Research on Application of Chinese Codes in Asphalt Pavement Design of French Speaking Countries

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Abstract. In this paper, based on the calculation of asphalt pavement of North-South Expressway in Algeria, the applicability of Chinese code in asphalt pavement design of French speaking countries is studied. Although there are differences in pavement design methods between China and France, by adjusting the pavement design parameters and asphalt mixture, it can be transformed into representative indicators applicable to the Chinese code in a targeted manner. The Chinese code was used to design and check the asphalt pavement of the North-South Expressway in Algeria. The results show that it is feasible to design asphalt pavement in French speaking countries by using Chinese codes, which provides basis and reference for the application of Chinese codes in French speaking countries.

Keywords. Asphalt pavement, Chinese standard, parameter adjustment, design checking calculation.

1. Introduction
In recent years, China's economy has gradually integrated into the world system, and Chinese companies, especially infrastructure construction companies, have chosen the "going global" development strategy, which is an urgent need for the country to promote the "Belt and Road" strategy. The highway construction is applied in French-speaking countries and regions with a wider coverage in Africa and the Americas outside of Europe. Participating companies are facing the difference between Chinese and foreign technical standards. This has become an impact on companies’ participation in market competition and implementation of project contracts, and the major challenge of technology and equipment output. The differences between Chinese and French road pavement design methods are mainly reflected in the pavement structure used, the pavement materials used and their mechanical parameters, the calculation method of the internal stress and strain of the pavement structure, and the control index [1-6]. In this paper, based on the calculation of the asphalt pavement in the French code for the north-south highway in Algeria, and by adjusting the relevant design parameters, the paper aims to transform it into the representative index applicable to the Chinese code, and studies the practical application of the Chinese code in the design of asphalt pavement in french-speaking countries.

2. Engineering Background
The North-south Expressway is a major traffic artery running through the north and south of Algeria. The Xifa section starts from La Chiffa in Blida province and the East-west expressway PK56+700 overpass, crosses the Chiffa Gorge in the form of Bridges and tunnels, enters El Hamdania town in...
Medea Province, and ends in Berrouaghia. The route is about 53.6 km in length.

3. Brief Introduction of Chinese Asphalt Pavement Design Method

The mechanical calculation of China’s asphalt pavement structure adopts a multi-layer elastic system under the action of double-circle uniformly distributed vertical loads, assuming that each layer of the roadbed is continuous and uninterrupted [7]. When calculating the roadbed and pavement, the design index of each item needs to be based on the stress-strain response in the vertical direction described in Table 1, and according to the calculation point position shown in Figure 1, select A (single circle center point), B (single circle edge point), C (double circle center distance midpoint), D (between B and C two points) four partial nodes analyze the extreme values of their stress and strain responses.

When calculating the asphalt pavement structure, the value of the structural layer modulus is specified as follows [8]:

- The surface layer and base layer of the asphalt shall be respectively based on the dynamic compression modulus measured under the environmental conditions specified in the specification;
- The modified elastic modulus of the mixed material mixed with inorganic binder (cement, etc.) in the original aggregate shall be the elastic modulus modified by the adjustment coefficient;
- The granular layer adopts the modulus of resilience adjusted by humidity;
- The roadbed adopts the equivalent elastic modulus of the top surface under the state of equilibrium humidity and considering the effects of dry-wet and freeze-thaw cycles.

Figure 2 shows the check calculation process of China's asphalt pavement structure.

