Scientific Journal of Silesian University of Technology. Series Transport
Zeszyty Naukowe Politechniki Śląskiej. Seria Transport

Volume 119 **2023**

p-ISSN: 0209-3324

e-ISSN: 2450-1549

DOI: https://doi.org/10.20858/sjsutst.2023.119.2

Journal homepage: http://sjsutst.polsl.pl

Article citation information:
Khabiri, M.M., Ghafori Fard, Z., Nik Farjam, H. Investigation of the parameters of the effective mixing design on bleeding asphalt and reducing the drivers' safety in right lane of tropical roads. *Scientific Journal of Silesian University of Technology. Series Transport*. 2023, **119**, 19-35. ISSN: 0209-3324. DOI: https://doi.org/10.20858/sjsutst.2023.119.2.

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INVESTIGATION OF THE PARAMETERS OF THE EFFECTIVE MIXING DESIGN ON BLEEDING ASPHALT AND REDUCING THE DRIVERS' SAFETY IN RIGHT LANE OF TROPICAL ROADS

Summary. Distresses are integral parts of pavement that occur during the life of the road. Bitumen distress is known as one of the most important problems of Iran's roads, especially in tropical areas and transit routes with heavy axes; so, identifying the effective factors in creating the bleeding phenomenon is very necessary and important. Therefore, this study was conducted to investigate the parameters of the mixing design in creation of bleeding phenomenon and its severity. The collected data were then analyzed and grouped using Design Expert and SPSS software. The results show that all five parameters of optimal bitumen percent, bitumen percent in asphalt mixture, void percent of Marshall Sample, percent void and filler to bitumen ratio are effective on bitumen and its intensity. Among the mentioned parameters, two parameters of percent of bitumen compared to asphalt mixture and the void percent in the Marshall sample have a greater effect on the severity of the bleeding phenomenon.

Keywords: bleeding, data mining, right lane, tropical regions, mixing design parameters, safety

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1. INTRODUCTION

Road accidents are undesirable and unavoidable events that lead to the loss of capital and human life. On the other hand, the high cost of traffic accidents has made investigating factors affecting safety and ways to increase it to be one of the most important goals of pavement engineers; because the conditions of the pavement and its damage have a significant impact on causing accidents and as a result road safety [1].

On the other hand, the quality of the works and the proper mixing design will play a significant role in increasing the productivity of the roads, reducing periodic costs and increasing the lifespan of the operation. Because if the pavement is not planned and executed in a principled and correct way, the road will not withstand the weather factors and the traffic of cars, and it will quickly be deteriorated, which leads to the depreciation of the initial investment and the wastage of national budgets [2-4]. In addition, the deterioration of the pavement will increase other costs, such as the cost of restoration and improvement, as well as the increase of indirect costs imposed on road users due to the bad pavement. Pavement failures have also a significant impact on road accidents and road safety [5-7]. Therefore, it can be said that knowing and predicting possible failures and using methods in the mixing design to prevent it from happening can be very cost-effective and useful in ensuring road safety and also in the final cost of road construction [8].

Bituminous bleeding is the formation of a thin layer of bituminous material on the surface of the pavement surface, which results in a shiny, glassy and reflective surface. The main cause of bitumen bleeding, which always occurs in hot weather and under the influence of heavy vehicles, is the presence of an excessive amount of bitumen in the asphalt mixture [9, 10]. In general, in various researches that have been carried out on the deterioration of bleeding and also the organizations that are responsible for the maintenance of roads, the basic mechanism related to the deterioration of bitumen has been found to be due to the presence of excess bitumen in the cavities between the particles of stone materials [11].

Bleeding, as one of the most important pavement failures in tropical regions, is one of the factors of reducing safety and increasing accidents, especially in rainy conditions, which causes countless problems on the roads. Among these problems can be reduced ride quality for users, reduced road safety and reduced slip resistance, creating a shiny and glass-like and slippery surface especially in rainy seasons, progressive deterioration of the road structure due to the change of mixing in bituminous areas and the increase in road repair and maintenance costs [12, 13]. Therefore, investigating and dealing with bitumen bleeding, and its causes becomes especially important.

