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# Application of concordance analysis method (CA) for optimal selection of asphalt mixtures reinforced with rubber powder and carbon fiber

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ABSTRACT: Unlike the conducted studies in the field of reinforcing the asphaltic mixture, this research has used the multi-criteria decision-making method to determine the optimal percentage of the asphalt mix, which was reinforced with rubber powder and carbon fibers. After adding different percentages of two kinds of additives, i.e. rubber powder and carbon fibers conjointly, conducting Marshall Tests, analyzing the data and plotting the needed diagrams, it was observed that adding these two additives leads to a change in the results of Marshall Tests. Analyzing the diagrams, the optimal percentages for combining the rubber powder with carbon fibers were obtained, 15% and 0.5%, respectively having the best effect on the asphalt mix. Subsequently, the extra cost caused by adding the additives to the asphalt was evaluated by conducting an economic analysis. Then, six Marshall Parameters were used as six indices in the concordance analysis method, which is a multi-criterion decision-making method. Ultimately, the superior alternatives were proposed according to the results of the ranking. According to the results, the suggested alternatives differed from the estimated alternative and the concordance analysis method proposed better alternatives.

*Keywords: concordance analysis, asphalt, rubber powder, carbon fiber, Marshall.*

## 1 INTRODUCTION

In order to improve the pavement performance, different additives have been added to the bitumen and the asphalt mixes [1], [2], [3], [4], [5], [6]. This study has used the rubber powder and carbon fibers to strengthen the asphalt mix. Based on ASTM standard, the asphalt mix with solid granulation was used to prepare the samples. Afterwards, the extra cost, which was caused by adding the additives, was calculated through an economic analysis. Then, six Marshall Parameters were used as six indices in the concordance analysis method, which is a multi-criteria decision-making method. In the following, the literature of the present article and the reasons for conducting this research have been discussed.

- Rubber powder

Nanomaterials, fibrous materials, etc. have been used to strengthen the asphalt mix. Jens Groenniger et al., Amir Tobakovic et al., R. Bharathi Murugan et al. and Zhen Fu et al., have studied the effects of the additive on the concrete and asphalt mixes. The results indicate that the additives improve the properties of the asphalt mixes [7], [8], [9], [10], [11]. Black Nano carbon, Nano-clay and rubber powder are among these types of additives. Zarei, Zahedi, and Salehifard et al., declared that Nanomaterials improve the technical properties of asphalt mixes [12] and [13].

Navaro et al., stated that adding rubber to bitumen in high temperatures improves the resistance to permanent deformation and rating. Increasing the rubber powder, the flexibility of bitumen increases, too. Subsequently, this process results in an increase in the resistance to the thermal cracks [14].

F Xiao and et al., concluded that regardless of the type and size of the rubber powder, adding it to the asphalt mix improves the resistance to asphalt mix rating and also increases its fatigue life and VMA [15].

In their research, F Xiao and et al., argued that the privileged pavement mix designing method and volumetric analyses can be used in asphalt mixes modified with rubber powder. They also found that bitumen optimal value increases by increasing the presence of rubber powder in bitumen [16].

Moghadas Nezhad et al., stated in their research that increasing the percentage of rubber powder in the bitumen, reduces the penetration grade, thermal sensitivity, elasticity, and Fraass breaking point and increases the softening point, elastic recovery and etc. [17].

Kim et al., concluded that the use of rubber powder in asphalt mixes not only increases the viscosity of bitumen and improves the penetration resistance of a mix, but also improves the resistance to permanent deformation at high temperatures and elasticity at lower temperatures [18].

Paje et al., showed that using the bitumen modified with rubber powder in the asphalt mix reduces the noise emitted from the mutual interaction of the tire rubber and the road pavement [19].

- Fibrous materials

Compared with other fibers, Carbon fibers are more suitable for equipping and reforming the specifications of bitumen in asphalt mixes compared with other fibers. Polyester fibers, polypropylene fibers, and carbon fibers are among this type of additive. Zahedi et al. (2017) and Mirbaha et al (2017) declared that fiber materials improve the mechanical properties of asphalt mixes [20] and [21]. Moreover, carbon fibers and the bitumen are made of carbon and hydrocarbon respectively; therefore, these two materials are inherently compatible with each other.

Since carbon fibers are produced at a very high temperature (more than 1000 °C), it is unlikely that the fiber will be melted due to the high mixing temperature required to produce the asphalt mix. Thanks to its high tensile strength, this fiber can play an important role in increasing the tensile strength of asphalt mixes. As it is reported in other studies, increasing the stiffness of the asphalt mix by adding other fibers to it, increases the fatigue life of the asphalt. It may also improve the fatigue life of the asphalt due to the addition of carbon fibers [22].