Table 1. Mechanical response and vertical position corresponding to each design index.

| Design specifications                      | Mechanical response                   | Vertical position                      |
|-------------------------------------------|---------------------------------------|---------------------------------------|
| Tensile strain of asphalt mixture         | Horizontal tensile strain along       | Asphalt mixture layer bottom          |
| Tensile stress at the bottom of           | the driving direction                 |                                       |
| stabilized layers with inorganic binder   |                                       |                                       |
| Permanent deformation of asphalt mixture  | Horizontal tensile stress along       | Inorganic binder stabilized layer      |
| layer                                      | the driving direction                 | bottom                               |
| Vertical compressive strain on top of     | Vertical compressive stress           | Top surface of each layer of asphalt  |
| subgrade                                   |                                        | mixture layer                         |
| Vertical compressive strain on top of     | Vertical compressive strain           | Top surface of Subgrade               |
| subgrade                                   |                                        |                                       |

![Figure 1. Diagram of the position of the mechanical response calculation point.](image-url)
4. Application of Chinese Asphalt Pavement Design Method

Due to the differences between Chinese and French standards, when applying Chinese standard methods to design the asphalt pavement of the Algeria North-South Expressway Xifa Section (hereinafter referred to as Xifa Section), the following points should be noted [9]:

- Transform the traffic design parameters in the French asphalt pavement design into design parameters suitable for domestic standards.
- When the road building materials used in French specifications are transformed into domestic standard materials, the corresponding domestic common road building materials and relevant design parameters should be selected according to the composition characteristics, grading characteristics, strength, porosity and other structural conditions of different road construction materials, so as to ensure the comparability of design.
- The asphalt pavement structure recommended by the French code is different from the commonly used asphalt pavement structure in my country, which is reflected in the name of the structure, design steps and principles, and design methods, and needs to be applied flexibly.

Figure 2. Flow chart of asphalt pavement structure design checking calculation.
4.1. Adjustment of Traffic Volume and Subgrade Design Parameters

As the key basic data for pavement structure design, the design codes of China and France have certain differences in terms of design life, standard axle load and number of action calculations, and climate zones, which need to be adjusted sequentially.

Both the Chinese and French asphalt pavement design methods use the equivalent axle load times as the main basic data for traffic conversion [10]. Section 3.0.2 of the "Chinese Code" stipulates the service life of newly-built asphalt pavements, which should not be less than the service life shown in Table 2, but the design life of the road can be determined according to factors such as the economic status of the highway and the highway grade [11]. As an important part of Algeria's north-south expressway, the Xifa section is a structural road network type. According to the "Chinese Code", the design life of the pavement structure is recommended to be 20 years.

Table 2. Pavement structure design service life (years).

| Highway class                  | Design service life | Highway class             | Design service life |
|--------------------------------|--------------------|---------------------------|--------------------|
| Expressway, first-class highway| 15                 | Third class highway       | 10                 |
| Secondary highway              | 12                 | Class IV Highway          | 8                  |

According to the calculation results of traffic volume obtained from French regulations, the number of heavy vehicles in the two-lane within the design period is 56.38×10^6, and the cumulative number of heavy vehicles in the single-lane is 28.19×10^6, and the traffic level is extremely heavy [12]. As a new highway, Xifa section can be selected according to historical traffic data and vehicle type composition. The traffic classification of TTC2 in our country is relatively close to the traffic composition of Shifa section project. According to the vehicle type distribution coefficient of TTC2, the proportion of different types of vehicles can be obtained.

The daily average equivalent axle number \( N_1 \) of the initial annual lane is calculated according to the equivalent design axle load conversion factor of various vehicles.

\[
N_1 = AADTT \times DDF \times LDF \times \sum_{m=2}^{11} (VCDF_m \times EALF_m)
\]

where, AADTT is the round-trip traffic volume of large vehicles (2 axles and 6 wheels and above), DDF is the directional coefficient, LDF is the lane coefficient, \( m \) is the vehicle type number, VCDF\(_m\) is the distribution coefficient of the \( m \) type of vehicle, and EALF\(_m\) is the current design reduction factor under axle load conditions.

The total number of times of heavy vehicles in the Shifa section of the project within the design life is known, so the total number of times of action of the equivalent axle load according to the design plan can be obtained according to equation (1). The total number of axial loads corresponding to the tensile strain of the asphalt mixture bottom layer and the permanent deformation of the asphalt mixture layer is 68,471,087 times, and the equivalent design cumulative number of axial loads corresponding to the compressive strain of the soil foundation top surface is 116,115,602 times.

