

Selection of Rigid-flexible Composite Pavement Construction Based on the Analytic Hierarchy Process

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Abstract: Summarizing the existing rigid-flexible composite pavement structure types in service, the paper recommends two pavement structures, adopts the method of expert evaluation of index quantification, sets up the quantitative evaluation model for asphalt pavement structure layer selection and works out the weight of each index model coefficient based on the analytic hierarchy process (AHP). Result show that through the comparison of two kinds of pavement structure scheme, the structure of double asphalt mixture layers has a certain advantage than single-layer. Because no rigid-flexible composite pavement design method at present, using the analytic hierarchy process in pavement structure type selection can better choose the more economic and reasonable pavement structure scheme combined with the actual situation and provide a reference for the selection of composite pavement structure.

Introduction

Rigid-flexible composite pavement is a kind of composite pavement structure that paves ordinary asphalt mixture layer (AC) on continuously reinforced concrete pavement (CRCP). At present, in terms of China's heavy highway traffic, and a serious phenomenon of heavy load and overload, CRC+AC composite pavement test roads and solid projects^[1] are built in HENAN, JIANGSU, HEBEI, SHANGHAI and SHANXI in China. In 2003, the CRC+AC composite pavement which constructed in the reconstruction of old cement concrete pavement of CHANGTAN in HUNAN Province adopted the structure type: 4cmSBS modified asphalt SMA-13+ modified emulsion asphalt +6cmSBS modified asphalt AC-20C; in 2004, two segments of YANJIANG highway in JIANGSU Province in the method of long-lived test road structure used CRC+AC structure. One structure is 4cmSMA-13+6cmCDAC-20+26cmCRCP panel, and another structure is 6cmSMA-13+24cmCRCP; in 2006, a composite pavement solid project with 8km was built in the reconstruction of old cement concrete pavement from HUANGHUA segment to YONG AN segment in CHANGYONG highway in HUNAN Province, and the adopted structure type is 4cmSBS modified asphalt (SMA-13) +SBS modified bitumen emulsified asphalt +5cm modified asphalt medium grained asphalt concrete (AC-20)+18cm continuously reinforced cement concrete face. In 2008, the new highway of ZHANGJIAKOU to SHIJIAZHANG used 40km CRC+AC composite pavement structure, and the composite structure type is 6cm modified asphalt concrete (AC-13C) +SBS modified bitumen +28cm continuously reinforced cement concrete plate^[2]. Currently, due to the backward design methods of composite pavement and engineering application^[3], the selection of composite pavement structure largely depends on foreign research

results and some successful practical experiences gained from test road paving at home. Based on summary of the types of composite pavement structures adopted by people now, including comparison of some elements, such as the durability and amenity of different pavement structures, the design of payment structure and construction difficulties, selection of materials, construction costs as well as the maintenance and management of the later operation, this paper selects the composite pavement structure types with a superior comprehensive performance, which provides a reference for the selection of composite pavement structure. Recommendation of rigid-flexible composite pavement structure schemes.

Summarizing the structure types of the paving rigid-flexible composite pavement at home, currently the asphalt layer of composite pavement mainly uses two paving structures of single-layer pavement and double-layer pavement. For selection of thickness of asphalt layer, NI FUJIAN [4] and others think that when the AC face's thickness is greater than 4cm, each additional 2cm is able to meet the requirement of 15% to 20% overload. According to the design specifications, when the reliability coefficient is above 1.2, then the thickness is 4cm, which can meet the requirement of 30% overload; while the thickness is 12cm, it can meet the requirement of 30% to 100% overload. The correlation calculation method recommended by Gregory [5] is too conservative. For the asphalt surface course with a thickness of 10cm, the thickness of CRC is reduced by 1.7cm to 2cm compared with that of CRCP pavement. LIU CHAOHUI and LI SHENG [6-8] believe that in the CRC+AC composite pavement structure, the thickness of CRC basically has no effect on the rutting depth of composite pavement, while the thickness of asphalt layer has a great impact on the rutting depth. With the increase of thickness of AC layer, the rutting depth increases linearly, and each additional 1cm of AC layer's thickness will make the rutting depth increase by about 20%. The thickness of continuously reinforcement cement concrete face is mainly concentrated between 18cm to 28cm, and the reinforcement percentage of cement concrete plates with different thicknesses is varied too. Based on the existing research results and practical experience, this paper selects two available schemes for pavement structure (Tab1). By using analytic hierarchy process (AHP), this paper builds the selection model of pavement structure based on AHP. According to the model assessment, it directly reflects the advantages and disadvantages of the sort of composite pavement structure schemes, which can better adjust the weights in real time by combining with the actual situation, so as to choose a more economical scheme with a reasonable technology.