Abtahi et al., stated that adding fibers increases the Marshall resistance, reduces the flow level, and increases the void spaces in the mix. Results show that carbon fibers have the potential for resisting the structural pavement damages by raising the loadings resulted from the traffic. It also contains an increase in resistance to cracking and permanent deformations [23].

Zahedi and Zarei evaluated the common effect of black Nano carbon and polyester fibers on the technical properties of the asphalt mix. Results showed that the resistance would increase, specific weight would decrease and other parameters of Marshall would change [24].

As it can be observed, the effect of an additive may not be able to meet the requirements of a civil engineer; so this study has tried to evaluate the technical properties of asphalt mix by adding two complementary materials. The effects of rubber powder and carbon fibers on the asphalt mix are evaluated jointly for the first time in the world. That's why this article is considered a new subject in this regard.

- Application of multi-criteria decision making in pavement

As a branch of operations research, Multi-criteria decision-making analysis (MCDA) as a branch of operations research concerns with designing tools for evaluating multiple conflicting criteria in decision making. From that onward, a great variety of multi-criteria decision making methods (MCDM) have been developed to tackle them under different conditions and fields of application [25].

The Multi-Criteria Decision Making (MCDM) methods are divided into two major categories, including Multiple Attribute Decision-making (MADM) and Multiple Objective Decision-making (MODM) as proposed by Hwang and Yoon (1981) [26]. MADM is a tool, which is used to evaluate discrete variables. Moreover, this is a priori process. Specialists participate in the initial stage of the process and then give the weightings of the criteria and evaluate the features of the problem. Ultimately, the best solution or a solution ranking is achieved [27]. The decision maker is allowed to attain a continuous set of solutions regarding two or more criteria, which is called a Pareto front.

A new multi-criteria model was proposed by Jato-Espino et al., which was based on combining several existing decision making tools for choosing the urban pervious pavements [28]. They used the Integrated Value Model for Sustainable Assessments (MIVES) method to develop their approach and then improved it by including some auxiliary complements such as Monte Carlo Simulations, Fuzzy Sets and the AHP method.

## 2 OBJECTIVES

As it can be seen, the effect of an additive on the asphalt may not meet the needs of a civil engineer by its own; therefore, this article tries to study the technical properties of asphalt mix by adding two supplementary materials. Considering the fact that rubber powder improves some asphalt mix properties and effects some results negatively, we attempt to return the properties of the asphalt mix in the appropriate range by adding the second additive to the mix. So, for the first time in the world, the effect of rubber powder and carbon fibers on the asphalt mix was evaluated conjointly which makes this article a novel one. Moreover, considering that different samples in laboratory conditions are developed to evaluate the changes in the properties of the asphalt, this article uses the multi-criteria decision-making method as a tool for selecting an appropriate asphalt mix. It also uses the concordance analysis as a multi-criteria decision-making method to determine an appropriate asphalt mix. The concordance analysis method will help to choose the best alternative by comparing them in pairs and according to the defined indices. The present article employs specialist teams in scoring and weighting.

## 3 METHODOLOGY

This research uses the multi-criteria decision-making method to determine the optimal percentage of the asphalt mix reinforced with rubber powder and carbon fibers. Concordance analysis method, which is a multi-criteria decision-making method, is used to select the appropriate mix.

### *3.1 Experimental*

In this article, rubber powder (in ratios of 5, 10, 15 and 20 percent) and carbon fibers (in ratios of 0.5, 1, 1.5 and 3 percent) are used to strengthen the asphalt mix. Based on ASTM standard, the asphalt mix with solid granulation is used to prepare the samples.

### *3.2 Concordance analysis*

Concordance analysis method which is taken from Giuliano's research, is defined as follows [29]:
Assume that the evaluation of i option should be based on j criterion:

If parameter j is a positive measure and more values is better.

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

If j is a negative value and less values is better.

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

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

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

$r =$ Dimensionless unit (its value is between 1 and 0).

Concordance and Non-Concordance series are as follows:

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

Where, the Concordance set $C_{ii'}$ 'is a set of all criteria where the $i^{th}$ option is better than the i' option on j criteria.

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

Where, the Non-Concordance set $D_{ii'}$ 'is a set of all criteria where the $i^{th}$ option is worse than the i' option on j criteria.

