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Application of Multi-Criteria Decision-Making in Achieving the Right Mix Asphalt Mixtures

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ABSTRACT: Marshall Test is one of the tests used for asphalt mixture. This test has six parameters, including stability, unit weight, flow, void in mineral aggregate, voids in total mix, and voids filled with asphalt. Further, the additional cost of various additives to the asphalt mixture for building one kilometer of the road is a negative parameter. However, using additives improves the technical characteristics of the asphalt mixture. Therefore, making a proper choice among the alternatives would be a hard task. This paper tries to provide an appropriate method for mixing the design of asphalt mixtures to select the best alternative by considering all technical criteria. For this purpose, the concordance analysis method, which is one of the compensation models of the Multi-Criteria Decision-Making (MCDM), was used. The results showed that the concordance analysis method using a pairwise comparison strategy combines the different criteria to prioritize alternatives and to propose the best alternative. Therefore, this method can be used as a superior method for mixing the design of asphalt mix compared to conventional methods.

Keywords: multi-criteria, concordance analysis, asphalt mixture, additives.

1 INTRODUCTION

In the design of asphalt mixtures, the aim is to determine the best mixture in terms of technical and functional characteristics [1-10]. Many researchers have suggested the modification of asphalt mixes using additives, and a majority of those additives have produced high-quality outcomes. Hence, modifying the properties of asphalt mixture using additives is of paramount importance in achieving the goal mentioned above [11-17].

Various methods, such as Marshall Test, have been proposed for mixing the design of asphalt mix. In this test, different alternatives are tested with different additives to achieve a high-quality asphalt mix, and its results are expressed based on six parameters. On the other hand, adding the appropriate additives to the mixture raises concerns about the increase in the construction cost (negative parameter). A combination of the different criteria, which may be opposing, to select the best alternative seems to be a challenging task.

In this paper, an attempt has been made to provide an appropriate method for mixing the design of asphalt mixtures to select the best alternative by considering all technical criteria. For this purpose, 25 alternatives and seven different criteria were introduced. Then, the evaluation of proposed alternatives using concordance analysis has been introduced. Finally, given the quantitative amounts of each criterion and determining the criteria weight, the best alternative is selected.

2 LITERATURE REVIEW

According to Hwang and Yoon 1981 classification, the Multi-Criteria Decision-Making (MCDM) is divided into multiple attribute decision-making (MADM) and multiple objective decision-making (MODM) [18]. MADM is used to evaluate discrete variables. In addition, this is an a priori process. Experts take part in the initial stage of the process, giving the weightings of the criteria, or assessing any attribute of the problem. Finally, the best solution is obtained. MODM allows for the obtainment of a continuous set of solutions regarding two or more criteria, called Pareto front. These solutions are characterized by each being considered equally good. The experts also take part in the end stage of the process, choosing one among the many solutions [19].

There are various techniques of MCDM to conduct multi-criteria decision analysis. There is no better or worse technique because the method's appropriateness depends on the specific decision situation [20]. Different MCDM techniques have been developed to tackle the different problems under different circumstances and fields of application [21]. MCDM methodologies are very similar and share almost similar steps of organization and decision matrix construction, but each methodology synthesizes information differently [22]. A brief description of some standard methodologies is presented in table 1. In an article by Jato-Espino et al. 2014, the Multi-Criteria Decision Analysis (MCDA) approach was chosen as a branch of operations research. The application of 22 different methods belonging to the construction field, which is classified into 11 groups, was examined. The most significant methods were briefly discussed, and their main strengths and limitations were stated. A great variety of MCDM methods have been developed to solve such problems in terms of practical features, [23].

For more detailed reviews of the literature on MCDA for the evaluation of transportation and construction projects, readers are referred to Macharis and Bernardini 2015 [21] and Jato-Espino el al. 2014 [23], respectively. Also, in this section, a brief review of MCDA is presented (table 1).