2. LITERATURE REVIEW

As mentioned, bleeding is one of the most important failures of asphalt pavement that occurs in tropical regions and transit roads with heavy traffic load and has a significant impact on pavement safety. Therefore, so far, many researches have been done in the field of asphalt damage, including bleeding. Among these researches, we can mention Sarvari's research. He stated that bleeding is one of the most important problems and breakdowns of the roads of the country and Khuzestan province, especially in the axes with heavy transit load, which strongly affects the safety of the roads, identified the causes of bleeding in the axes of Khuzestan province. In this research, sampling was done from bleeding areas and non-bleeding areas adjacent to the bleeding areas from different axes. Then, by collecting quality control information and using the results of the tests conducted on bleeding and non-bleeding samples, the possible causes of bleeding in the axes were determined. According to the results of this research, in general, the factors causing tarnishing can be divided into three groups: operational factors, theoretical factors, and environmental factors [12].

Also in 2018, Pouranian and Haddock, in a study investigated the analytical-experimental mechanism of bleeding in asphalt mixtures. This research is based on the distribution of air voids in asphalt mixtures, and the distribution of voids was obtained using CT scan and analysis of the resulting images before and after loading. The experiments conducted in this research are in two main parts. In the first part, the preliminary tests were conducted based on the bitumen extraction test that was performed according to the ASTM-D2172 standard, which includes sample making, impact load test, static load and bitumen extraction test. In the second part, the tests were performed based on image analysis. After making the samples and their initial CT scan, the dynamic loading test was performed by using UTM 5 kn machine, under temperature conditions of 5, 25, 40 and 60 degrees Celsius. The results of this research show that the asphalt mixture under loading with lower frequency has more strain and less air percent. In fact, the pavements under slow traffic of heavy trucks are more susceptible to bleeding damage due to the reduction of air voids in the asphalt mixture [14]. In a study, Izdiar and Mohammadzadeh Pudineh also investigated the effective factors in causing bleeding in the Karaj asphalt project, stating that bleeding is one of the most common failures of asphalt pavements. According to the results of this research, non-observance of the proper conditions of bituminous coating on the scraped surface and the heat of the air are the most important reasons for bleeding in the asphalt project of Karaj city [15].

Although many studies have been conducted in the field of bleeding, but few studies have been conducted regarding the presentation of a mathematical model to predict the amount of damage with the information of the asphalt mixing design. This is despite the fact that the presentation of the mathematical model for checking failures has been examined in many researches. Among these researches, we can mention the research of Anderson, Christensen, and Bonaquist (2003), who presented a model for asphalt rutting. They stated that rutting is one of the most important failures of flexible coatings that require a significant amount of maintenance, and presented a mathematical model to estimate the depth of the wheel rut. This model is validated using ANN and GA and enables the evaluation of rutting during the preparation of samples in the laboratory [16].

In another research, Wang et al. in 2018 presented a 3D finite element program capable of analyzing loads in real weather conditions; this model uses the simple viscoelastic damage model (S-VECD) to predict the fatigue life of asphalt pavement [17]. Also, Hu and Qian investigated the failure prediction between the adhesion of aggregates and asphalt mastic based on aggregate characteristics. They emphasized that the separation of the interface between aggregates and asphalt mastic reduces the strength of the asphalt mixture and causes failures such as cracks and grooves in the asphalt coating. This study was conducted with the aim of quantifying the effect of aggregate on the relationships and developing a method to predict the reduction of adhesion between aggregates and asphalt mastic. At first, the microstructural models of aggregate particles were reconstructed based on computerized images (CT), and then the overall characteristics and energy consumption during failure were determined by digital image processing and numerical simulation, respectively. Dissipative degradation energy (DDE) quantified the adhesion loss and a method using artificial neural network was developed to provide the relationship between DDE and asphalt properties. The results show that the effect of aggregate on asphalt deterioration can be evaluated by several parameters of aggregate properties [18].