Tab 1 Schemes of composite pavement structure

Scheme 1	Scheme 2
4cm SMA-13	SMA-16 6cm
6cm AC-20	
25cm CRC	26cm CRC
20cm Cement stabilized crushed stone	
20cm Integrated stabilized slag soil	

Selection model of pavement structure based on AHP

Selection and analysis of assessment indexes

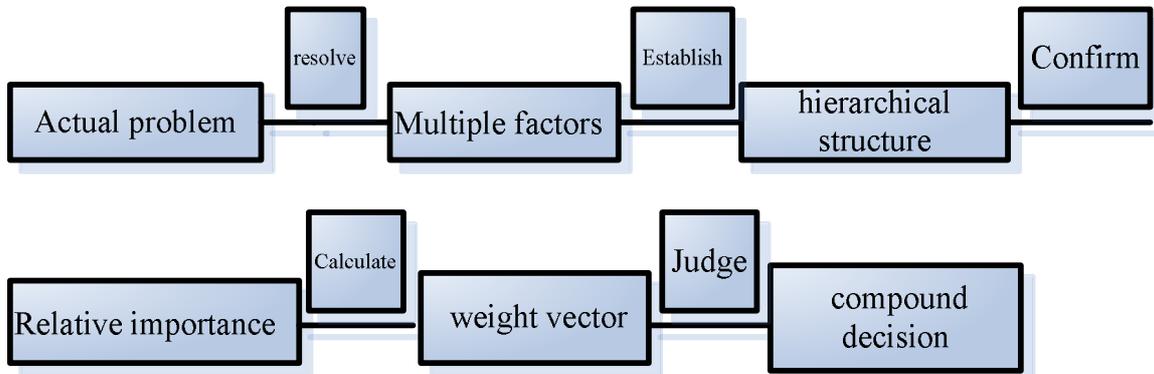
In general, the selection of pavement structure layer usually needs to take into account the durability and comfort, the design and construction difficulty of the payment structure, including the assessment indexes of some aspects, such as the selection of materials, construction costs as well as the maintenance and management of the later operation

Establishment of assessment model and calculation of weight indexes

Using AHP to carry out weight analysis of assessment indexes. AHP is a systemic analysis

method proposed in the late 1970s, which is suitable for those decision problems[9] with a complicated structure and have more decision principles and are inappropriate for QUANTIZATION.

Basic principles of AHP:



AHP consists of the following four steps:

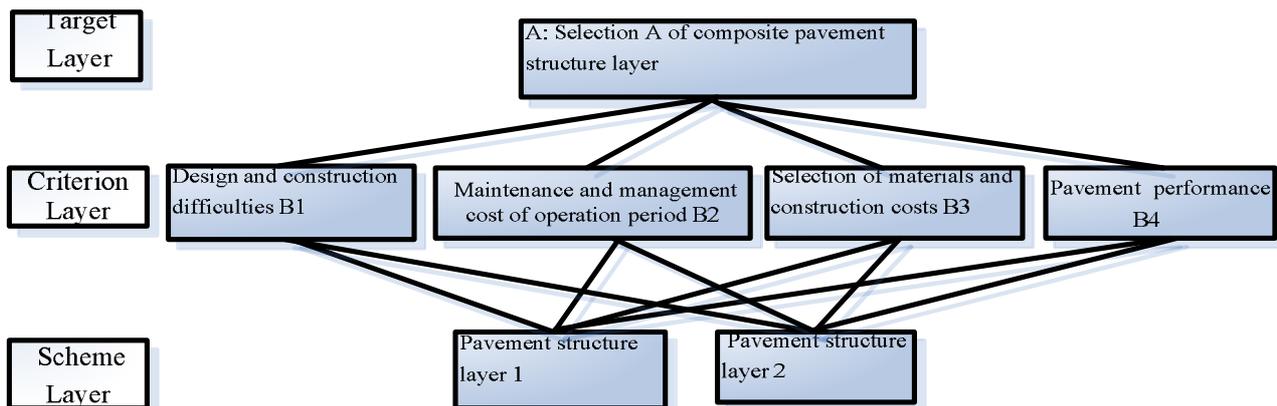
- (1) Establishment of hierarchical structure model;
- (2) Establishment of judgment (paired comparison) matrices;
- (3) Single hierarchical taxis and the test of its consistency;
- (4) Total taxis of hierarchy and the test of its consistency.

Establishment of hierarchical structure

Define the problem, and propose the general target (the selection of rigid-flexible composite pavement structure layer).

Establish hierarchical structure, and break the problem down into a number of layers. The first layer is the general target; middle-layer is criterion layer (influencing factors); the lowest layer is scheme layer (selection of scheme), shown in Fig1.

Fig 1 Hierarchical structure of selection of pavement structure layer



Establishment of judgment matrices

The criterion layer judgment matrix value of $A = (\alpha_{ij})_{n \times n}$, α_{ij} is determined by using the 1 to 9 scale method established by SAATY [10]. This paper selects the a group of experts who are

familiar with the conditions of SHANXI Province and can accurately grasp the composition of regional traffic and the overload characteristics, so as to offer the judgment matrix A which is suitable for the project.

