible Pavement	ACR ≤ 1.10 × PCR, with restricted overload operation. (Number of annual overload operations not exceeding 5% of total annual operations.)
	Rigid Pavement or Composite Pavement Dominated by Rigid Pavement	ACR ≤ 1.05 × PCR, with restricted overload operation. (Number of annual overload operations not exceeding 5% of total annual operations.)
	Rigid Pavement or Composite Pavement Dominated by Rigid Pavement	1.05 × PCR < ACR < 1.10 × PCR, specialized evaluation for overload operations.

PCR Technical Evaluation Method: Inverse Process for Calculating Pavement Structure Thickness

- **Thickness Calculation:**, calculate the satisfied pavement thickness based on given aircraft type combinations, weight, and traffic information.
- **PCR Calculation:** calculate the maximum allowable aircraft mass based on given pavement structure combinations, thickness, and etc.



PCR Technical Evaluation: Calculation Process

PCR: ACR of the maximum allowable mass of the critical aircraft type.

- **Step 1**: Determine pavement structural parameters, evaluation period, the combination of aircraft types, and traffic parameters within the evaluation period.
- **Step 2**: Calculate the maximum cumulative fatigue damage (CDF_{max}) of the pavement under all aircraft types within the evaluation period.
- **Step 3**: Identify the critical aircraft type based on the proportion of cumulative fatigue damage.
- **Step 4**: Calculate the maximum allowable mass of the critical aircraft using the pavement design specifications' thickness calculation method.
- **Step 5**: Calculate the ACR corresponding to the maximum allowable mass of the critical aircraft type, which is PCR_i.
- **Step 6**: If the critical aircraft identified in step 3 is not the aircraft with the maximum ACR in the combination, remove this aircraft and repeat steps 3 to 5 with the remaining aircraft combination.
- **Step 7**: PCR = max(PCR_i), rounded to the nearest multiple of 10.

PCR Technical Evaluation: Identifying the Critical Aircraft Type

- **Calculate cumulative fatigue damage based on pavement design specifications , the critical aircraft type is defined as the highest contributing to pavement damage.**

  - Cumulative fatigue damage curve of the pavement under a single aircraft type

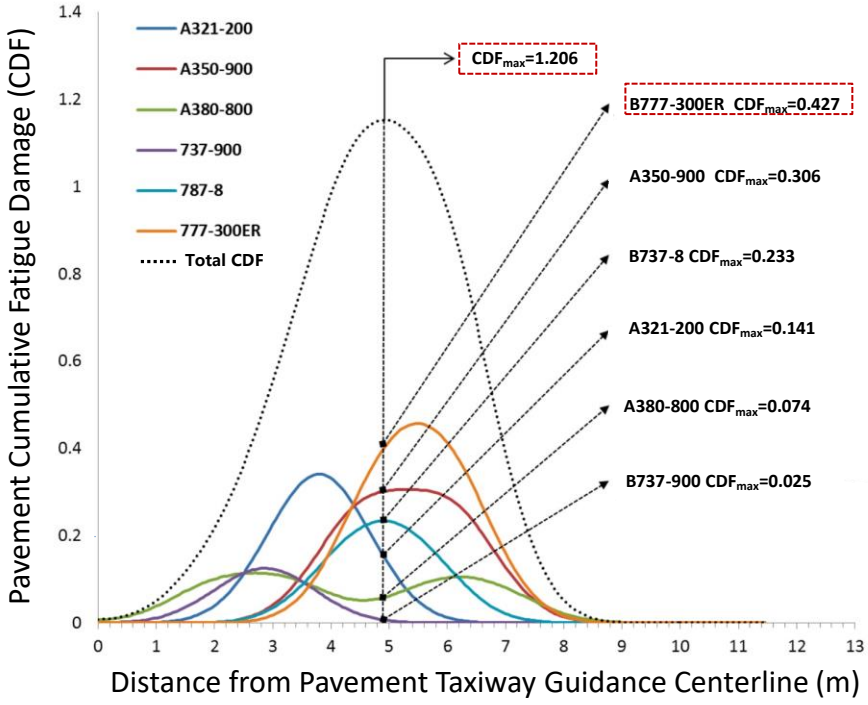
$$CDF_{ij} = \frac{N_{ij}}{Nei}$$

  - Cumulative fatigue damage curve of the pavement under all aircraft types

$$CDF_j = \sum_{i=1}^{I} (CDF_{ij})$$

  - Maximum cumulative fatigue damage of the pavement under all aircraft types

$$CDF_{max} = Max(CDF_j)$$



PCR Technical Evaluation: Calculating the Maximum Allowable Mass of the Critical Aircraft Type

Mass of the aircraft type when the cumulative damage of pavement reaches CDF_{max} during the evaluation period

Step 1: Calculate the Cumulative Number of Operations of the Critical Aircraft Type

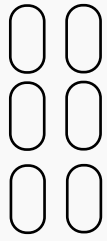
Keep the maximum takeoff weight of the critical aircraft type constant. Iteratively calculate the cumulative number of operations for the critical aircraft type so that the maximum cumulative fatigue damage (CDF) of pavement under the action of the critical aircraft type equals CDF_{max}.

Step 2: Calculate the Maximum Allowable Mass of the Critical Aircraft Type

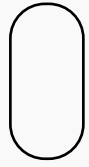
Keep the cumulative number of operations for the critical aircraft type constant. Iteratively calculate the maximum allowable mass of the critical aircraft type so that the maximum cumulative fatigue damage (CDF) of pavement under the action of the critical aircraft type equals 1.0.