In addition, Moghaddas Nejad and Mohiuddin investigated the mechanism of moisture failure in asphalt mixtures using thermodynamic parameters and mixing design. They say that moisture failure in asphalt mixtures is defined as the loss of strength and durability caused by the presence of water; they presented a model for predicting humidity sensitivity using thermodynamic parameters and mixing scheme. Based on the presented model, it can be said that the parameters of the free energy of cohesion, the free energy of bitumen-aggregate adhesion in dry conditions, the ability to cover aggregate by bitumen, the specific surface area of aggregates and the apparent thickness of the bitumen membrane on the aggregate surface directly and the released energy of the system during the bare event becoming, the percent of saturation and the permeability of the asphalt mixture have a significant effect on the resistance of the asphalt mixture against moisture damage [8]. In 2021, Sun et al. conducted a study in this regard. They developed a deformation prediction model by analyzing the effective factors, fitting the model parameters and validating the model. The results of this research show that this model can accurately express the contact sliding characteristics of aggregates and predict the permanent deformation which is mainly caused by the sliding deformation of aggregate particles, and it can be divided into three stages of rapid growth, fluctuation and stability [19].

Also, in 2021, Majidi Fard et al. presented a model for predicting the depth of rutting of asphalt mixture using programming. This study presents a new model for predicting the deterioration depth of asphalt mixtures using a machine learning technique called gene expression programming (GEP) which is formulated based on typical influencing variables such as bitumen high temperature (PG), mixture type, aggregate size, aggregate grading, asphalt content and total recycled asphalt content. The accuracy of the model was evaluated through a rigorous validation process. It should be noted that this model is recommended for pre-design purposes or as a tool for determining rut depth in asphalt mixtures [20]. Finally, in 2013, in a research, Saad investigated the presentation of a mathematical model for predicting the level of bituminization in tropical axes. He emphasized that the prediction of asphalt bleeding is one of the most important issues in road construction engineering, especially in tropical regions, and determining and predicting the tarnishing model in asphalt concrete makes it easier to understand the pavement failure mechanism and helps to design more economical and resistant roads. In this research, an index based on the changes in the thickness of the bitumen membrane during the construction, operation and maintenance period has been discussed in order to estimate and predict bleeding in the pavement. For this purpose, in this study, it is possible to predict the behavior of asphalt mixture against the amount of bitumen used, gradding, ratio of filler to effective bitumen, weather and traffic. The research was conducted in three stages. Firstly, using ARC-GIS software, Khuzestan province was divided into four climatic zones and finally six axes: Serahi Haft Gol-Ahvaz, Hamidiyeh-Ahvaz, Bagh Malek-Izeh, Ahvaz-Shush, Haft Gol-Bagh Malek and Abadan-Darkhoin were selected for sampling. Secondly, after determining the axes, sampling was done from the points in the bleeding and non-bleeding range. In this regard, in order to use the presented index, by collecting information from the archives of the Road and Transport Department, the status of the initial mixing design of the sampling site was examined. In the third stage, using the adaptive neuro fuzzy inference system (ANFIS), bleeding was estimated. Paying careful attention to the results of this modeling, it is determined that with the reduction of the ratio of filler to effective bitumen, due to the increase of plasticity of the asphalt mixture, the bleeding index increases. It was also observed that traffic and temperature at a depth of 2 cm from the surface of the pavement have an in-phase effect on the changes of bitumen membrane in asphalt mixture [21].

Also, in the field of detecting and determining the amount of bleeding with the help of image processing, Ranjbar et al. conducted research under the title of an image-based system for bleeding pavement inspection. This program includes three main parts of detecting the occurrence of bleeding, dividing the area of bleeding and classifying areas of bleeding according to severity. To implement the proposed system, the model based on deep learning and transfer method in the detection section and wavelet transform is the main process in the segmentation section. Then, a decision tree is built based on the extracted features for intensity-based classification. The proposed system can show the index of bleeding based on the density and severity of distress. The results show that in the sections of diagnosis, division and classification based on severity, the average performance indicators perform well with 98, 89 and 93%, respectively [22].