The meaning of scale methods of judgment matrix element α_{ij} is shown in Tab 2:

Tab 2 Meaning of 1-9 scale methods

Scale	Meaning
1	It indicates the two elements are equally important
3	A factor is slightly important than another
5	A factor is obvious important than another
7	A factor is strongly important than another
9	A factor is extremely important than another
2,4,6,8	Mid-value of two adjacent judgment above
Reciprocal	$\alpha_{ji}=1/\alpha_{ij}$

According to the above 1-9 scale method, the judgment matrix A is determined, shown as follows:

$$A = \begin{bmatrix} 1 & 1/4 & 1/3 & 1/2 \\ 4 & 1 & 2 & 3 \\ 3 & 1/2 & 1 & 1/2 \\ 2 & 1/3 & 2 & 1 \end{bmatrix}$$

Calculation of weight indexes

The weight indexes are calculated with the root method.

(1) Calculate \bar{w}_i ;

$$\bar{w}_i = \sqrt[n]{\prod_{j=1}^n a_{ij}} \quad (i=1,2,3,4)$$

$$\text{Solve } \bar{w}_i = (0.452, 1.778, 0.931, 1.075)$$

(2) Normalize \bar{w}_i and gain the weight coefficient w_i

$$w_i = \frac{\bar{w}_i}{\sum_{i=1}^n \bar{w}_i} = \begin{bmatrix} 0.106 \\ 0.420 \\ 0.220 \\ 0.254 \end{bmatrix} \quad (i=1,2,3,4)$$

(3) Solve I_{\max}

$$I_{\max} = \sum_{i=1}^n \frac{\sum_{j=1}^n a_{ij} w_j}{n w_i} = 4.211$$

$$(i=1,2,3,4; j=1,2,3,4)$$

(4) Test of consistency

After gaining the judgment matrix A, a test need to be carried out by using the consistency index C.I., and if:

$$C.I. = \frac{I_{\max} - n}{n - 1} = \frac{4.211 - 4}{3} = 0.07 < 0.1$$

That means the judgment matrix is satisfactory and acceptable.

Find the mean random consistency index R.I., and the mean random consistency index is gained by repeatedly carrying out random judgment matrix characteristic root calculation for over 500 times. And the mean random consistency index of repeatedly calculating the judgment matrix from 1 to 15 stage for 1000 times obtained by GONG LINSEN and XU SHUBAI in 1986 is shown in Tab3:

Tab 3 Random consistency index of judgment matrix from 1 to 7 stage

Stage	1	2	3	4	5	6	7
RI	0	0	0.52	0.89	1.12	1.26	1.36

Define the ratio of consistency: $C.R. = \frac{C.I.}{RI} = \frac{0.07}{0.89} = 0.08 < 0.1,$

When $C.R. < 0.1$, it is generally considered that the consistency of judgment matrix is acceptable. Otherwise, some appropriate amendments should be made to the judgment matrix.

The structure scheme relative to the judgment matrix of assessment index

The road experts are invited to give judgment matrix of various assessment indexes of the two payment structure schemes, shown in Tab4 (a, b, c, d).

Tab 4 Judgment matrix of various assessment indexes

B1	C1	C2
C1	1	1/2
C2	2	1

(a)

B2	C1	C2
C1	1	3
C2	1/3	1

(b)

B3	C1	C2
C1	1	1/2
C2	2	1

(c)

B4	C1	C2
C1	1	1/4
C2	4	1

(d)

Weight index calculation for the matrices above including consistency test are carried, the above four matrices are satisfactory and acceptable, and then according to the characteristic vector of the matrices, matrix M is formed.

$$M = \begin{bmatrix} 0.333 & 0.750 & 0.333 & 0.2 \\ 0.667 & 0.250 & 0.667 & 0.8 \end{bmatrix}$$

$$W \times w_i = \begin{bmatrix} 0.474 \\ 0.526 \end{bmatrix}$$

Judging from the above structures, structure 2 has obvious advantages, that is, double-layer asphalt armor layer is better than single-layer structure in comprehensiveness of various assessment indexes. Meanwhile, according to the assessment model proposed in this paper, it can reflect the advantages and sort of various schemes more directly, which can also better adjust the weights combined with the actual situation, so as to choose a more economical scheme with a reasonable technology.

Conclusions

(1) Carry out analysis of the recommended two composite pavement structure schemes based on AHP. The results show that double-layer asphalt armor layer structure has more advantages than single-layer asphalt payment structure in comprehensiveness of various assessment indexes.

(2) Optimizing the selection of composite payment structure types by using analytic hierarchy process can better combine with the actual situation, so as to select a more economical pavement structure scheme with better performance.

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