Research on Fatigue Prediction Model of Asphalt Mixture with High RAP Content

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Abstract: Asphalt pavement hot recycling technology can improve resource utilization efficiency, reduce energy waste and CO$_2$ emissions, and bring huge economic and social benefits, further promoting the realization of "carbon peak and carbon neutrality". This paper uses single logarithmic regression fitting on the fatigue failure life of recycled asphalt mixture with high RAP content to characterize the influence of RAP content (R), stress ratio (C), loading frequency (H) and test temperature (T) on the fatigue life of recycled asphalt mixture. Subsequently, the relationship between fatigue life and stress ratio of recycled asphalt mixture, under the influence of different RAP content, loading frequency and test temperature was analyzed. The results showed that the fatigue life of recycled asphalt mixture decreased with an increase in RAP content, stress ratio and test temperature, and decreased as loading frequency increased. Fatigue life and stress ratio were found to be approximately logarithmic, and based on the relationship between fatigue equation parameters a, b and R, T, H, the fatigue prediction model for recycled asphalt mixtures with independent variables R, C, H, and T was established.

Keywords: asphalt mixture; RAP; fatigue performance; prediction model

1. Introduction

In recent years, with the rapid development of highway construction, the scale of highway maintenance projects and services has also continued to expand [1]. Existing road pavements continue to degrade year by year, leading to the production of large amounts of recyclable waste materials. If these old materials are simply piled up, they will not only unduly occupy otherwise usable land areas, but will also cause serious environmental pollution. However, with the advent of recycled asphalt mixtures, these waste materials can finally be put to good and efficient use [2–4]. The use of recycled asphalt mixture means that the old asphalt pavement materials that need to be renovated or discarded, are instead milled, recycled, crushed, screened, and then mixed with regenerant (if necessary). Furthermore, new aggregates as well as new asphalt are also often mixed in a certain proportion with the recycled asphalt mixture [5–7]. Reclaimed Asphalt Pavement (RAP) refers to the asphalt mixture recovered from the damaged road surface through milling and planning. At present, the RAP content in RAP recycling is mainly controlled at about 15–25% [8,9]. One of the main reasons for limiting the high content (≥30%) of RAP is that the fatigue performance of the recycled asphalt mixture is difficult to guarantee, so that the hot recycling technology of asphalt pavement has not been widely promoted and applied [10–12]. Conversely, on the basis of ensuring the recycling of asphalt pavement materials, the increase of RAP content will bring huge economic and social benefits [13].
Basueny A [14] found that asphalt mixtures containing RAP have high fatigue resistance at lower temperatures or high frequencies. Benedetto HD et al. [15] studied the fatigue behavior of asphalt mixtures containing RAP and asphalt shingles. Through indoor tensile and fatigue tests, they found that when 40% RAP was added, the stiffness and fatigue properties of asphalt mixtures were significantly improved. Zaumanis M [16] mentioned that the stiffness of the high RAP content mixture is higher than that of the original mixture, which aggravates the fatigue and cracking of the road surface. Norouzi A [17] established that high RAP content will reduce fatigue resistance, which may be due to the addition of an aging binder that hardens the asphalt mixture. Tomlinson C [18] showed that, with the increase of RAP content in asphalt concrete, the dynamic modulus and fatigue life will increase. Fatigue life is closely associated with RAP percentage, adhesive type, frequency and temperature. Arsenie I M [19] uses four-point bending test results and finite element modeling to describe fatigue behavior. Hou T [20] found that the simplified viscoelastic continuous damage (VECD) model can predict the fatigue life of asphalt mixtures very well, and can predict fatigue test results fairly accurately under various temperature conditions and strain levels. Mannan U A [21] modified the traditional fatigue life prediction model to incorporate the influence of RAP into the fatigue equation. Cao W [22] introduced the critical strain energy release rate (Jc) as an index of crack resistance into the fatigue model, which has a greater correlation with the test results. Mohammadreza [23] proposed a method to predict the fatigue life of asphalt concrete mixtures under different load modes, temperatures and strain amplitudes within the range of typical differences between samples observed in fatigue tests.