Table 1. A summary of some standard MCDM methodologies[22]

Abbre-	Method	Description
AHP	Analytic hierarchy pro-	Structured technique for analysing MCDM problems according to a pairwise compari-
ANP	Analytic network process	Generalization of the AHP method which enables the existence of interdependences
COPRAS	Complex proportional	Stepwise method aimed to rank a set of alternatives according to their significance
DEA	Data envelopment anal-	Non-parametric system for measuring the efficiency of a set of multiple decision mak-
DRSA	Dominance-based rough	Derivation of rough set theory which allows defining a MCDM problem through a series
ELECTR	Elimination et choix	Group of techniques addressed to outrank a set of alternatives by determining their con-
FSs	Fuzzy sets	Extension of the traditional concept of crisp sets which states that the belongingness of
GST	Grey system theory	Philosophy of handling data according to the information contained in them, from black
GT	Game theory	Area of applied mathematics that studies the interaction of formalized structures to make
IFSs	Intuitionistic fuzzy sets	In addition to the belongingness grade of an element to a set proposed by FSs, IFSs also
MAUT	Multi-attribute utili-	Methodology employed to make decisions by comparing the utility values of a series of
MAVT	Multi-attribute val-	Non-deterministic methods used to find approximate solutions to complex problems by
SAW	Simple additive	Technique aimed to determine a weighted score for each alternative by adding the con-
SIR	Superiority and inferiori-	Method that uses six generalized criteria to establish the preferences of a decision maker
SMAA	Stochastic multiobjec-	Methodology that determines the acceptability index of an alternative as the variety of
TOPSIS	Technique for order of preference by similarity	Technique based on the concept that the best alternative to a MCDM problem is that which is closest to its ideal solution
UT	Utility theory	Method for measuring the degree of desirability provided by tangible and/or intangible

Saphira and Goldenberg (2005) presented a selection model based on the Analytical Hierarchy Process (AHP), a multi-attribute decision analysis method. Their model can handle a significant number of different criteria in a way that genuinely reflects the complex reality, incorporates the context and unique conditions of the project, and allows for the manifestation of user experience and subjective perception. The problem was divided into four criteria and eighteen sub-criteria hierarchy, which addressed three perspectives: cost evaluation benefits evaluation and total evaluation [24].

Chou (2008) proposed a Case-Based Reasoning (CBR) estimation method model that compares and retrieves the most similar instance across the case library. Four CBR approaches were presented and assessed in terms of their mean absolute prediction error rates. The similarity between current and previous cases was measured after establishing pairwise comparisons through the AHP technique [25].

Rahman et al. (2012) developed the Knowledge-based Decision Support system for roofing Material Selection and cost estimating (KDSMS) system, a knowledge-based decision support system for the selection of optimal Materials for building design. The system uses product cost modeling techniques and the MCDM technique of TOPSIS for optimal materials selection and has been implemented as a prototype system for optimal roofing material selection and cost modeling [26].

Şimşek et al. (2013) applied a multi-response Taguchi method to investigate the ranking of the different factor levels and the best possible mix proportions of high strength self-compacting concrete (HSSCC). They proposed a hybrid Taguchi method and Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) to solve the multi-response optimization problem in a ready-mixed concrete plant. In fact, the TOPSIS method was used to transform the multi-response problem into a single-response problem. The results showed that the produced concrete samples satisfied the expected properties of the HSSCC [27].

Li et al. (2013) developed a Data Envelopment Analysis (DEA) system to compare the performance of three different Warm Mix Asphalt (WMA) technology and a conventional Hot Mix Asphalt (HMA). The dynamic modulus of the mixtures was compared and analyzed. The unit costs defined the inputs, whiles the outputs were a series of environmental factors [28].

Various methods have been proposed by researchers for the optimal design of the asphalt mix.

Lim et al. introduced a new design method for asphalt mixes containing additives. The laboratory results showed that careful selection of the additive dose is required to balance the cracking and groove performance of asphalt mixtures [29].

Other methods have been proposed for the optimal design of the type of concrete pavement. In another study, a method was proposed to determine the optimum amount of water for roller compacted, steel fiber-reinforced, and polymer-modified bonded concrete overlays [30].

Jato-Espino et al. (2014) proposed a new multi-criteria model based on the combination of several existing decision-making tools for the selection of urban pervious pavements. They developed a Multi-criteria approach based on the Integrated Value Model for Sustainable Assessments (MIVES) method and improve the model by including some auxiliary complements such as Monte Carlo simulations, fuzzy sets and the AHP method [31].

There is also some successful application of MCDM in prioritizing highway safety improvement projects [32, 33, 34, and 35].

Yu and Liu (2012) proposed a method based on fuzzy AHP to tackle the difficulties of multi-criteria decision-making environment of prioritizing highway safety improvement projects and considering the effect of using uncertain data. Their research indicated that AHP could be used as an efficient tool in selecting and prioritizing the most beneficial projects given budget constraints [32].