The Concordance index is as follows:

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

Where, $W_j$ is $j^{th}$ criterion weight than other criteria. Therefore:

$$\sum_j W_{ij} = 1 \, , \; 0 \leq c_{ii'} \leq 1 \quad (6)$$

Non-Concordance index is defined as follows:

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

Where,

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

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

The net value of the Concordance index:

$$c_i = \sum_{i \neq i'} c_{ii'} - \sum_{i \neq i'} c_{i'i} \quad (9)$$

$c_i =$ The net value of Concordance index for i option

The net amount of Non-Concordance index:

$$d_i = \sum_{i \neq i'} d_{ii'} - \sum_{i \neq i'} d_{i'i} \quad (10)$$

$d_i =$ The net value of Non-Concordance index for $i^{th}$ option.

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

$$c_i > 0 \; , \; d_i < 0$$

## 4 MATERIAL AND METHOD

### *4.1 Materials*

Materials needed for this research were bitumen, aggregates, rubber powder, and carbon fibers, each explained in the following.

#### *4.1.1 Bitumen*

In order to evaluate the effect of additives on the mechanical properties of the asphalt mix, the asphalt samples made of standard bitumen 85-100 in Kermanshah refinery were used. The aggregates granulation, type and specifications of black Nano-carbon and polyester fibers with high resistance, and the way of producing the asphalt samples will be discussed in the following.

### *4.1.2 The stone materials*

Figure 1 compares the granulation curve of the required weight percentages with granulation used in the preparation of the samples.

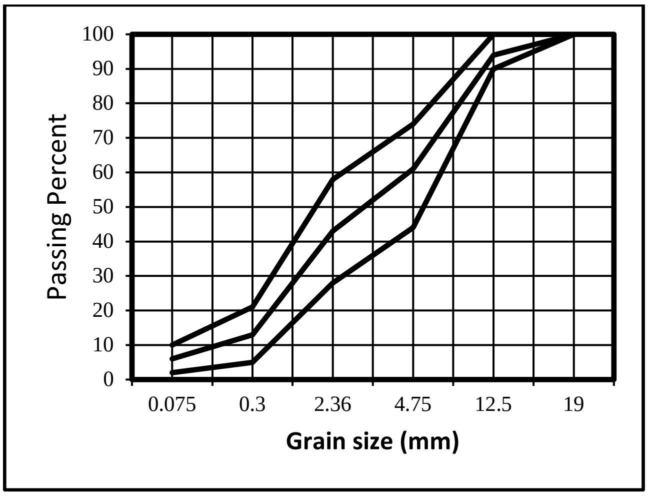


Figure 1. Stone materials granulation of asphaltic mixture of Topeka layer 0-19 mm

### *4.1.3 Consumed rubber powder*

The rubber powder used in this research is produced in Iran. It was added to the mix as a very fine powder.

Table 4. Rubber powder granulation (aggregation)

| Sieve size (mm) | Percent passing |
|---|---|
| 0.063 | 100 |
| pan | 0 |

### *4.1.4 Carbon fibers*

The carbon fibers used in this research were made in America, which was cut by scissors in a length of 10 mm. Table 4 shows the properties of carbon fibers used in the paper.

Table 1. The properties of carbon fibers

| Structure | Density (Gr / cm3) | Elastic modulus (N / mm2) | Tensile strength (N / mm2) |
|---|---|---|---|
| Isotope | 1.5-1.6 | 40000 | 900-1100 |

First, the aggregates are put in a dish after granulation; then the fibers are added in a string form and with high-precision to materials. The obtained complex is put in the oven. Also, the bitumen used in this research is heated up to 150 degrees centigrade and then the black Nano carbon is added slowly to the lubricated bitumen. Finally, the complex is mixed so that it covers the total surface of aggregates.

Figure 2. Obtained mixture of effect of additives

## 5 PERFORMING THE TEST

Construction and designing method of the asphalt mix were performed according to the standard procedure of ASTM-D 1559 [30].

The percentage of fiber additive was 0.5, 1.0, 1.5 and 3 percent, and the percentage of rubber powder additive was 5.0, 10, 15, and 20 wt.% Bitumen.

In Figures 3 to 7, the horizontal axis indicates the various percentages of the additive (for example, 0.5, 5, i.e. 0.5% fibers and 5% rubber powder).

### *5.1Analysis of the results of Marshall Resistance*

As shown in figure 3, joint combination of these two increases their Marshall resistance so that adding 15 percent of rubber powder and 1 percent of fiber obtains resistance equal to 1304. This shows an increase in the resistance which is 56 percent more than the base sample’s. The resistance increases relatively and then decrease in fixed percentages of rubber powder by increasing the carbon fibers. This indicates that the presence of too much fibers results in reducing the resistance since it is placed between the materials and the interlocking reduction.