Based on previous studies, this paper adopts the indirect tensile test method to consider the influence of RAP content, stress ratio, temperature and frequency on the fatigue performance of recycled asphalt mixtures. Furthermore, based on the indoor indirect tensile fatigue test data and relying on simple empirical expressions to determine the model parameters, the relationship between the fatigue life and the influencing factors is fitted, and the fatigue prediction model for recycled asphalt mixtures was established with four influencing factors: RAP content, stress ratio, test temperature, and loading frequency.

2. Materials and Methods

2.1. Materials

2.1.1. Asphalt

Recycled asphalt was obtained from RAP after extraction and the Abson method was used to obtain reclaimed bitumen, referring to ASTM D1856. Its basic performance indicators were tested, as shown in Table 1. Conversely, the newly added 70# matrix asphalt test indicators are shown in Table 2.

| Detection Item | 25°C Penetration/0.1mm | Softening Point/°C | 15°C Ductility/cm |
|---------------|------------------------|------------------|-----------------|
| Recycled asphalt | 31.9 | 54 | 60 |
| 70# asphalt | 65.6 | 47 | >100 |
| Specification requirements | 60–80 | 42–52 | >100 |

| Test Index | Measured Values | Standard Values |
|------------|----------------|-----------------|
| Penetration (25°C, 100 g, 5 s) 0.1 mm | 65.6 | 60–80 |
| Penetration index (PI) | -1.43 | -1.5~+1.0 |
| Ductility (5cm/min, 10°C/5°C) (cm) | >100 | ≥20 |
| Softening point (°C) | 47 | ≥46 |
| Flash point (°C) | 273.3 | ≥260 |
2.1.2. Aggregate

The recovered RAP is extracted by centrifugation, the asphalt on the surface is removed and then sieved. The RAP mixture gradation inspection was tested in accordance with the test methods T0722-1993 and T0725-2000 in the “Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering”, which were similar to ASTM 2172 and ASTM C 136. The physical and mechanical performance test results of the old aggregate performed are shown in Tables 3 and 4. The properties of the new aggregates and mineral powders added are shown in Tables 5–7.

Table 3. Performance test results of old fine aggregate.

| Test Items                  | Unit       | Test Results | Experiment Method |
|-----------------------------|------------|-------------|-------------------|
| Effective density           | g/cm³      | 2.693       | -                 |
| Effective relative density  | -          | 2.689       | -                 |
| Sand equivalent             | %          | >100        | >100              |

Table 4. Performance test results of old coarse aggregate.

| Performance                  | Unit | Test Results |              |
|------------------------------|------|--------------|--------------|
| Crush value                  | %    | 16.5         |              |
| Los Angeles wear value       | %    | 8.37         |              |
| Needle flake particle content| %    | 8.4          |              |
| Effective density            | g/cm³| 2.712        |              |
| Effective relative density   | -    | 2.717        |              |
| Apparent relative density    | g/cm³| 2.683        |              |
| Water absorption             | %    | 0.6          |              |

Table 5. Density test results of new aggregate and new asphalt.

| Mineral       | Apparent Relative Density | Gross Volume Relative Density | Water Absorption/% |
|---------------|--------------------------|-------------------------------|--------------------|
| 0–4.75 mm     | 2.709                    | 2.653                         | 0.78               |
| 4.75–9.5 mm   | 2.730                    | 2.704                         | 0.35               |
| 9.5–19 mm     | 2.732                    | 2.706                         | 0.36               |
| Asphalt       | 1.036                    |                               |                    |

Table 6. Coarse aggregate property index test results.