Dadashi and mirbaha (2019) proposed a new multi-criteria methodology based on the integration of DEA and Monte-Carlo simulation to consider existing uncertainties of the problem. Results indicate how their proposed methodology can be useful for detecting sensitive decision-making units and providing a more comprehensive view for decision-makers to allocate a limited budget to the most efficient safety improvement projects [35].

According to the discussions, the application of the MCDM method has been widely used in engineering sciences. However, the use of this method in the mixing design of asphalt pavement has not been investigated. Hence, in this article, for determining the best mixing design, the concordance analysis method was used to select the best alternative from 25 different potential alternatives.

3 METHODOLOGY

In this paper, the selection of the appropriate mixture was investigated by using the results of the Marshall Test and using the concordance analysis method. Concordance analysis is one of the most critical methods of evaluating the cases whose criteria do not fit together and cannot be converted to each other. The concordance analysis method using a pairwise comparison strategy combines the different criteria to prioritize alternatives and to propose the best alternative. This method ranks the alternatives using a concordance and non-concordance sets, through pairwise comparison of alternatives.

Concordance and non-concordance indices can be calculated for each weighting system for various purposes. The concordance index shows the dominance of one alternative over the other alternatives, and the non-concordance index indicates the dominance of other alternatives on the desired alternative. The domination index is constructed by Using concordance and non-concordance indices, which is used to determine the dominance of either alternative. The alternatives that are better than average are called non-dominated alternatives. We assume that the evaluation of i alternatives to be considered based on j criteria [36]:

If j is a positive measure:

$$r_{ij} = \frac{z_{ij}}{\max\ z_{kj}} \quad (1)$$

If j is a negative value (fewer values is preferred.):

$$r_{ij} = 1 - \frac{z_{ij}}{\max\ z_{kj}} \quad (2)$$

$Z_{ij} =$ The j^{th} evaluation criterion for the i^{th} option

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$\max\ Z_{kj} =$ The maximum value for different alternatives in a particular criterion

r_{ij}= Dimensionless unit, and its value is between 1 and 0.

Concordance and Non-Concordance series are as follows:

$$C_{ii'} = \left\{ j : r_{ij} \geq r_{i'j} \right\} \quad (3)$$

The concordance set $C_{ii'}$ ‘is a set of all criteria where the i^{th} alternatives are better than the i' option.

$$D_{ii'} = \left\{ j : r_{ij} \leq r_{i'j} \right\} \quad (4)$$

The non-concordance set $D_{ii'}$ ‘is a set of all criteria where the i^{th} alternatives are worse than the i' option.

The concordance index is as follows:

$$C_{ii'} = \sum_{j \in C_{ii'}} W_j , \quad 0 \leq C_{ii'} \leq 1 \quad (5)$$

Where Wj is jth criterion weight than other criteria.

Therefore, it can be said [9]:

$$\sum_j W_{ij} = 1, \qquad 0 \le c_{ii'} \le 1 \tag{6}$$

The non-concordance index is defined as follows:

$$d_{ii'} = \frac{1}{m} \sum_{j \in D_{ii'}} \frac{W_j \left| r_{ij} - r_{i'j} \right|}{d^{\max}}, 0 \le d_{ii'} \le 1 \tag{7}$$

Where:

$$d^{\max} = \max_{i,i',j} W_j \left| r_{ij} - r_{i'j} \right| \tag{8}$$

$$m = \max_{i,i'} \{number\ of\ elements\ in\ D_{ii'}\}$$

By using these indicators, the concordance and non-concordance indicators can be prepared as follows:

The net value of the Concordance index:

$$c_i = \sum_{i \ne i'} c_{ii'} - \sum_{i \ne i'} c_{i'i} \tag{9}$$

c_i = The net value of the concordance index for i option

The net amount of Non-Concordance index:

$$d_i = \sum_{i \ne i'} d_{ii'} - \sum_{i \ne i'} d_{i'i} \tag{10}$$

$\boldsymbol{d_i}$ = The net value of the non-concordance index for the i[th] option

For weighting system W, alternatives that are true for two following equations constitute a set of non-dominated alternatives:

$\boldsymbol{c_i} > 0, \boldsymbol{d_i} > 0$

Non-dominated alternatives refer to those alternatives that, for a specific weighting system, operate better than average. By changing the weighting system, non-dominated alternatives change. Conventional alternatives in the non-dominated set can be considered in a set, called competitor alternatives. This set operates better than average for any weighting system. The selection of any of the alternatives of the competitor set is the proper solution for the problem.

Finally, using the Giuliano method, various options using a concordance and non-concordance net ranking have been compared, and the results were evaluated [36].