The climatic characteristics of the central part of the Shifa section of the project are Savannah climate, which is characterized by low air humidity and low rainfall, low temperature in winter and high temperature in summer. The overall climate conditions of the project are similar to those of Shanghai, my country. A dimensionless reduction factor \( K_s \) used in calculating the design value of the subgrade elastic modulus can be 0.95. When considering the dry and wet freeze-thaw effects of subgrade caps, the corresponding reduction coefficient \( K_\eta \) can be taken as 1.00. Therefore, the elastic modulus of the top of the roadbed after the above reduction treatment is 114 MPa.

4.2. Adjustment of Building Materials and Design of Pavement Structure Parameters

In order to apply my country’s highway code to the design of the French-speaking country’s asphalt
pavement, the asphalt mixtures BBMA3 0/10, BBME1 0/14, and EME2 0/20 used in the Xifa section of the project need to be adjusted to the commonly used asphalt mixtures in my country’s standards [13,14]. According to the relevant specifications on the gradation of different types of asphalt mixtures and other related characteristics, referring to the gradation composition of BBMA3 0/10, BBME1 0/14, EME2 0/20 asphalt mixtures, it is determined to use SMA-10 instead of BBMA3 0/10. AC-13 replaces BBME1 0/14, AC-20 replaces EME2 0/20.

From this, the pavement structure schematic diagram and standard diagram of my country’s highway asphalt pavement design specification can be analogized as shown in figure 3 and figure 4. According to the pavement structure drawing, the design and calculation parameters of the pavement structure are determined in accordance with Chinese standards, as shown in table 3.

| Material                | $E$ (MPa) | $\mu$ |
|-------------------------|-----------|-------|
| SMA-10                  | 9200      | 0.25  |
| AC-13                   | 11000     | 0.25  |
| AC-20                   | 12000     | 0.25  |
| Graded crushed stone    | 400       | 0.35  |
| Soil base               | 114       | 0.40  |

Figure 3. Schematic diagram of asphalt pavement structure.

Figure 4. Standard diagram of asphalt pavement structure.
4.3. Pavement Structure Check Calculation

4.3.1. Permanent Deformation of Asphalt Mixture Layer. The climate type of the project area is similar to that of Shanghai in China. Therefore, for the value of design parameters, the equivalent temperature of asphalt mixture layer is 27.9°C and the reliability coefficient is 1.65. When analyzing the permanent deformation of asphalt mixture layer, it is often necessary to layer the pavement system with multi-layer structure, and calculate the deformation amount of each layer structure respectively. According to the pavement structure form shown in figure 3, the asphalt mixture structural layer is divided into seven layers.

The final permanent deformation value of each layer is determined according to the relevant test results of anti rutting performance of asphalt mixture. After calculating the permanent deformation of each layer, the total permanent deformation of asphalt mixture structure can be obtained by superposition, as shown in the following equation:

\[
R_{ai} = \sum_{i=1}^{n} R_{aii}
\]

\[
R_{ai} = 2.31 \times 10^{-8} k_{Ri} T_{pef}^{2.93} \left( p_i \right)^{1.80} N_{e3}^{0.48} (h_i / h_0) R_{0i}
\]

where, \( R_{ai} \) is the permanent deformation of the asphalt mixture layer, \( R_{aii} \) is the permanent deformation of the i-th sublayer, \( T_{pef} \) is the final equivalent temperature, \( N_{e3} \) is the number of cumulative effects of the design load on the design lane during the specified period of use, or after the road is opened to traffic until the first maintenance for the rut, \( h_i \) is the thickness of the i-th sublayer, \( h_0 \) is the thickness of the standard sample in the rutting test, \( R_{0i} \) is the final rutting deformation of asphalt mixture used in layer i under the condition of test pressure of 0.7 MPa, constant test temperature of 60 °C, and cyclic loading of more than 2500 times, \( k_{Ri} \) is the correction coefficient considering the combined effect, \( p_i \) is the vertical load experienced by the top of the i-th layer of the asphalt mixture layer based on the elastic theory of layered structure.