| Pilot Projects | 4.75–9.5 mm | 9.5–19 mm | Requirements |
|----------------|------------|----------|--------------|
| Crush value/%  | 19.5       | 19.3     | ≤26          |
| Polish value   | 46         | 47       | ≥42          |
| Needle flake content/% | 9.7  | 7.7  | ≤12          |
| <0.075 mm Particle content | 0.6  | 0.5  | ≤1           |
Table 7. Test results of fine aggregate properties.

| Pilot Projects | 0~4.75 mm | Requirements |
|----------------|-----------|--------------|
| Sand equivalent is not less than | 66 | 60 |
| Angularity/% | 48 | >45 |
| Moisture content/% | 3.4 | ≥2 |

2.2. Method

2.2.1. The Ratio and Mix Ratio of New and Old Aggregates

In this paper, AC-20 gradation type is used for the experimental research of recycled asphalt mixture. Figures 1 and 2 below showed the additional ratio of each grade of the new aggregate in the recycled asphalt mixture with different RAP content and the new aggregate ratio.

Figure 1. The proportion of new aggregates added in each grade under different RAP content.

Figure 2. New aggregate ratio tables under different RAP content.
2.2.2. Indirect Tensile Fatigue Test (ITFT)

This test evaluates the influence of RAP content (30%, 40%, 50%, 60%), stress ratio (0.3~0.6), loading frequency (2 Hz, 5 Hz, 10 Hz) and test temperature (5 °C, 15 °C, 25 °C) on the fatigue life of recycled asphalt mixtures. The stress ratio refers to the ratio of the minimum stress to the maximum stress in a load cycle in a fatigue test. The loading frequency is the working frequency of the fatigue testing machine and represents the number of stress cycles per second. The UTM-30 dynamic servo hydraulic multifunctional material testing machine was adopted as the test equipment. The loading mode was haversine wave loading stress-control mode. The total loading time is 0.4 s, the initial minimum loading force is 50 N, and four sets of parallel experiments are performed.

2.2.3. Fatigue Prediction Model

Under the conditions of different RAP content R, test temperature T and loading frequency H, there is a good linear correlation between log fatigue life \( \log N_f \) and stress ratio \( C \). This correlation indicates that there may be a contradiction between the fatigue life \( N_f \) and \( C \) of recycled asphalt mixture. The influence of RAP content \( R \), test temperature \( T \) and loading frequency \( H \) on fatigue life \( N_f \) can therefore be realized by modifying the empirical relationship coefficient between \( N_f \) and \( C \), namely, the following form of fatigue prediction model is established:

\[
\ln N_f = a + b \ln C \quad (1)
\]

\[
a = f_1(R, H, T) \quad (2)
\]

\[
b = f_2(R, H, T) \quad (3)
\]

In the Equations (1)–(3): \( N_f \) is the fatigue life when the specimen is broken, times; \( C \) is the applied stress ratio; \( R \) is the RAP content, %; \( T \) is the test temperature, °C; \( H \) is the loading frequency, Hz; \( a \), and \( b \) are functions of the three parameters \( R, T \) and \( H \), respectively.

2.2.4. Research Process

The flow chart of the research approach in this paper is shown in Figure 3.

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Figure 3. The flow chart of the research approach.
3. Results and Discussion

3.1. Analysis of Factors Affecting Fatigue Performance

3.1.1. The Effect of RAP Content on Fatigue Performance

The indirect tensile fatigue test (15 °C, 10 Hz) was carried out on recycled asphalt mixtures with different RAP content. The test data is shown in Table 8. The calculated logarithmic fatigue life with RAP content is shown in Figure 4.

Table 8. Fatigue test results of mixtures with different RAP content (15 °C), respectively, Function of parameters R, T and H.

| RAP Dosage% | Stress Ratio | Fatigue Life/Times | Logarithmic Fatigue Life |
|-------------|--------------|--------------------|-------------------------|
| 0           |              | 68,050             | 4.833                   |
| 30          | 0.3          | 60,180             | 4.779                   |
| 40          |              | 54,850             | 4.739                   |
| 50          |              | 35,840             | 4.554                   |
| 60          |              | 11,040             | 4.043                   |

Figure 4. Fatigue test results of recycled asphalt mixtures with different RAP content.