4 DATA ANALYSIS

Here, the alternatives examined based on the results of the Marshall test as their criteria. By creating concordance and non-concordance sets according to r_{ij} parameters, which are calculated for different weighting systems, concordance, and non-concordance indices are determined, leading to the identification of the non-dominated alternatives and finally determining a set of competitor alternatives. Here, the top alternatives are better asphalt mixture.

The following tables (Table 2, Table 3, and Table 4) show the properties of bitumen and materials that have been used [37- 39]:

Table 2. Aggregate Gradation [37-39]

Sieve Number	Grain Size (mm)	Percentage of Passing
#200	0.075	6
#50	0.3	13
#8	2.36	43
#4	4.75	61
½”	12.5	94
¾”	19	100

Table 3. Proportions aggregate asphalt mixture [37-39]

Types of Aggregates	Medium gravel	Fine Gravel	Sand
Grain size	4.75-25 mm	0-19 mm	0-6 mm
The percentage of aggregate	10	42	48

Table 4. Results of standard tests used in research on bitumen (85/100) [37-39]

Characteristic	Standard	Results
Specific gravity at 25℃	T228	1.012
The penetration grade in 25℃ (100 g-5 seconds), in 0.1 mm	T49	98
Softening point (ring and ball), in C	D36	45
the amount of stretch at 25℃ in cm	D113	More than 100
The degree of flammability (open-Cleveland), in Celsius	D92	289
The amount of stretch at 25℃, in cm	--	More than 100

4.1. Data inputs (raw data)

In this paper, six parameters of Marshall Test including as well as the cost of the construction of one kilometer of asphalt were selected(unlike previous research [12]) as evaluation criteria in the concordance analysis. Therefore, seven factors entered in the calculations as a factor (j).

The cost criteria were calculated as the additional cost of adding additives to the mixture for each kilometer of a highway [1, 2] and [14, 15]. The following table shows raw P_{ij} data (results of Marshall) used in the Concordance analysis [37- 39].

Table5 Result of Marshall P_{ij}[37- 39]

Objective / Alternative	Percent of nano carbon black in the mixtures	Percent of polyester fiber in the mixtures	Stability (kg)	Unite Weight	VTM	Flow	VMA	VFA	Price ($)
1	0	0	835	2.36	4.5	2.7	16.11	72.07	0
2	0	0.5	1010	2.32	6.04	3.46	17.44	65.37	1511288.9
3	0	1	815	2.29	7.38	3.84	18.64	60.1	3022577.8
4	0	1.5	775	2.25	8.37	3.97	19.93	55.5	4533866.7
5	0	3	550	2.16	12.5	4.22	23.13	45.95	9067733.4
6	5	0	734	2.3	7.04	3.15	18.33	61.59	239887125
7	10	0	848	2.41	2.38	1.72	14.23	83.3	479774250
8	15	0	1427	2.41	2.38	1.3	14.23	83.3	719661375
9	20	0	1304	2.4	2.79	1.3	14.59	80.88	959548500
10	5	0.5	999	2.33	5.79	4.45	17.3	66.4	241398413.9
11	5	1	1120	2.26	8.4	5.97	19.5	57	242909702.8
12	5	1.5	1265	2.29	7.38	6.91	18.6	60.4	244420991.7
13	5	3	1200	2.31	6.44	7.17	17.8	63.8	248954858.4
14	10	0.5	1140	2.33	5.79	5	17.3	66.4	481285538.9
15	10	1	1140	2.35	4.65	4.65	16.2	71.3	482796827.8
16	10	1.5	1140	2.27	8.13	3.58	19.3	57.9	484308116.7
17	10	3	1100	2.25	8.37	3.07	19.9	55.5	488841983.4
18	15	0.5	1305	2.37	4.08	4.1	15.7	74.1	721172663.9
19	15	1	1100	2.31	6.44	4.61	17.8	63.8	722683952.8
20	15	1.5	1430	2.31	6.44	6.66	17.8	63.8	724195241.7
21	15	3	1200	2.3	6.68	7.17	18	62.9	728,729,108.40
22	20	0.5	980	1.3	6.68	6.91	18	62.9	961059788.9
23	20	1	1265	2.3	6.68	5.89	18	62.9	962571077.8
24	20	1.5	815	2.29	7.38	5	18.6	60.4	964082366.7
25	20	3	800	2.28	7.65	4.35	18.9	59.3	968616233.4

Note that the costs of additives were high in this project, and using additives with reasonable prices can help reduce the costs in various alternatives. Also, different alternatives included different percentages for adding additives to the asphalt mixture, and thus, 25 alternatives (i) were entered in calculations and were compared. The percentage of polyester fibers and nano-carbon black added to the asphalt mixtures are presented in Table 5 [37-39].