As mentioned, limited studies have been presented regarding the numerical investigation and presentation of the mathematical model of bitumen; therefore, the aim of this research is to investigate the effect of mixing design parameters on the phenomenon of bleeding and predicting it with the help of mixing design parameters and presenting its mathematical model.

3. RESEARCH METHODOLOGY

Ever since the aim of this research is to investigate the effect of mixing design parameters on bleeding and its severity and to provide a mathematical model to predict the phenomenon of bleeding and its severity, the first step involved extracting the parameters of the mixing design of the desired axes were extracted from the laboratory sheets and also, the removal of bleeding damage was done in the field from the same axes. Then Design Export and SPSS software were used to analyze the collected data. Fig.1 briefly shows the method and steps of conducting the research. It should be noted that in this research, bleeding in Bafq-Yazd axes, Yazd ring road in Yazd province and three projects of industrial town, landscaping of Nain industrial town, implementation of entrance and exit of Najafabad industrial town and bleeding of roads in Kuhpayeh industrial town were evaluated.

3.1. Preparation of laboratory sheets and determination of effective parameters in bleeding failure

The laboratory sheets of the selected axes were prepared to check the parameters of the mixing design and then according to the previous research, the parameters of the optimal bitumen percent, the percent of bitumen compared to the asphalt mixture, the percent of void of the Marshall sample, the volume percent of the void of stone materials and the ratio of filler to bitumen as effective parameters were chosen due to the deterioration of bleeding.

3.2. Field sampling

In order to determine the amount of bleeding and its intensity, a field sampling of the selected routes was done. Also, in order to determine the severity of the damage, experienced and successful experts were also interviewed in the field of bleeding. The images in Fig. 2 are samples of bleeding of selected routes.