It can be seen from Figure 4 that the log fatigue life of the new asphalt mixture with a RAP content of 0% and the log fatigue life of the recycled asphalt mixture with a RAP content of 30% are approximately at the same level. This shows that the incorporation of a small amount of RAP has little effect on the fatigue performance of the recycled asphalt mixture. However, as the RAP content gradually increased to 30%, the fatigue life of the recycled asphalt mixture shows a significant decrease, which means that the RAP content of 30% is an optimal content. When the optimum content is exceeded, the fatigue performance of the recycled asphalt mixture will be greatly reduced, and as the content of RAP continues to increase, the degree of this influence becomes increasingly high. This is because, as the amount of RAP increases, the proportion of old asphalt in the recycled asphalt mixture also increases, while the proportion of new asphalt is relatively low, as the old asphalt can only be partially fused with the new asphalt. Therefore, as a result, the fatigue performance of recycled asphalt mixture is significantly reduced.
3.1.2. The Effect of Stress Level on Fatigue Performance

Figure 5 shows the results of the fatigue test of recycled asphalt mixtures under different stress ratios.

It can be observed from Figure 5 that the low content of RAP has little effect on the fatigue life of the mixture, when the stress level increases from 0.3 to 0.4, the fatigue life of the recycled asphalt mixtures in each content decreases significantly, indicating that the fatigue life is more sensitive to the stress ratio at low stress levels. Meanwhile, when compared with 0% and 60%, the fatigue life curve of RAP content found that the incorporation of RAP makes the reclaimed asphalt mixture more sensitive to the stress level than the new asphalt mixture.

3.1.3. The Influence of Loading Frequency on Fatigue Performance

The change characteristics of fatigue life under different loading frequencies are shown in Figure 6.
0.30 0.35 0.40 0.45 0.50 0.55 0.60

0 10,000 20,000 30,000 40,000 50,000 60,000 70,000

Fatigue life / times

Stress ratios

0%
30%
40%
50%
60%

Figure 5. Fatigue life curve of recycled asphalt mixtures under different stress ratios.

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3.1.3. The Influence of Loading Frequency on Fatigue Performance

The change characteristics of fatigue life under different loading frequencies are shown in Figure 6.

It can be seen from Figure 6 that the fatigue life of the recycled asphalt mixture is obviously smaller when the loading frequency is lower than when it is high, with fatigue life at 10 Hz close to 7 times that at 2 Hz. As the load frequency acting on the recycled asphalt mixture increases to 5 Hz and 10 Hz subsequently, the difference in fatigue life of the recycled asphalt mixture specimens becomes increasingly smaller. Therefore, it can be concluded that when the loading frequency increases to a certain value, the fatigue life of the recycled asphalt mixture specimen tends to be stable.

3.1.4. The Influence of Test Temperature on Fatigue Performance

The change law of fatigue life at different test temperatures is shown in Figure 7.

It can be seen from Figure 7 that when the stress ratio is the same, the fatigue life of the recycled asphalt mixture increases sharply as the temperature decreases. This is mainly because when the test temperature drops within a certain range, the stiffness of the recycled asphalt mixture increases. Furthermore, the strain produced by the specimen under the same stress condition is smaller, leading to an increase in fatigue life.