Substituting the relevant data to obtain the permanent displacement \( Rai \) of each layer, the calculation results are shown in table 4. When the permanent deformation of each layer is calculated, the data is superimposed and summed, and the total deformation is 5.4mm, which is within the limit value of the specification. Therefore, the proposed pavement structure meets the requirements of the specification for permanent deformation of the asphalt mixture layer.

| Layer number | Layer thickness (mm) | Vertical pressure (MPa) | Correction factor \( k_{Ri} \) | Permanent deformation (mm) |
|--------------|----------------------|------------------------|-----------------------------|---------------------------|
| 1            | 15.0                 | 0.70                   | 3.98                        | 1.0                       |
| 2            | 20.0                 | 0.70                   | 6.24                        | 2.1                       |
| 3            | 20.0                 | 0.68                   | 7.34                        | 0.8                       |
| 4            | 20.0                 | 0.63                   | 6.41                        | 0.6                       |
| 5            | 20.0                 | 0.57                   | 4.97                        | 0.4                       |
| 6            | 120.0                | 0.49                   | 1.39                        | 0.3                       |
| 7            | 120.0                | 0.14                   | 0.09                        | 0.0                       |
| Total        | -                    | -                      | -                           | 5.4                       |
4.3.2. Fatigue Cracking of Asphalt Mixture Layer. The equation for calculating the fatigue cracking life of the asphalt mixture layer is as follows:

$$ N_{i1} = 6.32 \times 10^{15.96-0.29\beta} k_b k_a k_{T1} \left( \frac{1}{\varepsilon_a} \right)^{3.97} \left( \frac{1}{E_a} \right)^{1.58} (\text{VFA})^{2.72} $$

(4)

Where, $N_{i1}$ is the fatigue cracking life of the asphalt mixture layer, $\beta$ is the target reliability index, $k_b$ is the adjustment coefficient, $k_a$ is the fatigue loading factor, $k_{T1}$ is the temperature adjustment coefficient, $\varepsilon_a$ is the tensile strain at the bottom of the asphalt mixture layer, $E_a$ is the compressive modulus of the asphalt mixture at a specific temperature ($T=20^\circ C$), VFA is the saturation of the asphalt mixture.

According to the elastic layered system theory, the horizontal tensile strain at the bottom of the asphalt layer is calculated to be $29.1 \mu \varepsilon$, and the longest period of cracking of the asphalt layer under fatigue loading conditions is 68,709,208 times. From the calculation results of traffic volume, it can be known that during the specified service life, The superimposed value of the anti-fatigue equivalent axle load times of the asphalt layer is 68,471,087 times. The fatigue life is slightly longer than the cumulative number of axle loads that the asphalt mixture will experience, which meets the requirements of the specification.

4.3.3. Checking Calculation of Compressive Strain on the Top Surface of Soil Foundation. According to the area where the Shifa section of the project is located, the adjustment coefficient of the upper part of the subgrade at a certain temperature is 1.1. According to the relevant parameters, the calculated $k_{T3}$ is 1.55. Therefore, the vertical compressive strain permitted by the specification on the top surface of the subgrade can be calculated according to equation (5):

$$ [\varepsilon_a] = 1.25 \times 10^{4-0.10} (k_{T3} N_{e4})^{-0.21} $$

(5)

Where, $[\varepsilon_a]$ is the allowable compressive strain value of the road surface in the vertical direction, $\beta$ is the target reliable indicator, $N_{e4}$ is the total number of loads acting on the planned traffic lane within the specified period of use, $k_{T3}$ is the temperature adjustment coefficient.

The cumulative number of equivalent design axle loads $N_{e4}$ for this project is 116,115,602 times. Under this equivalent number of axle loads, the allowable compressive strain value $[\varepsilon_a]$ of the top surface of the subgrade according to the specification is $157.8 \mu \varepsilon$. According to elastic mechanics, the compressive deformation of the road surface in the vertical direction is calculated to be $63.8 \mu \varepsilon$, which meets the requirements of the specification.