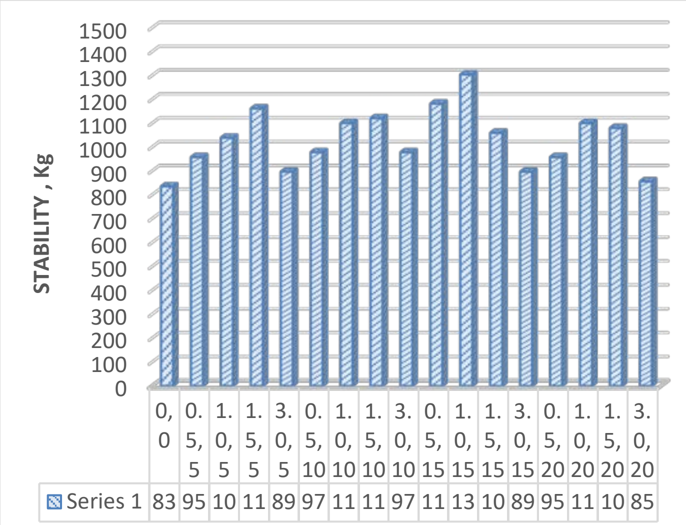


Figure3. effect of different percentages of rubber powder and carbon fibers in common form on the Marshall resistance

### *5.2 Analysis of the flow results of Marshall*

According to the diagram and the obtained results of the tests, the highest amount of flow results in higher percentages of rubber powder and carbon fibers and the lowest flow results in low percentages of these two additives. Results are shown in figure 4.

Due to the high strain resistance of the fibers, increasing the percentage of carbon fiber increases the flow in the fixed ratios of rubber powder.

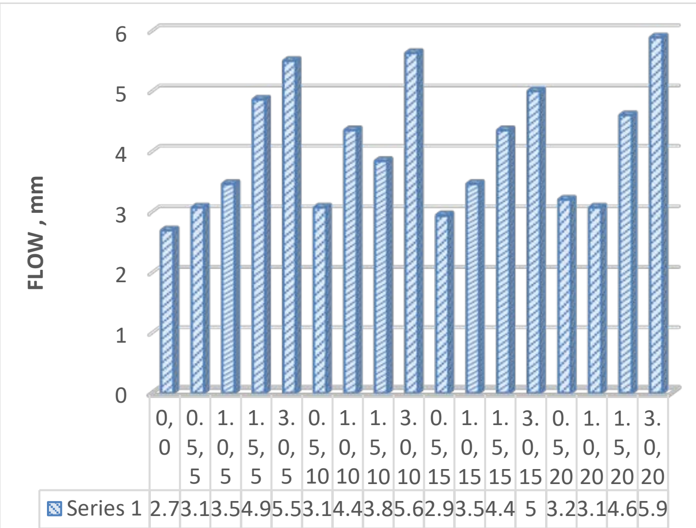


Figure 4. Effect of different percentages of rubber powder and carbon fibers in common form on the flow

### *5.3 Analysis of the results of VTM*

The common effect of these two additives has unbalanced effects in the mix. As in the ratios of 1% fiber and 5% rubber powder, it was observed that compared to the base sample, the total volume of void space in the mix increased up to 87%, (Figure 5). Also, the total volume of the mix increases in fixed percentages of rubber powder (with the exception of 15%) by increasing the percentage of fiber in the mix, which indicates the effectiveness of total volume of the mix of carbon fibers.

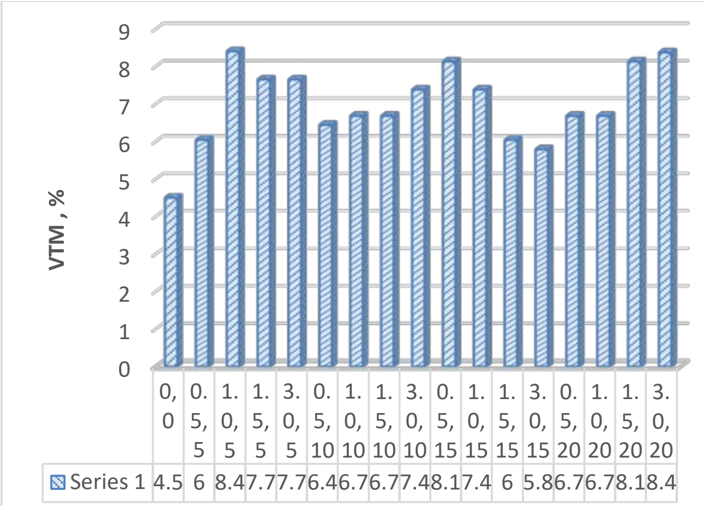


Figure 5. Effect of different percentages of rubber powder and carbon fibers in common form on VTM

### *5.4 Analysis of the results of specific weight*

As it can be observed from the diagram, a decrease in specific weight was observed in all percentages. This can be said to be the result of the low density of carbon fibers.