3.2. Establishment and Evaluation of Fatigue Prediction Model for Recycled Asphalt Mixture

3.2.1. The Influence of RAP Content on Fatigue Prediction Model Parameters

In the fatigue prediction model, when T = 15 °C and H = 10 Hz, $N_f = a \times C_b$ is used to fit the fatigue life and fatigue life under different RAP content, which is based on the change law of fatigue life with RAP content shown in the test results. The relationship of the loading stress ratio is shown in Figure 8, where it can be deduced that the model can fit the fatigue test data of recycled asphalt mixtures under different blending ratios and stress levels. The obtained fatigue equation is fitted and the relationship between parameters $a$, $b$ and different RAP content is plotted in Figure 9.
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![Figure 8. Fitting curves of fatigue life and stress ratio of recycled asphalt mixtures with different RAP content.](image)

It can be seen from Figure 9 that when $R < 30\%$, the change of $a$, $b$ and the content of RAP satisfies a linear relationship. Therefore, a function form of $a = A_1 + B_1 \times x$, $b = A_2 + B_2 \times x$ is used to fit. Conversely, when $R \geq 30\%$, the change value of $a$, and $b$, as well as the RAP content, satisfies the nonlinear relationship. Thus, in order to improve the accuracy of parameter fitting, a cubic polynomial $a = C_1 + D_1 \times x + E_1 \times x^2 + F_1 \times x^3$, $b = C_2 + D_2 \times x + E_2 \times x^2 + F_2 \times x^3$ is used to fit the parameters of the fatigue equation, and the fitting parameters of the fatigue equation are shown in Table 9 below.
Figure 8. Fitting curves of fatigue life and stress ratio of recycled asphalt mixtures with different RAP content.

Figure 9. Fitting curves of fitting parameters a, b and RAP content.

Table 9. Fitting values of fatigue equation parameters a and b under different RAP content.

| Parameter Value | A_1  | B_1  | C_1  | D_1  | E_1  | F_1  |
|-----------------|------|------|------|------|------|------|
| a               | 23.83| -12.14| 138.22| -596.86| 724.13| -153.61 |
| Parameter value | A_2  | B_2  | C_2  | D_2  | E_2  | F_2  |
| b               | -6.61| -0.12| -27.37| 179.98| -498.55| 429.70 |

Therefore, in the fatigue prediction model, when H = 10 Hz and T = 15 °C, the characteristics of a and b for the variation of RAP content are as Equations (4) and (5):

\[
a = \begin{cases} 
23.83436 - 12.1436R \\
138.22 - 596.86R + 724.13R^2 - 153.61R^3 
\end{cases} \quad R < 30\% \\
\begin{cases} 
R \geq 30\% 
\end{cases} 
\]

\[
b = \begin{cases} 
-6.60789 - 0.12123R \\
-27.37 + 179.98R - 498.55R^2 + 429.70R^3 
\end{cases} \quad R < 30\% \\
\begin{cases} 
R \geq 30\% 
\end{cases} 
\]

3.2.2. The Influence of Loading Frequency on Fatigue Prediction Model Parameters

This article focuses on the fatigue prediction model of recycled asphalt mixture under high RAP content (R ≥ 30%), therefore, in the following fatigue prediction model establishment, only the case where the RAP content is greater than or equal to 30% is considered. In the fatigue prediction model, when R = 0.3 and T = 15 °C, according to the change law of fatigue life with loading frequency shown in the experimental research, \( N_f = a \times C^b \) is used to fit the fatigue life and fatigue life under different loading frequencies. The relationship of the loading stress ratio is shown in Figure 10, while the relationship between the fitting parameters a and b of the fatigue equation in Figure 10 and the different loading frequencies is plotted in Figure 11.
Figure 10. Fitting curve of fatigue life and stress ratio of recycled asphalt mixture under different loading frequencies.

Figure 11. The curve of the fitting parameters a, b and the loading frequencies.