4.3.4. Asphalt Mixture Penetration Strength Check. When the asphalt pavement adopts a granular base layer or an asphalt binder base layer, the penetration strength of the asphalt mixture should meet the calculation requirements of equation (6).

$$ R_{a0} \geq \left( \frac{0.35 \lg N_{e5} - 1.16}{\lg[R_a] - 1.62 \lg T_3 - \lg \psi_g + 2.76} \right)^{1.38} $$

(6)

where, $\psi_g$ is the pavement structure coefficient, and $R_{a0}$ is the comprehensive penetration strength of each layer of asphalt mixture on the pavement.

According to the survey, the monthly temperature in the Shifa section of the project area is always higher than zero degrees Celsius. From the characteristics of the temperature in the area where the road is located, it can be determined that the $N_{e5}$ is 62,765,163 times. From the characteristics of the local temperature, it is known that the pavement structure coefficient is 0.50 and the comprehensive penetration strength is 1.00MPa. The calculated penetration strength of the asphalt mixture layer is 0.68, which meets the requirements of the specification.

4.3.5. Acceptance Deflection Value of Subgrade Top Surface and Road Surface. Subgrade top surface deflection value and road surface deflection value are important indicators for my country’s subgrade...
and pavement acceptance. According to the requirements of the code, the subgrade top surface deflection value $l_g$ should be calculated according to equation (7).

$$l_g = \frac{176pr}{E_0}$$  \hspace{1cm} (7)

where, $l_g$ is the acceptance deflection value of the top surface of the roadbed, $p$ is the load applied to the bearing plate of the drop hammer deflection meter, $r$ is the radius of the bearing plate of the falling weight deflectometer, $E_0$ is the elastic modulus of asphalt concrete under equilibrium humidity conditions.

In Xifa section project, the diameter of load disc is 300 mm, the load applied on the surface is 50 kn, the elastic modulus of Subgrade under standard environmental conditions is 120 MPa, and its humidity coefficient can be taken as 0.95, so the elastic modulus of subgrade surface can be 114 MPa under the condition of balanced humidity. Using this formula, the acceptance deflection value of foundation top surface can be calculated as 163.8 (0.01 mm).

When checking and accepting the deflection value of subgrade surface, it is necessary to consider the specific structure of pavement and calculate according to elastic theory, as shown in equation (8).

$$l_a = \frac{p}{k_a}$$  \hspace{1cm} (8)

$$\bar{l}_a = f\left(\frac{h_1}{\bar{s}}, \frac{h_2}{\bar{s}}, \ldots, \frac{h_{n-1}}{\bar{s}}; \frac{E_2}{E_1}, \frac{E_3}{E_2}, \ldots, \frac{k_l E_2}{E_{n-1}}\right)$$  \hspace{1cm} (9)

where, $P$ is the deflectometer load, $\bar{l}_a$ is the theoretical deflection coefficient, $K_L$ is the adjustment coefficient of pavement elastic modulus coefficient, which can be taken as 1.0, $E_0$ is the resilient modulus of pavement.

According to the elastic layer theory and equation (8), the acceptance deflection value $l_a$ of the road surface can be calculated as 15.5 (0.01 mm).

5. Conclusion

This article refers to the relevant design parameters of the North-South Expressway in Algeria, and through targeted conversion into representative indicators applicable to the Chinese code, the asphalt pavement design is carried out in accordance with the requirements of the Chinese code, and the asphalt mixture layer of the asphalt pavement structure is permanently deformed Check calculations with design indicators such as fatigue cracking, top surface compressive strain of soil foundation and penetration strength of asphalt mixture. It shows that although the Chinese and French codes are different in the form of pavement structure, the used pavement materials and their mechanical parameters, the calculation method and control index of the internal stress and strain of the pavement structure, etc., through targeted conversion, the Chinese code can be applied to the French-speaking countries The design and verification of asphalt pavement provide a basis and reference for the application of Chinese codes to the design of asphalt pavement in French-speaking countries.

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