4.2 Weighting system

Different pavement experts cooperated on the current study by providing their opinions on the importance of each of the items in the objective function based on a scoring method. According to experts' opinions, a group of weights was provided for objective functions. Each category is called a weighting system.

Based on the weighting system, the net values of concordance and non-concordance indices were calculated for each mixture, and accordingly, the proper mixture is introduced. In this paper, eight weighing systems were considered in table 6. As can be seen, in one of the weight systems, the weight of all the criteria is considered equal, and in 7 other weight systems, stability and price of asphalt mixture due to extremely high importance have had higher weight than other indicators.

4.3 Data normalization

Normalization of various criteria was performed in this way. For criteria with a better maximum and minimum values, it should be done as in section 2, but for some criteria which the regulations restrict them periodically, it was done in such a way that the middle of the interval is considered as the maximum value and equal to 1. The further we get from the middle of the interval, the lower the number.
This approach is summarized as follows:

Suppose the interval of the regulation is (a, b), and the obtained numbers are maximum and minimum for a specific criterion. The middle of the interval is defined as follows:

$$C = \frac{a+b}{2} \qquad (11)$$

And also,

$X = \max P_{ij}$

$Y = \min P_{ij}$

$P_{ij} = raw\ \ data$

$$r_{ij} = 1 + \frac{P_{ij} - C}{C - X} \quad for\ P_{ij} \geq C$$

$$r_{ij} = \frac{P_{ij} - C + X}{X} \quad for\ P_{ij} \leq C \qquad (12)$$

So, the VTM, FLOW, and VFA Criteria, were normalized as follows:

Table 6. Weighting to criterions

	Stability	Unite weight	Flow	VTM	VMA	VFA	Price per (Km)
W1	0.2	0.2	0.1	0.1	0.1	0.1	0.2
W2	0.3	0.08	0.08	0.08	0.08	0.08	0.3
W3	0.3	0.3	0.08	0.08	0.08	0.08	0.08
W4	0.5	0.05	0.05	0.05	0.05	0.05	0.25
W5	0.0667	0.0667	0.0667	0.0667	0.0667	0.0667	0.6
W6	0.6	0.05	0.05	0.05	0.05	0.05	0.15
W7	0.6	0.0667	0.0667	0.0667	0.0667	0.0667	0.0667
W8	0.142857	0.142857	0.142857	0.142857	0.142857	0.142857	0.142857

Table 7 Competitor alternatives for top asphalt mix

alternative	w1	w2	w3	w4	w5	w6	w7	w8	total
1	1	1	1	1	1	1	0	1	7
2	1	1	1	1	1	1	1	1	8
3	1	1	1	1	0	1	1	1	7
4	0	1	0	1	0	0	0	0	2
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	1	1	1	0	1	1	0	1	6
8	1	1	1	1	1	1	1	1	8
9	1	1	1	0	1	1	1	1	7
10	1	1	1	1	1	1	0	1	7
11	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	1	1	1	1	0	1	1	1	7
14	1	1	1	1	1	1	1	1	8
15	1	1	1	1	1	1	1	1	8
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	1	1	1	1	1	1	1	1	8
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	1	0	1	2
21	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0

5 RESULTS AND DISCUSSION

As seen in table 7, the alternatives 2, 8, 14, 15, and 18 compared with the first alternative (do nothing) have participated in all eight weight designs, and have priority. Also, the alternatives 3, 9, 10 and 13 with the first option (do nothing) were involved in seven weight design, and any of the four alternatives can be used rather than the first option (do nothing). Due to the high expense or mechanical properties, other alternatives have had the lowest frequencies in different weighting designs and, therefore, are out of the competition with other alternatives. The following table shows the results of the Concordance analysis.

On the other hand, as shown in Table 8, alternative two compared to the first option (do nothing), have had a lower average and a priority. Also, alternatives 8, 18, and 15 after the first alternative (do nothing) have had the lowest average, and the three alternatives for technical reasons and in the absence of economic trouble can be used instead of the first alternative (do nothing). Due to the high price or due to mechanical properties, other alternatives have had a high average, and so are out of line with other alternatives. The following table shows the results of the rank of Concordance analysis.