The ACR corresponding to the maximum allowable mass of the critical aircraft type is the pavement PCR

PCR Technical Evaluation: Rigid Pavement - Critical Aircraft ACR Calculation



- Critical Aircraft Main Landing Gear
  - Actual Tire Pressure
  - Single Main Landing Gear Load



- Equivalent Single Wheel Load
  - Constant Tire Pressure of 1.5 Mpa
  - Converted Single Wheel Load (DSWL) (kg)

- Critical Aircraft ACR for Given Subgrade Strength

$$ACR=2\times\frac{DSWL}{100}$$

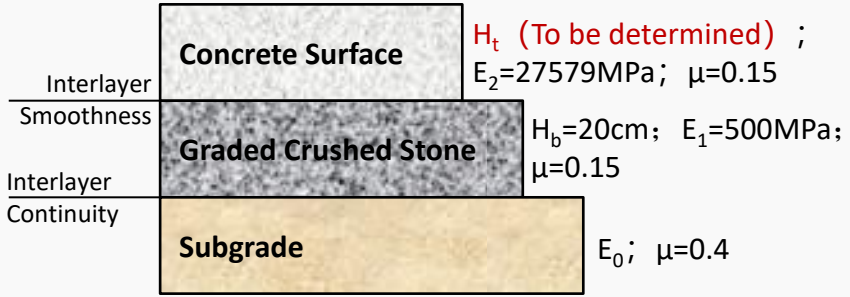
Step 1

- Control Maximum Flexural Tensile Stress at Bottom of Pavement Slab: 2.75 MPa
- Based on Elastic Layered System Theory
- Calculate Slab Thickness H_t for Given Subgrade Strength

Step 2

- Control Maximum Flexural Tensile Stress at Bottom of Pavement Slab: 2.75 MPa
- Based on Elastic Layered System Theory
- Calculate Equivalent Converted Single Wheel Load (DWSL)

Standard Structure for ACR Calculation on Rigid Pavement



H_t (To be determined)；
E_2=27579MPa；μ=0.15

H_b=20cm；E_1=500MPa；μ=0.15

E_0；μ=0.4

Subgrade Strength Grade	Range of Subgrade Top Surface Resilient Modulus (MPa)	Characteristic Value of Subgrade Top Surface Resilient Modulus E_0 (MPa)
A	$E_0 \geq 150$	200
B	$100 \leq E_0 < 150$	120
C	$60 \leq E_0 < 100$	80
D	$E_0 < 60$	50

Note: If H_t is less than 50.8 mm, the slab thickness is set to 50.8 mm. The maximum flexural tensile stress at the bottom of the slab under the load of a single main landing gear is calculated as the control mechanical response value for the second step. For aircraft with multiple main landing gear configurations, the highest ACR value obtained from all main landing gear is used as the representative ACR value for that aircraft type.

PCR Technical Evaluation: Flexible Pavement - Critical Aircraft ACR Calculation

- Critical Aircraft Main Landing Gear
- Actual Tire Pressure
- All Main Landing Gear Load

- Equivalent Single Wheel Load
- Constant Tire Pressure of 1.5 MPa
- Converted Single Wheel Load (DSWL) (kg)

- Critical Aircraft ACR for Given Subgrade Strength

$$ACR=2\times\frac{DSWL}{100}$$

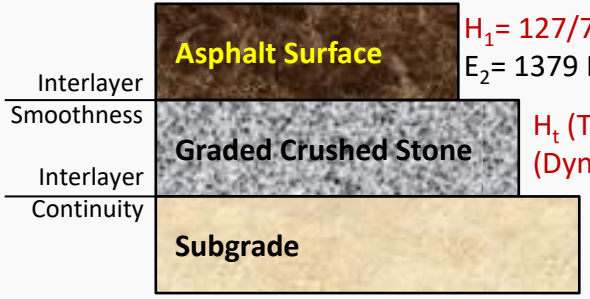
Step 1

- Control vertical compressive strain at the subgrade top surface to reach the allowable value (CDF=1) after 36,500 operations.
- Based on Elastic Layered System Theory
- Calculate Subgrade Thickness H_t for Given Subgrade Strength

Step 2

- Control vertical compressive strain at the subgrade top surface to reach the allowable value (CDF=1) after 36,500 operations.
- Based on Elastic Layered System Theory
- Calculate Equivalent Converted Single Wheel Load (DWSL)

Standard Structure for ACR Calculation on Flexible Pavement



H_1= 127/76mm ;
E_2= 1379 MPa; μ=0.35

H_t (To be determined); E_1 (Dynamically adjusted); μ=0.35

E_0; μ=0.35

Subgrade Strength Grade	Range of Subgrade Top Surface Resilient Modulus (MPa)	Characteristic Value of Subgrade Top Surface Resilient Modulus E_0 (MPa)
A	$E_0 \geq 150$	200
B	$100 \leq E_0 < 150$	120
C	$60 \leq E_0 < 100$	80
D	$E_0 < 60$	50

Note: If the number of wheels on a single main landing gear is greater than 2, set H_1 to 127 mm; otherwise, set H_1 to 76 mm. If H_t is less than 25.4 mm, the base course thickness is set to 25.4 mm. Calculate the maximum vertical compressive strain at the subgrade top surface under the load of all main landing gear as the control mechanical response value for the second step.