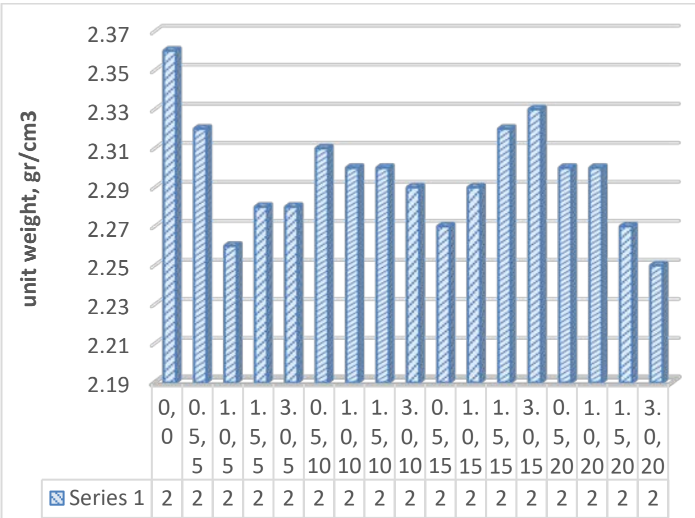


Figure 6. Effect of different percentages of rubber powder and carbon fibers in common form on the specific weight

### *5.5 Analysis of the results of VMA*

The joint effect of these two additives is unbalanced (Figure 7). According to the figure, it is obvious that carbon fibers, due to their technical properties, effects the asphalt mix more than rubber powder. This increases the volume of void space in the aggregates. Procedural requirements have been considered and there is no matter of concern in this regard.

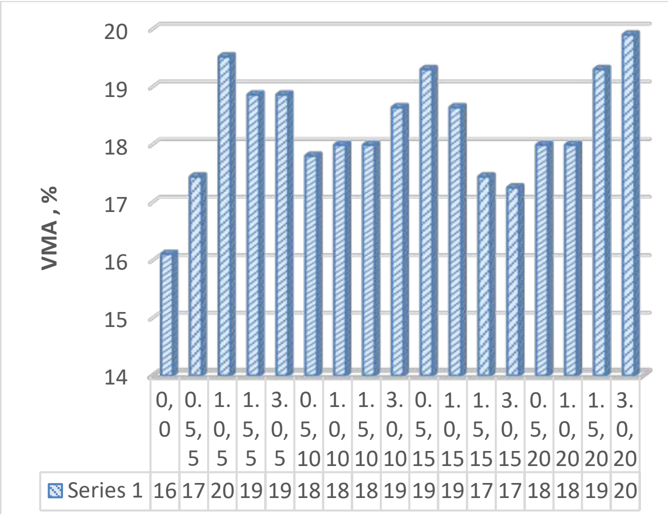


Figure 7. effect of different percentages of rubber powder and carbon fibers in common form on VMA

### *5.6 Analysis of the results of VFA*

According to the results, there will be about 9 percent reduction in 0.5% of fibers and 5% percent of rubber powder (Figure 8).

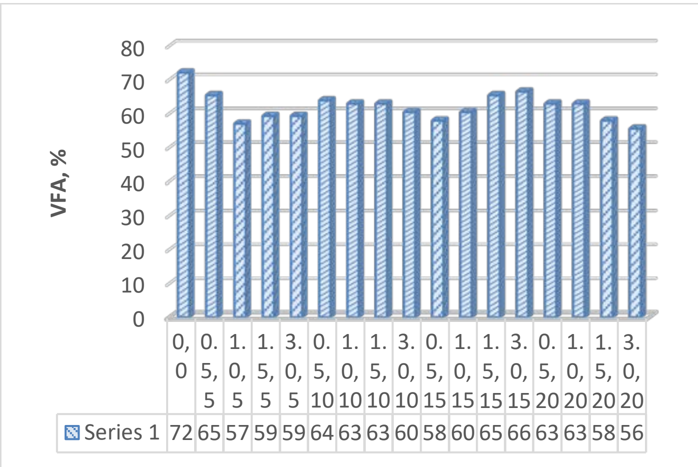


Figure 8. Effect of different percentages of rubber powder and carbon fibers in common form on VFA

## 6 COST ANALYSIS

An economic analysis was carried out to calculate the cost of one kilometer of asphalt [21]. A case study was conducted based on Huang's book [31]. The AASHTO method was used to calculate the structural number (SN) and thickness of the asphalt layer (Di) [32]. The thickness of each asphalt concrete layer can be found from:

$$D_i = \frac{SN_i}{a_1} \qquad (11)$$

It should be noticed that due to the increased resistance, the intended digit cannot be reached by using the above graph. On the other hand, AASHTO standard limits coefficient of a1 to 0.44. But, Timm and Priest (2006) announced in a research that extrapolation can be used in order to determine value of a1. They attributed this value to 0.54 according to figure 12 [33].