Table 8. Average rank based on Giuliano method

alternative	w1	w2	w3	w4	w5	w6	w7	w8	Average rank
1	2	2	3.5	6	4.5	3.5	7.5	2.5	3.9375
2	1	1	1.5	1.5	3	1	3.5	1	1.6875
3	5	3	7	5	10.5	11	9	8	7.3125
4	12.5	11	16	12	14.5	17	15	14.5	14.0625
5	21	21	19.5	16	16	22	16.5	20.5	19.0625
6	13.5	12.5	16	14.5	11.5	15	13.5	14.5	13.875
7	7.5	13.5	6	14	8.5	7.5	11.5	7.5	9.5
8	3.5	6	3.5	8	8.5	3	5.5	3	5.125
9	9.5	11	5.5	9	10.5	4.5	7	6	7.875
10	6.5	6.5	7.5	9.5	7	8	9	6.5	7.5625
11	22.5	21.5	23	20	18	22.5	20	21.5	21.125
12	14.5	13.5	14.5	13	16	16.5	13.5	15	14.5625
13	10	9.5	11.5	9.5	12	11.5	10.5	10.5	10.625
14	9.5	6.5	8	8.5	8	8	7.5	9.5	8.1875
15	6.5	6.5	7	6	8.5	6.5	6	7.5	6.8125
16	17.5	15.5	17	14.5	15.5	16	14	17	15.875
17	20	18	20.5	17.5	18	19	18	20	18.875
18	5	4.5	6.5	4.5	8	3	7	4.5	5.375
19	16	16	15.5	17.5	15	16	17.5	15	16.0625
20	13.5	15.5	11	11	12.5	10.5	9.5	11.5	11.875
21	18	20.5	16.5	20	18.5	17	18	18	18.3125
22	24	24	22.5	24	22.5	22	23	23.5	23.1875
23	19.5	21.5	18	18.5	16.5	15.5	17	19	18.1875
24	24	23.5	23	22	22.5	23.5	22.5	24.5	23.1875
25	22	21	24.5	23	19	25	23	24	22.6875

8 CONCLOSION

For the first time in this study, an alternative method was used to mix the design of asphalt mixture. For this purpose, the concordance analysis method was used to rank, and thus acquire the right asphalt mix.

The concordance analysis method with the possibility of involving different weighted combinations in the calculations reduces the effect of error in weighting. As mentioned in the previous section, alternatives 2, 8, 14, 15, and 18 compared with the first option (do nothing) have participated in all eight weight designs and are in priority.

On the other hand, alternative 2 has a lower average rating than the first alternative (do nothing), and alternatives 8 and 18 were ranked as third and fourth. Comparing the results from both methods, alternative two is better than the first alternative (do nothing), and alternatives 8 and 18 due to better technical properties were second and third. Table 9 lists the top 10 alternatives in order of priority based on the results of both methods.

The summary of the results is as follows:

- If the Concordance method is used, alternatives 2, 8, and 18 recommended.
- If this method is not used, with evaluation and comparison of different alternatives in table 5, and with this assumption that we can apply all alternatives (for establishing a balance between this case and the case using concordance analysis), the alternative 18 would have better state than other alternatives, and alternative 20 would be the second one (because of high stability).
- It seems that concordance analysis proposes better alternatives than the conventional method. Therefore, the use of this method in the mixing design of the asphalt mix has resulted. Also, the use of this method can be used to obtain the optimal bitumen percentage.

Conflict of Interest: The authors declare that they have no conflict of interest.

Table 9. final results and ranking of the top options

	alternative	percent of polyester fiber in the mixtures	total	Average rank
1	2	Mixture with 0.5% replacement polyester fiber	8	1
2	8	Mixture with 15% replacement Nano carbon black	8	3
3	18	Mixture with 0.5% replacement polyester fiber and 15% of the bitumen weight of Nano carbon black	8	4
4	15	Mixture with 1% replacement polyester fiber and 10% of the bitumen weight of Nano carbon black	8	5
5	1	The mixture without additives	7	2
6	14	Mixture with 0.5% replacement polyester fiber and 10% of the bitumen weight of Nano carbon black	8	9
7	3	Mixture with 1% replacement polyester fiber	7	6
8	10	Mixture with 0.5% replacement polyester fiber and 5% of the bitumen weight of Nano carbon black	7	7
9	9	Mixture with 20% replacement Nano carbon black	7	8
10	7	Mixture with 10% replacement Nano carbon black	6	10

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