PCR Empirical Evaluation

- **The pavement PCR is the maximum ACR among all aircraft types operating at the airport**

  - Step 1: Determine the pavement structural parameters, aircraft combination within the evaluation period and traffic parameters
  - Step 2: Exclude aircraft types with an operational proportion of less than 5% within the evaluation period
  - Step 3: Calculate the ACR_i for each aircraft type in the combination
  - Step 4: Round the maximum ACR_i to the nearest multiple of 10 to obtain the pavement PCR

Case Study: PCR Technical Evaluation

- **Step 1:** Determine pavement structural parameters, evaluation period, and aircraft traffic parameters
  - Evaluation period: 30 years, pavement slab flexural strength: 5.0 MPa

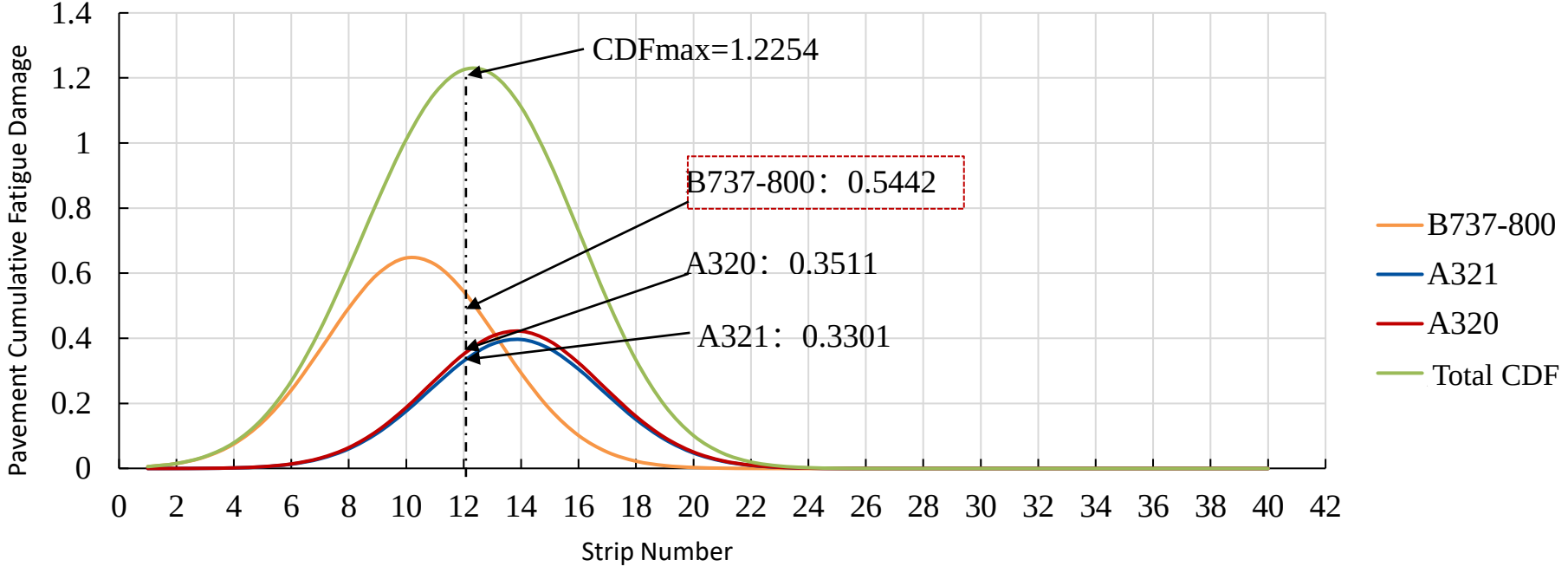
Structure Name	Material Type	Thickness (mm)	Modulus (MPa)	Poisson's Ratio
Surface Layer	Cement Concrete	330	27579	0.15
Upper Base	Cement Stabilized Gravel	180	2250	0.2
Lower Base	Cement Stabilized Gravel	180	2250	0.2
Subgrade Top Reaction Modulus (MN/m^3)			80	——

Aircraft Type	Maximum Takeoff Weight (kg)	Main Gear Load Distribution Coefficient	Annual Aircraft Take-off Sorties
B737-800	79004	0.95	1045
A321	83000	0.956	523
A320	76440	0.95	3658

Aircraft Type	B737-800	A321	A320
Corresponding ACR	530	540	480

Case Study: PCR Technical Evaluation

- **Step 2:** Calculate the maximum cumulative fatigue damage (CDF_{max}) of the pavement under all aircraft types: CDF_{max} = 1.2254
- **Step 3:** Identify the critical aircraft type based on the proportion of pavement cumulative fatigue damage: B737-800