It can be seen from Figure 11 that the changes of the fatigue equation fitting parameters a, b, and different loading frequencies approximately satisfy the quadratic function relationship, so the binomial polynomial \( a = A_3 + B_3 + C_3 + T^2 \), \( b = A_4 + B_4 + C_4 + T^2 \) is used to fit, and the fitting parameters of the fatigue equation are shown in Table 10 below.
Table 10. Fitted values of fatigue parameters a and b under different loading frequencies.

| Parameter | Value | Parameter | Value | Parameter | Value |
|-----------|-------|-----------|-------|-----------|-------|
| a         | -28.70 | B3        | 19.78 | C3        | -1.49 |
| b         | -6.55  |           |       |           |       |

Finally, in the fatigue prediction model, when \( R = 30\% \) and \( T = 15^\circ C \), the change characteristics of \( a \) and \( b \) with respect to the loading frequency are shown in Equation (6): 

\[
\begin{align*}
  a &= -28.7002 + 19377514H - 1.4886H^2 \\
  b &= -6.55016 + 0.398H - 0.04074H^2
\end{align*}
\]  

(6)

3.2.3. The Influence of Test Temperature on Fatigue Prediction Model Parameters

In the fatigue prediction model, when \( R = 30\% \) and \( H = 10 \, Hz \), and according to the variation law of fatigue life with test temperature shown in the test research, \( N_f = a \times C^b \) is also used to fit the fatigue life under different test temperatures with the same loading, and the relationship of the stress ratio is shown in Figure 12. The relationship between the fitting parameters \( a, b \) of the fatigue equation in Figure 12, and different test temperatures are plotted in Figure 13.

It can be seen from Figure 13 that the change values of the fitting parameters \( a, b \) of the fatigue equation and different test temperatures, also approximately satisfy the quadratic function relationship. Therefore, this paper uses the binomial polynomial \( a = A_5 + B_5 \times T + C_5 \times T^2 \), \( b = A_6 + B_6 \times T + C_6 \times T^2 \) to fit, the fitting parameters of the fatigue equation are shown in the table fitting, and the fitting parameters of the fatigue equation are obtained. See Table 11.

Table 11. Fitting values of fatigue parameters a and b at different test temperatures.

| Parameter | Value | Parameter | Value | Parameter | Value |
|-----------|-------|-----------|-------|-----------|-------|
| a         | 315.81 | B5        | -32.60 | C5        | 0.86  |

Figure 12. Fitting curves of fatigue life and stress ratio of recycled asphalt mixture at different test temperatures.
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Figure 13. The curve of the fitting parameters a, b and the test temperature.

Table 11. Fitting values of fatigue parameters a and b at different test temperatures.

| Parameter Value | A5        | B5        | C5        |
|-----------------|-----------|-----------|-----------|
| a               | 315.81    | −32.60    | 0.86      |
| Parameter value | A6        | B6        | C6        |
| b               | −4.93     | −0.24     | 0.01      |

Finally, in the fatigue prediction model, when R = 30% and H = 10 Hz, the characteristics of the change of a and b with respect to the test temperature are shown in Equation (7):

\[
\begin{align*}
    a &= 315.81 - 32.6032T + 0.85969T^2 \\
    b &= -4.93026 - 0.23893T + 0.00831T^2
\end{align*}
\]  

Equation (7)

3.2.4. The Comprehensive Influence of RAP Content, Loading Frequency and Test Temperature on Fatigue Prediction Model Parameters

For the fatigue equation of reclaimed asphalt mixture with high RAP content (R ≥ 30%), the fitting relationship of the above a and b values with individual changes of RAP content R, test temperature T and loading frequency H has been established. A, and B need to consider the influence of three variables on it at the same time, and it may be assumed that the coefficients A and B of such a fatigue equation satisfy the following from Equation (8):

\[
\begin{align*}
    a &= P_1 + P_2R + P_3R^2 + P_4H + P_5H^2 + P_6T + P_7T^2 + P_8R^3 \\
    b &= P_1 + P_2R + P_3R^2 + P_4H + P_5H^2 + P_6T + P_7T^2 + P_8R^3
\end{align*}
\]  

Equation (8)

In this paper, Algorithms, the Levenberg–Marquardt method and general global optimization algorithms were used to obtain all the parameters of the fatigue equation of recycled asphalt mixture, and the fitting correlation coefficient $R^2$ reached 99.99%. The specific parameter values are shown in Table 12 below.
Table 12. Value table of each parameter of fatigue life prediction equation.