Table.2 design result

| %additive | Marshall stability (Pound) | $a_1$ | $D_i$ |
|---|---|---|---|
| 0.0, 0.0 % | 1840.841 | 0.41 | 4.804878 |
| 0.5, 5.0 % | 2112 | 0.445 | 4.426666 |
| 1.0, 5.0 % | 2291 | 0.465 | 4.236559 |
| 1.5, 5.0 % | 2562 | 0.489 | 4.028630 |
| 3.0, 5.0 % | 1976 | 0.425 | 4.635294 |
| 0.5, 10 % | 2156 | 0.448 | 4.397321 |
| 1.0, 10 % | 2425 | 0.480 | 4.104167 |
| 1.5, 10 % | 2469 | 0.481 | 4.104165 |
| 3.0, 10 % | 2156 | 0.448 | 4.397321 |
| 0.5, 15 % | 2606 | 0.491 | 4.012222 |
| 1.0, 15 % | 2875 | 0.511 | 3.855786 |
| 1.5, 15 % | 2336 | 0.467 | 4.218415 |
| 3.0, 15 % | 1978 | 0.425 | 4.635294 |
| 0.5, 20 % | 2112 | 0.446 | 4.417040 |
| 1.0, 20 % | 2425 | 0.480 | 4.104167 |
| 1.5, 20 % | 2381 | 0.468 | 4.209401 |
| 3.0, 20 % | 1887 | 0.415 | 4.746988 |

Here, the costs of adding carbon fiber and rubber powder into the mix of asphalt concrete are evaluated for a 6-line way (each direction 3 lines) for the construction length of one kilometer. Specific weight of asphalt was considered approximately ɣ = 2.3 ton/m3. The prices of each ton of asphalt and rubber powder and carbon fiber (per kg) were considered about 51$, 1$ and 43$, respectively. The cost of adding additives is calculated using the following formula [21], [34] and [35]:

$$\text{Cost}=1000*6*3.65*\frac{D_i*2.54}{100}*\ ɣ\ *1000*\text{additive percent}*\text{carbon fiber price} \qquad (12)$$

$$\text{Cost}=1000*6*3.65*\frac{D_i*2.54}{100}*\ ɣ\ *1000*\frac{63}{1000}*\text{additive percent}*\text{rubber powder price} \qquad (13)$$

Table3. Economical Result

| additive % | Cost |
|---|---|
| 0,0 % | 0 |
| 0.5,5 % | 1130628.095 |
| 1,5 % | 2071944.732 |
| 1.5,5 % | 3033345.134 |
| 3,5 % | 6114849.724 |
| 0.5,10 % | 1052707.424 |
| 1,10 % | 2071193.709 |

| | |
|---|---|
| 1.5,10 % | 3089679.994 |
| 3,10 % | 6198574.839 |
| 0.5,15 % | 1045043.261 |
| 1,15 % | 2074889.048 |
| 1.5,15 % | 2719907.211 |
| 3,15 % | 6175558.813 |
| 0.5,20 % | 1146215.576 |
| 1,20 % | 2078537.212 |
| 1.5,20 % | 3535341.771 |
| 3,20 % | 7027507.438 |

## 7 CONCORDANCE ANALYSIS

### 7.1 Weighting system

The present article employs specialist teams in scoring and weighting. In this study, 6 weighting systems presented in Table (4) are considered. As it can be observed, the weight of all criteria is considered as equal in one of the weighing systems. In seven other weighing systems, the resistance and the price of asphalt mix is heavier than other criteria due to the extraordinary importance.

Table 4. Weighting to criterions (According to expert opinion)

| Weights | stability | Unite weight | flow | VTM | VMA | VFA |
|---|---|---|---|---|---|---|
| W1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 |
| W2 | 0.5 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| W3 | 0.6 | 0.0625 | 0.15 | 0.0625 | 0.0625 | 0.0625 |
| W4 | 0.6 | 0.15 | 0.0625 | 0.0625 | 0.0625 | 0.0625 |
| W5 | 0.6 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| W6 | 0.16 667 | 0.16 667 | 0.16 667 | 0.16 667 | 0.16 667 | 0.16 667 |

### 7.2 Normalizing data

Normalization of various criteria with better maximum and/or minimum value was done as in section 2.2. However, for some criteria limited at intervals by regulations, the middle of the interval is considered to have the maximum value equal to one. This number decreases as we take distance from the middle of the interval.