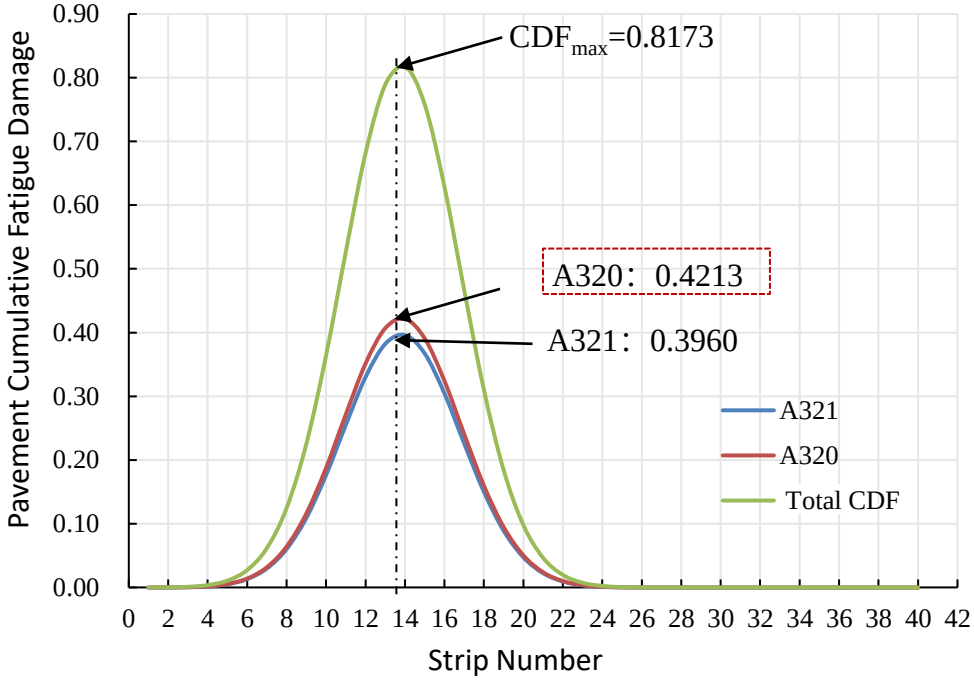
Case Study: PCR Technical Evaluation

- **Step 4:** Calculate the maximum allowable mass of the critical aircraft type B737-800
  - 1: Under the action of B737-800, when CDF_{max} = 1.2254, the cumulative number of operations is 19,098
  - 2: At 19,098 load applications, when CDF_{max} = 1, the mass of the B737-800 is 78,216 kg
  - 3: The maximum allowable mass of the B737-800 is 78,216 kg
- **Step 5:** Calculate the ACR value of the B737-800 at the maximum allowable mass of 78,216 kg using the rigid pavement ACR calculation method, resulting in 508.25. Therefore, PCR_1 = 508.25

Case Study: PCR Technical Evaluation

- **Step 6:** B737-800 is not the aircraft type with the maximum ACR in the aircraft combination by comparing the results. Exclude the B737-800 and form a new aircraft combination with A321 and A320, then repeat the calculation process

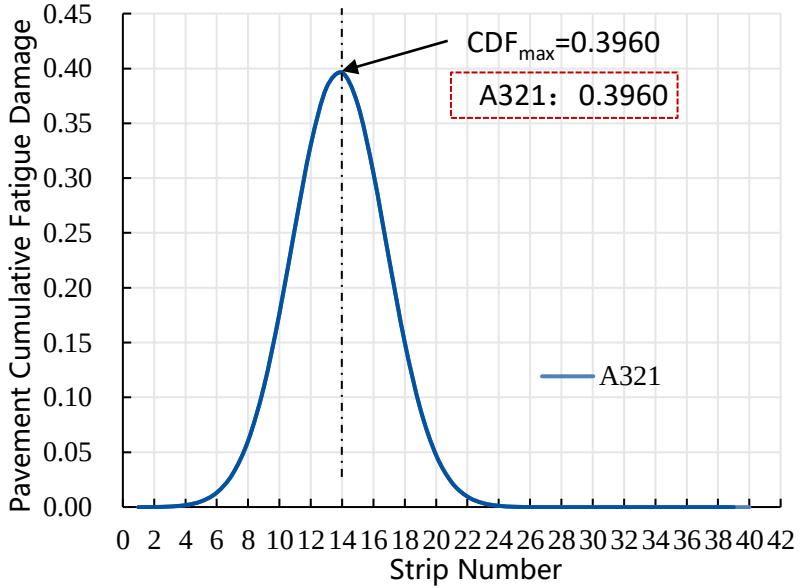
  - In the new aircraft combination, the critical aircraft type is the A320
  - The equivalent cumulative number of operations is 100,987 under the action of the A320, when the pavement cumulative fatigue damage is 1.2254
  - Under 100,987 operations, when the cumulative fatigue damage is 1, the mass of the A320 is 75,723 kg
  - The maximum allowable mass of the A320 is 75,723 kg, and the corresponding ACR is 459.81. Therefore, PCR_2 = 459.81