| Model Parameters | P1     | P2       | P3       | P4       | P5       | P6       | P7       | P8       |
|------------------|--------|----------|----------|----------|----------|----------|----------|----------|
| a                | 384.95 | −596.86  | 724.13   | 19.78    | −1.49    | −32.60   | 0.86     | −153.61  |
| b                | −25.56 | 179.98   | −498.55  | 0.40     | −0.04    | −0.24    | 0.01     | 429.70   |

After finishing, the fatigue prediction model of recycled asphalt mixture under high RAP content (R ≥ 30%) is finally obtained as seen in Equation (9):

\[
\ln N_f = 384.95 - 596.86R + 724.13R^2 + 19.78H - 1.49H^2 - 32.60T + 0.86T^2 - 153.61R^3 + (25.56 - 179.98R + 498.55R^2 - 0.40H + 0.04H^2 + 0.24T - 0.01T^2 - 429.70R^3)\ln \left(\frac{1}{C}\right)
\]  

(9)

3.2.5. Estimated Effect Evaluation Based on Fatigue Test Data of Recycled Asphalt Mixture

In order to verify the fatigue life prediction model established in this paper, the aforementioned test conditions were substituted into the above formula. This helped to obtain the prediction model’s fatigue life N_f to loading stress ratio C at different RAP content R, test temperature T and loading frequency H. The relationship between these values and the test data were then compared and analyzed, as shown in Figure 14.

![Fatigue life model and test data comparison](image)

(a) The prediction curve of fatigue life under different RAP content

(b) The prediction curve of fatigue life under different temperatures

(c) The prediction curve of fatigue life under different loading frequencies

Figure 14. The prediction curve of fatigue life N_f under different influencing factors.

It can be seen from Figure 14 that under different influencing factors, the prediction data of the prediction model established in this paper are in good agreement with all the
experimental data. It is also observable that the two trends are approximately the same, and that the recycled asphalt mixture is obtainable under low stress ratio. Hence, the fatigue life can guide the use of recycled asphalt mixture in pavement design and verification.

4. Conclusions

In this paper, a single logarithmic regression fitting was performed on the fatigue life of recycled asphalt mixtures with high RAP content. Through fitting the relationship between fatigue life and stress ratio of recycled asphalt mixture under the influence of different RAP content, as well as loading frequency, test temperature, based on the fatigue equation parameters $a$, $b$, $R$, $T$, and $H$, the fatigue prediction model of recycled asphalt was established as a mixture of the parameters $R$, $C$, $H$ and $T$. Thereafter, the prediction effect of the indoor fatigue prediction model was then evaluated. The main conclusions obtained are as follows:

1. The logarithmic fatigue life of the new asphalt mixture with 0% RAP content is approximately at the same level as the logarithmic fatigue life of the recycled asphalt mixture with 30% RAP content. This reveals the little effect of low RAP content on the fatigue life of the mixture. However, when the RAP content exceeds 30%, the fatigue life of the recycled asphalt mixture shows a significant decrease, indicating that the 30% RAP content is a critical content. This indicates further that when the critical content is exceeded, the fatigue performance of the recycled asphalt mixture will be greatly attenuated.

2. The fatigue life is more sensitive to stress ratio at low stress levels and decreases as the stress ratio increases. The fatigue life of recycled asphalt mixture is obviously smaller when the loading frequency is low than at high frequency. When the loading frequency is increased to a certain value, the fatigue life of the recycled asphalt mixture specimen tends to be stable. In addition, the fatigue life of recycled asphalt mixtures increases sharply as the temperature decreases.

3. The fatigue life and the stress ratio are approximately logarithmic. The fatigue equation parameters $a$ and $b$ are approximately cubic curves with RAP content, and are approximately quadratic with temperature and loading frequency. Under different influencing factors, the prediction model and test data established in this paper have approximately the same changing trends.

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