It is assumed that the regulation interval is (p,q), and for a particular criterion, the resulting numbers are max and min. The middle of the interval is defined as follows:

$$F = \frac{p+q}{2} \tag{14}$$

Also,

$\alpha = \max P_{ij}$

$\beta = \min P_{ij}$

$P_{ij}$ = Raw data (Marshall Results and cost)

Therefore, normalization for the volume of the total asphalt mix, flow, and void filled with asphalt criteria (which are in the interval) are performed as follows:

$$\begin{cases} r_{ij} = \frac{F-\alpha+P_{ij}-F}{F-\alpha} & \text{for } P_{ij} \geq F \\ r_{ij} = \frac{P_{ij}-F+\alpha}{\alpha} & \text{for } P_{ij} \leq F \end{cases}$$

(15)

### 7.3 Results and discussion

As seen in the table below, the alternatives 2, 3, 4, 7 and 15 compared with the first alternative (do noting) have participated in all 6 weight designs, and are in priority. Also, the alternatives 3 along with the first alternative (do noting) have participated in five weight plans and this alternative can be used instead of the first alternative (do noting). Other alternatives have the lowest repetition in different weight plans due to the high prices and the technical properties, so they are not able to compete with other alternatives. The following table shows the results of the concordance analysis method.

Table 5. Competitive options set for superior asphalt mixtures

| | Alternative | W1 | W2 | W3 | W4 | W5 | W6 | total |
|---|---|---|---|---|---|---|---|---|
| 1 | 0, 0 (base)% | 1 | 0 | 0 | 0 | 0 | 1 | 2 |
| 2 | 0.5, 5.0 % | 1 | 1 | 1 | 1 | 1 | 1 | 6 |
| 3 | 1.0, 5.0 % | 1 | 1 | 1 | 0 | 1 | 1 | 5 |
| 4 | 1.5, 5.0 % | 0 | 0 | 1 | 1 | 1 | 1 | 4 |
| 5 | 3.0, 5.0 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0.5, 10 % | 0 | 0 | 1 | 1 | 1 | 0 | 3 |
| 7 | 1.0, 10 % | 1 | 1 | 0 | 0 | 1 | 1 | 4 |
| 8 | 1.5, 10 % | 1 | 1 | 0 | 1 | 0 | 0 | 3 |
| 9 | 3.0, 10 % | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0.5, 15 % | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 11 | 1.0, 15 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 1.5, 15 % | 1 | 1 | 0 | 0 | 0 | 0 | 2 |
| 13 | 3.0, 15 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0.5, 20 % | 0 | 0 | 0 | 1 | 1 | 0 | 2 |
| 15 | 1.0, 20 % | 1 | 1 | 0 | 1 | 1 | 0 | 4 |
| 16 | 1.5, 20 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 3.0, 20 % | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

The results analysis of paragraph 2.2 is presented in Table 6 based on the Giuliano method. According to this table, the second alternative has a lower average than the first alternative (do noting) and it is a priority. Also, after the first one (do noting), alternatives 3, 4, 7 and 15 had the lowest average and these four alternatives can be used instead of the first one (do noting) due to the technical problems and in the absence of the economic problem. The other alternatives had a high average due to the high prices and/or because of the technical properties and so they are deprived from competing with other alternatives. The following table shows the results of the concordance analysis method ranking.