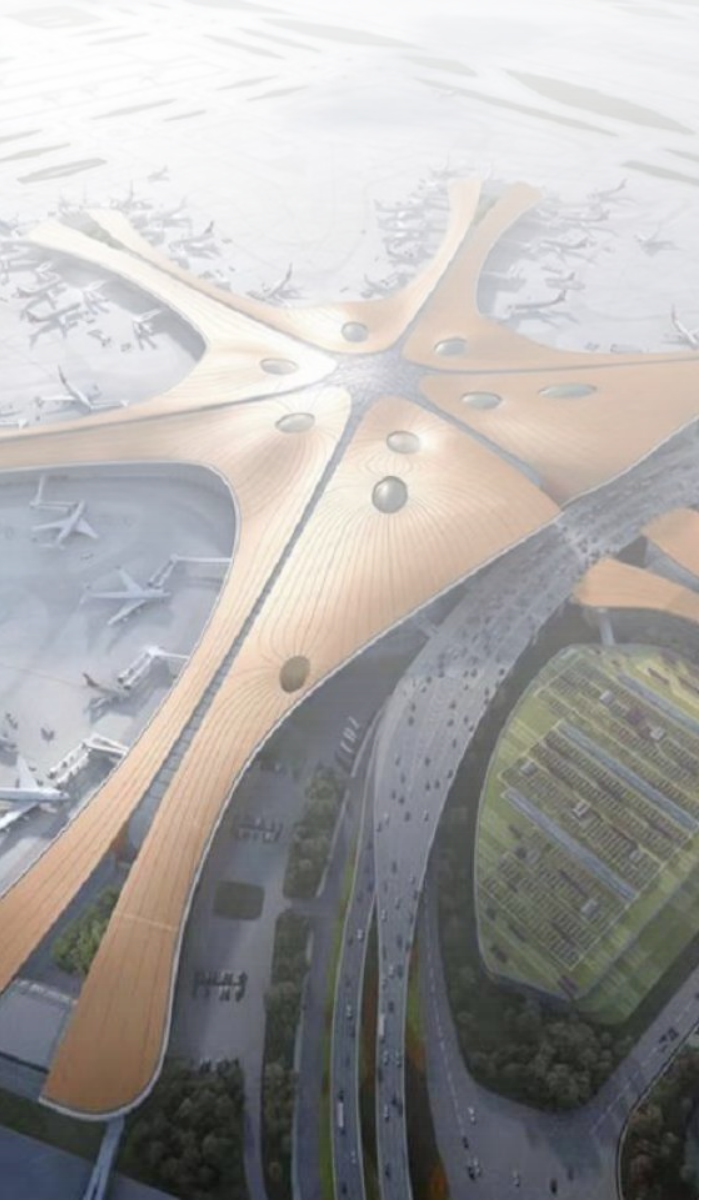
Case Study: PCR Technical Evaluation

- **Step 7:** Upon comparison, it is found that the A320 is also not the aircraft type with the maximum ACR in the aircraft combination. Exclude the A320 and form a new aircraft mix with the A321, then continue the calculation

  - In the new aircraft combination, the critical aircraft type is the A321
  - Under the action of the A321, when the pavement cumulative fatigue damage is 1.2254, the equivalent cumulative number of operations is 16,729
  - Under 16,729 operations, when the cumulative fatigue damage is 1, the mass of the A321 is 82,155 kg
  - The maximum allowable mass of the A321 is 82,155 kg, and the corresponding ACR is 518.24. Therefore, PCR_3 = 518.24



- **Step 8:** As the A321 is the aircraft type with the maximum ACR in the combination, PCR = max(PCR_1, PCR_2, PCR_3) = 518.24, rounded to 520



Outline

1. PCR Calculation Method
2. CAAC-PCR Evaluation Software
3. Next Tasks

Current Stage

- The evaluation software of rigid and flexible PCR has been completed
- The evaluation software of flexible channel PCR technology is being compiled

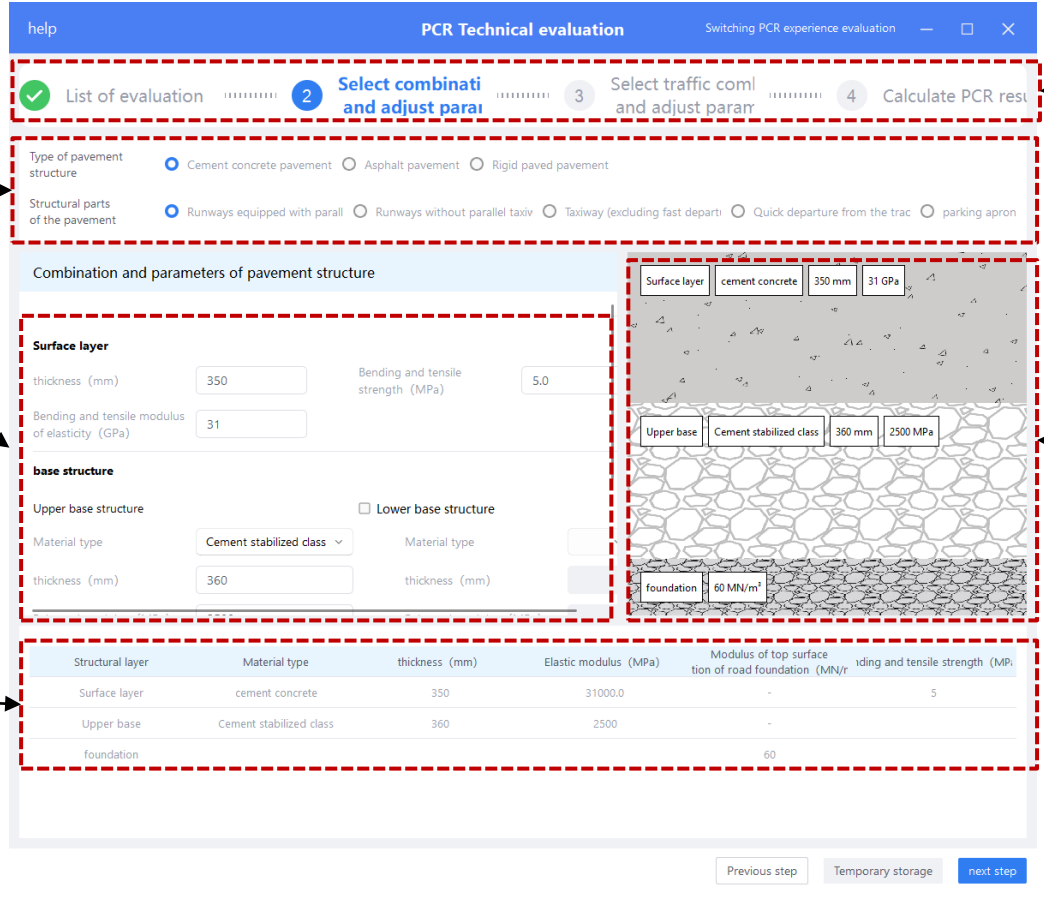
PCR Technical evaluation

PCR Experience evaluation

Shanghai Tongke Co., Ltd AVIC-APC Co., Ltd Tongji University

Technology Evaluation

☐ Structural parameter input (Rigid pavement)



Type of pavement structure

Pavement structure input parameters

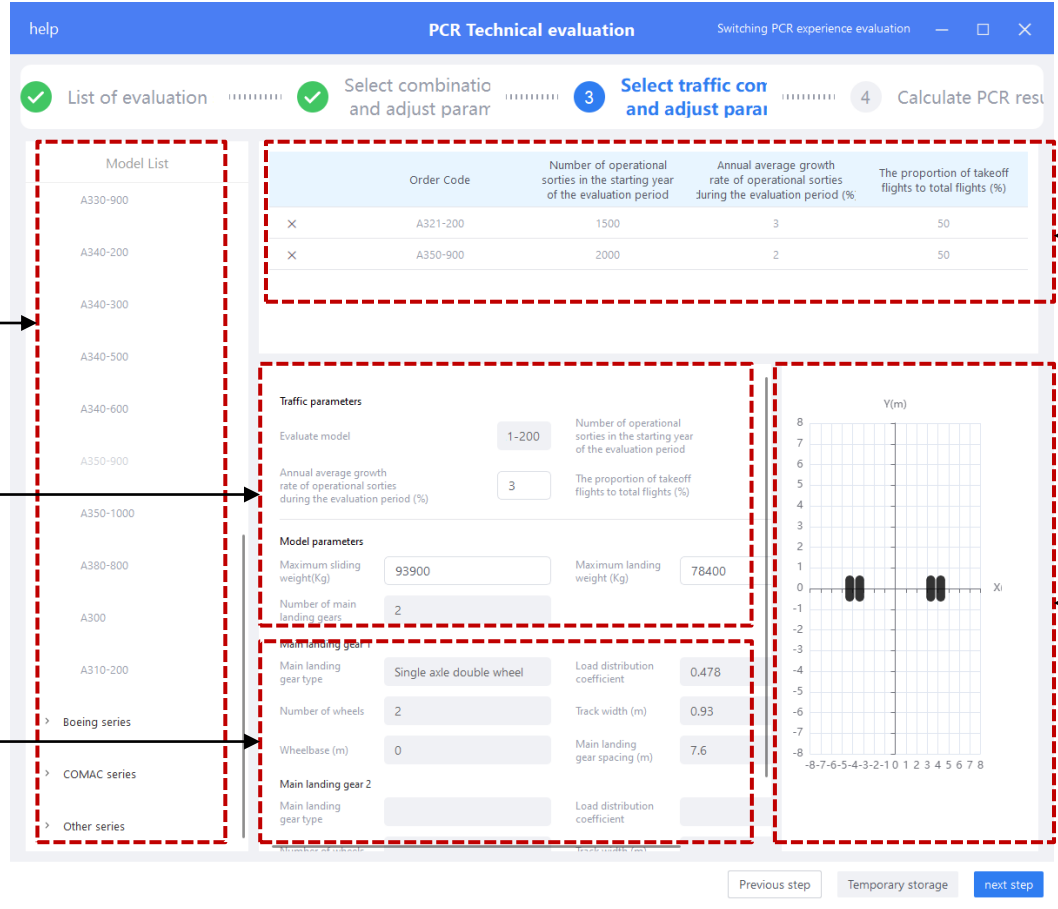
Pavement structure layer information

Calculation procedure

Pavement structure diagram

Technology Evaluation

☐ Traffic parameter input



Aircraft list (Boeing, Airbus, ComAC, others)