Table 6. Average rank based on Giuliano method

| | alternative | w1 | w2 | w3 | w4 | w5 | w6 | Average rank |
|---|---|---|---|---|---|---|---|---|
| **1** | 0, 0 (base)% | 1 | 4.5 | 5.5 | 6 | 7 | 1.5 | 3.1875 |
| **2** | 0.5, 5.0 % | 2.5 | 1 | 1.5 | 1.5 | 1.5 | 1.5 | 1.1875 |
| **3** | 1.0, 5.0 % | 8 | 3 | 4 | 6.5 | 5.5 | 4.5 | 3.9375 |
| **4** | 1.5, 5.0 % | 11 | 9.5 | 2.5 | 3.5 | 3.5 | 5.5 | 4.4375 |
| **5** | 3.0, 5.0 % | 14 | 7.5 | 13 | 13 | 154.5 | 11.5 | 9.3125 |
| **6** | 0.5, 10 % | 12.5 | 13.5 | 6 | 5 | 5.5 | 6.5 | 6.125 |
| **7** | 1.0, 10 % | 2.5 | 3 | 8.5 | 8.5 | 5 | 4.5 | 4.0 |
| **8** | 1.5, 10 % | 4.5 | 6.5 | 8.5 | 8.8 | 5 | 4.5 | 5.1875 |
| **9** | 3.0, 10 % | 7 | 7.5 | 14 | 13 | 10.5 | 13 | 8.125 |
| **10** | 0.5, 15 % | 11 | 15 | 6 | 8 | 11 | 12 | 7.875 |
| **11** | 1.0, 15 % | 15 | 13.5 | 10.5 | 11 | 10.5 | 15 | 9.4375 |
| **12** | 1.5, 15 % | 5.5 | 7 | 9.5 | 12 | 10.5 | 8 | 6.5625 |
| **13** | 3.0, 15 % | 11 | 13.5 | 11 | 10 | 12 | 9 | 8.3125 |
| **14** | 0.5, 20 % | 10.5 | 8 | 13 | 10 | 9.5 | 12.5 | 7.9375 |
| **15** | 1.0, 20 % | 5.5 | 9 | 9 | 8.5 | 5 | 9 | 5.75 |
| **16** | 1.5, 20 % | 14.5 | 14 | 14 | 13.5 | 14 | 16 | 10.75 |
| **17** | 3.0, 20 % | 17 | 17 | 16.5 | 16.5 | 17 | 17 | 12.625 |

Finally, according to Tables 5 and 6, the results of the final ranking and the appropriate asphalt mix for all of the various parameters are given in Table 7.

Table 7. Final results and ranking of superior options

| rank | alternative | percent of polyester fiber in the mixtures | total | Average rank |
|---|---|---|---|---|
| 1 | 2 | Mixture with 0.5% replacement carbon fiber and 5% of the bitumen weight of rubber powder | 6 | 1 |
| 2 | 1 | The mixture without additives | 5 | 2 |
| 3 | 3 | Mixture with 1% replacement carbon fiber and 5% of the bitumen weight of rubber powder | 4 | 3 |
| 4 | 7 | Mixture with 1% replacement carbon fiber and 10% of the bitumen weight of rubber powder | 4 | 4 |
| 5 | 4 | Mixture with 1.5% replacement carbon fiber and 5% of the bitumen weight of rubber powder | 4 | 5 |
| 6 | 15 | Mixture with 1% replacement carbon fiber and 20% of the bitumen weight of rubber powder | 4 | 7 |

## 8 CONCLOSION

This is a new research in the world in the sense that carbon fibers and rubber powder are used jointly as a string; consequently, the results of tests need more reflection and deduction. But, the positive and acceptable effects on the results of Marshall are more obvious. The summary of the results is as follows:

Marshall Resistance increase in combination of two additives so that resistance equal to 1304 and 1182 kg has been recorded in the case of adding 1% carbon fibers and 15% rubber powder and then 0.5% fiber and 15% rubber powder. It shows that resistance has increased 56% and 42% compared to the control sample.

Flow increased relatively.

It seems that carbon fibers have a more highlighted role than rubber powder in the mix due to the increase in VTM in this section.

Specific weight of mix decreased due to the mix being affected by the presence of the carbon fibers.

It seems that carbon fibers have a more highlighted role than rubber powder in the mix due to the increase in VMA in this section.

Loss of the percentage of void spaces filled with asphalt completely was clear.

For the first time, the present study examines the simultaneous effect of two additives, the results of which were expressed separately. This research uses the concordance analysis method, for the first time, for ranking and consequently obtaining an appropriate asphalt mix. The concordance analysis method reduces the effect of weighting error with the possibility of involving different weight combinations in calculations. As it was stated in the previous section, the alternatives 2, 3, 4, 7, and 15 have priority over the first alternative (do noting) in all participated 6 weight plans. Moreover, the alternative 2 has a lower average score than the first alternative (do noting) and the alternatives 3, 4, 7, 8 and 15 were ranked 3, 4, 5, 6 and 7. Comparing the results obtained from both methods, the alternative 2 is better than the first alternative (do noting), and the alternatives 10 and 1 are ranked second and third due to better technical properties.

According to the results, adding 15% of rubber powder and 0.5% of fibers (for cost-effective reasons) effects the mix in the best possible way provided that this method is not used, different alternatives are evaluated and compared, and all of the alternatives can be used.

Thus, as it can be observed, the use of the method outlined in the present study suggests some alternatives that differ from the second one, which clearly demonstrates the superiority of using this method.

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