Air traffic input

Main landing gear parameters

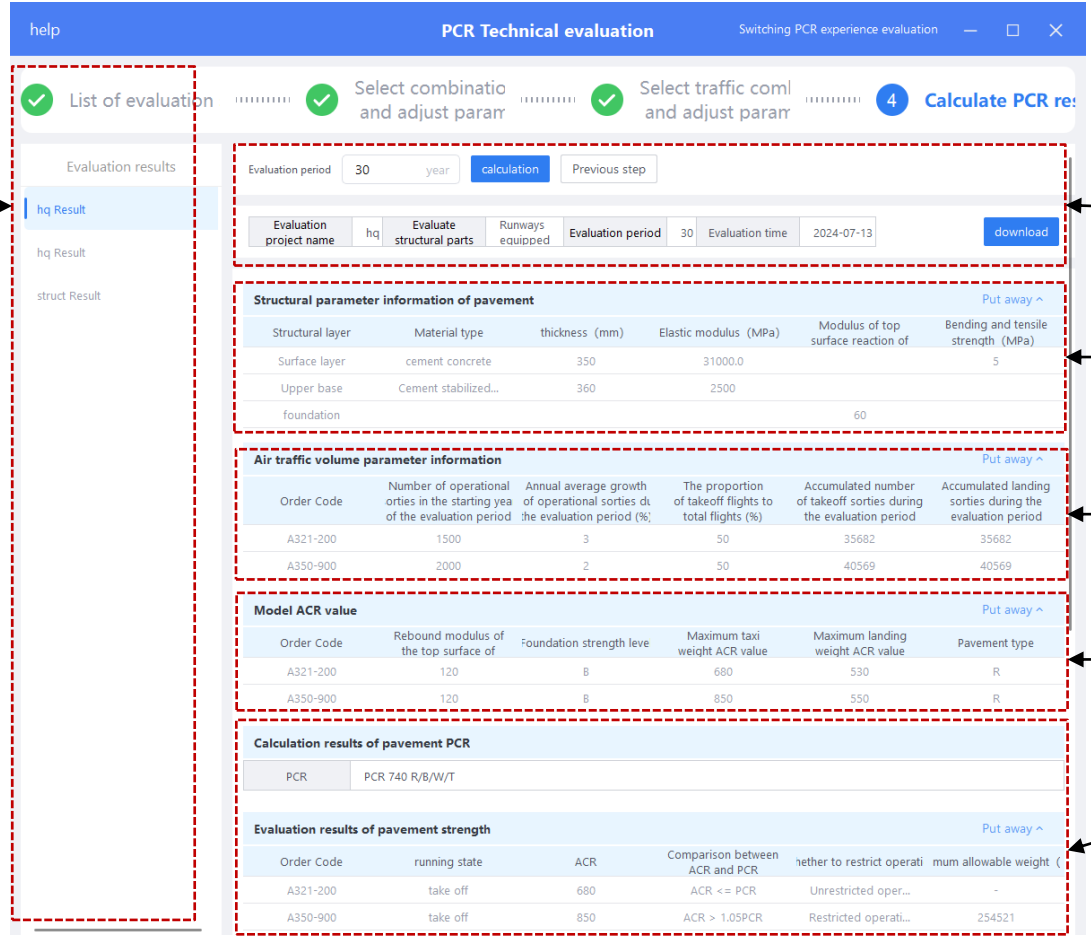
Aircraft mix and traffic volume list

Main landing gear configuration diagram

Technology Evaluation

Evaluation Results

List of evaluation results



Basic project information

Structure combination and parameters

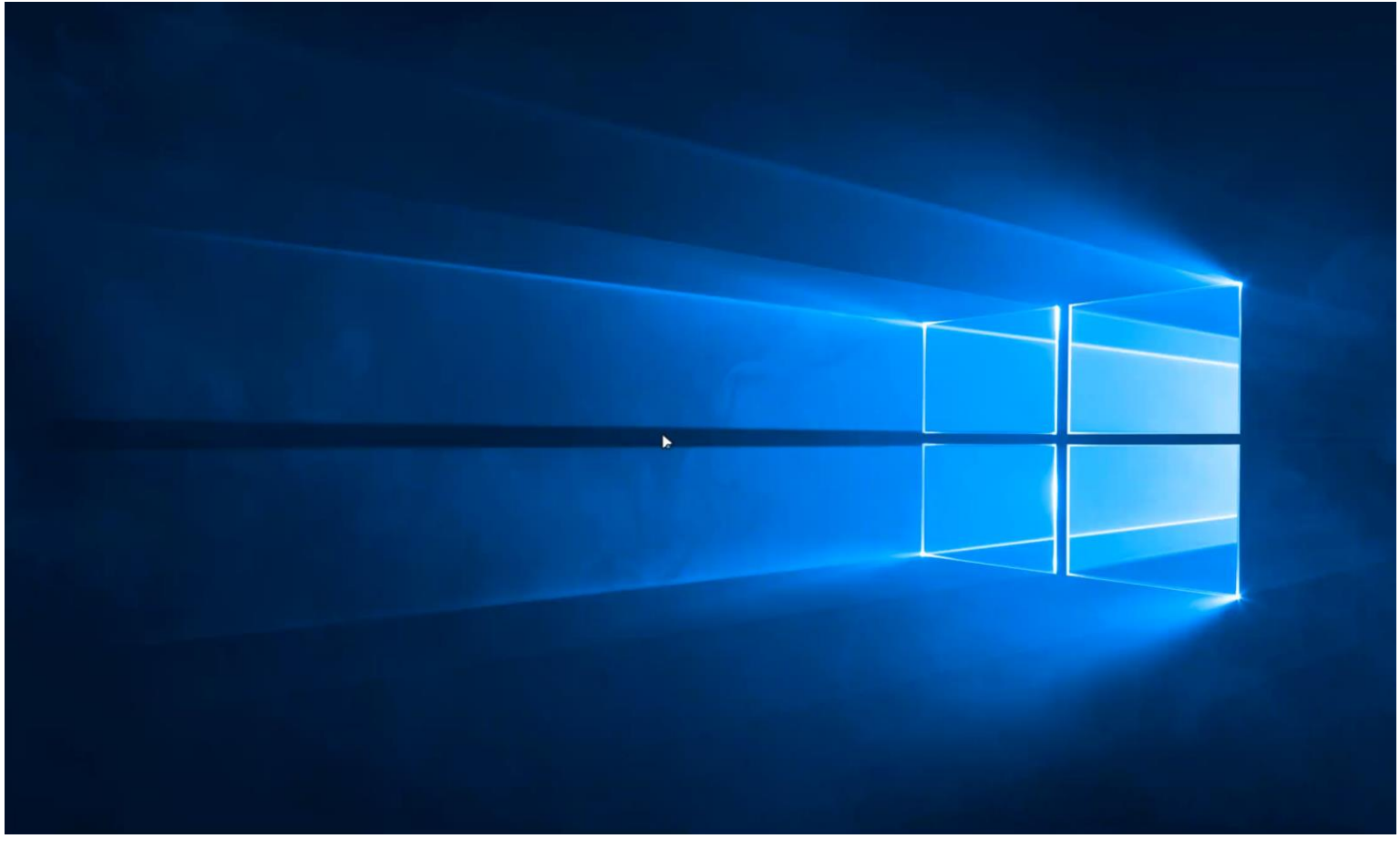
Aircraft mix and traffic volume

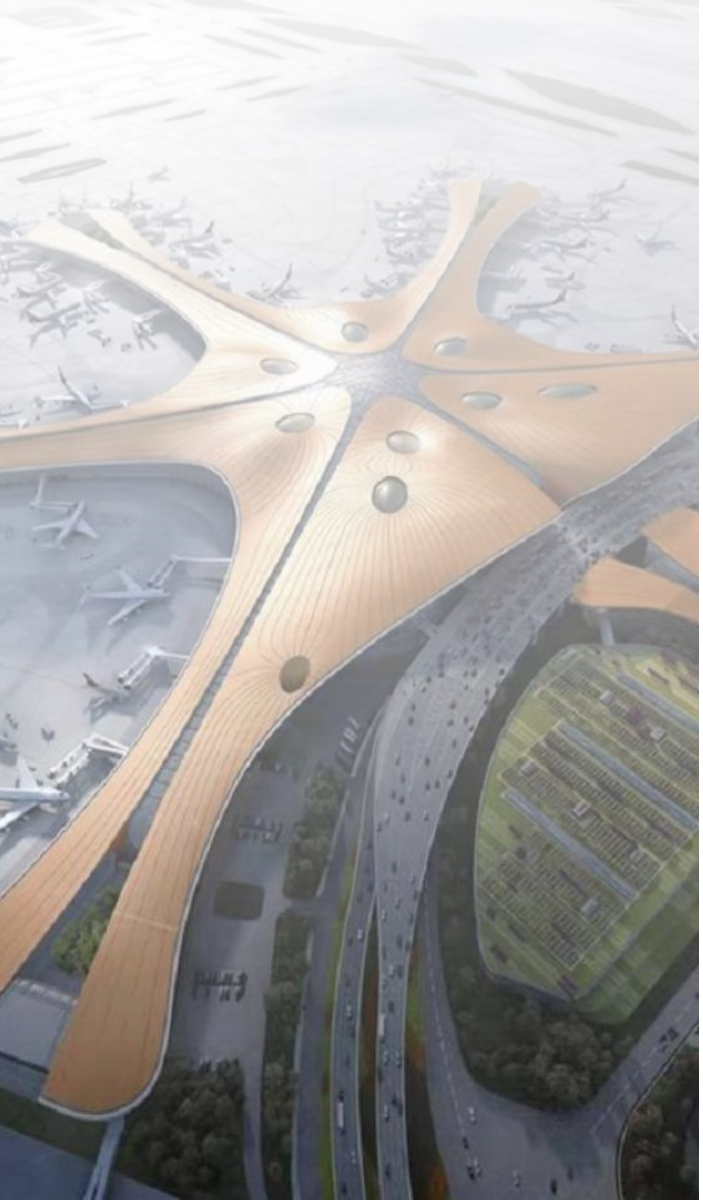
ACR calculation results

Evaluation results: **PCR, overload operating conditions, maximum permissible mass**

Technology Evaluation

- **Entire Procedure**





Outline

1. PCR Calculation Method
2. CAAC-PCR Evaluation Software
3. Next Tasks

Tasks of PCR Evaluation Program for Flexible Pavements

- Clarify the calculation method for asphalt pavement structure thickness in the Chinese design specifications (currently under revision)
- Develop the PCR technology evaluation calculation process for flexible pavements.
- Develop the PCR technology evaluation program for flexible pavements in the CAAC-PCR software.
- Implement the PCR technology evaluation software at multiple flexible pavements.
- Complete the pavement PCR evaluation software for both rigid pavements and flexible pavements.

Select 25 Typical Airports (10%) for PCR Evaluation

Select 25 Typical Airports (10%) for PCR Evaluation: Data Collection

- Select typical areas of the runway (area ≮ 13,500 m^2 / length ≮ 300 m), or the areas with structural damage.
- Relevant information on the pavement structure, and the key technical parameters were verified through on-site recheck.
  - Structural layer thickness
  - Split tensile strength
  - Pavement foundation strength
  - … …
- Collect historical data on the combination of aircraft types operated at the airport and the annual number of flights for each aircraft type

Select 25 Typical Airports (10%) for PCR Evaluation: Evaluation Plan

- Collect maintenance records for the evaluating pavements.
- Collect information on structural damage of the evaluating pavements.
  - Pavement cracks, etc.
  - Faulting of the rigid pavement.
  - Rutting of the flexible pavements.
  - … …
- Using CAAC-PCR to calculate pavement PCR.
- Using FAARFIELD to calculate pavement PCR.
- Analyze the differences between the actual pavement overload and the CAAC-PCR software calculated PCR results.
- **Update** the pavement CAAC-PCR calculation and evaluation methods.

Thank You for Your Attention

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