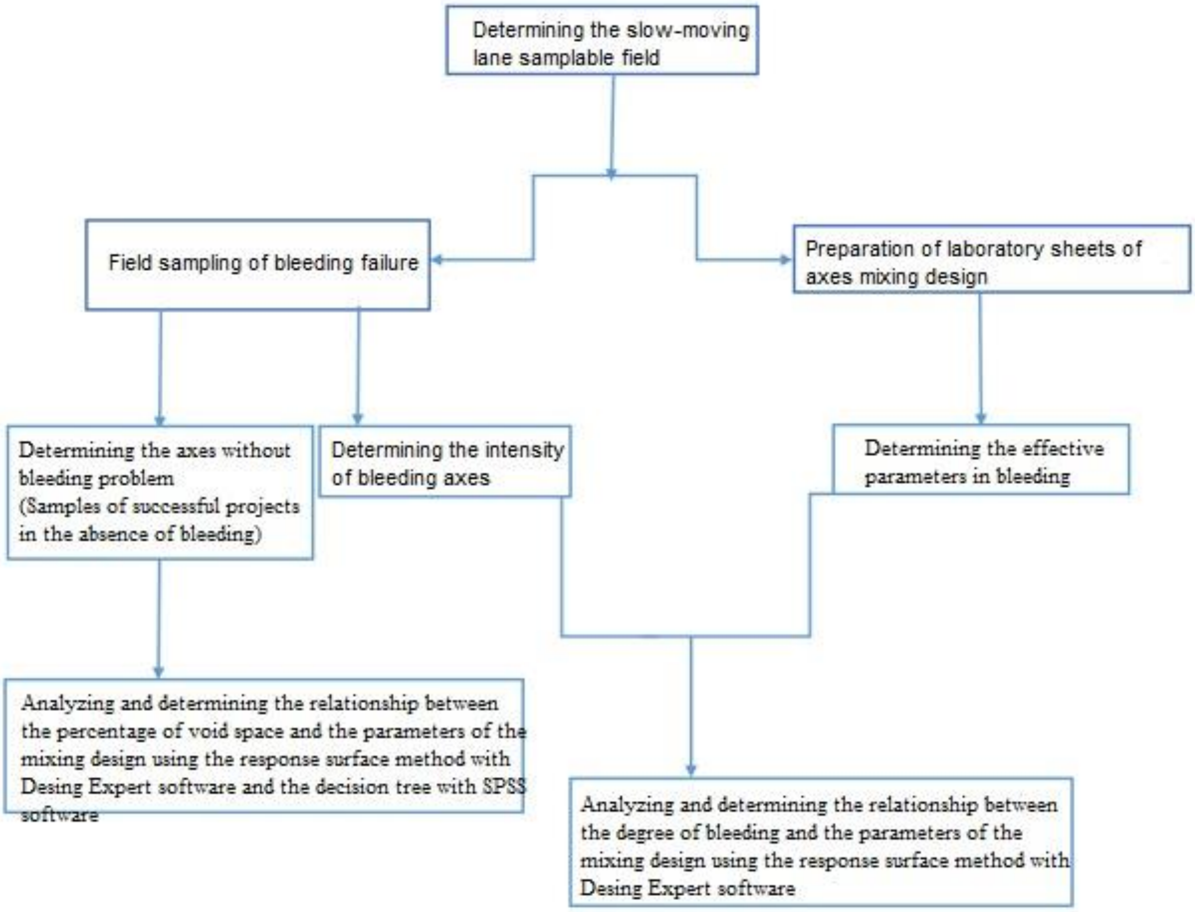


Fig. 1. Flowchart of the research process

(A)

(B)

Fig. 2. The examples of the removal of bleeding from the Bafaq-Yazd axes (A), and Yazd ring road bleeding removal (B)

3.3. Determining the relationship between the amount of bleeding and the parameters of the mixing design using the response surface method and Design Expert software

The response surface methodology or abbreviated RSM, which was introduced in 1951 by Box and Wilson, is a set of statistical methods and applied mathematics for constructing experimental models. The purpose of this method is to optimize the response (output variable) that is affected by several independent variables (input variables) and in each experiment, changes in the input variables are made in order to determine the causes of changes in the response variable [23].

In this research, the response surface method was used to determine the relationship between the amount of bleeding and the parameters of the mixing design. For this purpose, Design Expert software was used to perform statistical analysis and provide a mathematical model between independent and dependent parameters. The independent variables include optimal bitumen percent, bitumen percent compared to asphalt mixture, Marshall sample void percent, volume percent of void of stone materials and the ratio of filler to bitumen and dependent variables or the response of the bleeding area of the road were considered.

3.4. Analyzing the effect of the parameters of the mixing design on the void percent with data grouping in SPSS software

SPSS is the name of a computer software, the first version of which was designed and published by "Norman Nie" in 1968, and is widely used for statistical analysis. One of the important and practical features of this software is decision tree drawing. Decision trees are a powerful and popular tool used for both classification and prediction. In fact, the decision tree is a method that uses a series of special algorithms to classify data into separate categories in the form of a tree [24-26]. In this research, Design Expert and SPSS software were used to analyze the effects of the mixing design parameters on the percent of void and to draw a decision tree in order to examine the projects in which there was no bleeding and the parameter of void percent was considered as a dependent variable and the parameters of bitumen percent compared to asphalt mixture, optimal bitumen percent, void percent of stone materials (VMA), the ratio of weight percent of filler to weight percent of bitumen were considered as independent parameters.

4. RESEARCH RESULT AND DISCUSSIONS

4.1. The parameters of the effective mixing design in bleeding damage

In Fig. 3 and Fig. 4, the average parameters of the void percent of asphalt, the void percent of stone materials, the percent of bitumen used in the asphalt mixture and the ratio of filler to bitumen of Bafq-Yazd axes, Yazd ring road in Yazd province and three projects of the landscaping of the industrial town of Nain industrial town, the implementation of the entrance and exit of Najafabad industrial town and the asphalt of the roads of Kohpayeh industrial town are given. It should be noted that the average percent of optimal bitumen in these projects is 1.4. It should be noted that no bleeding was observed in the three projects of the industrial town.

4.2. Determining the relationship between the amount of bleeding and the parameters of the mixing design using the response surface method and Design Expert software

The changes in the amount of bleeding are presented in Figure 5. It should be noted that the definition of bleeding in this software is given according to Table 1.

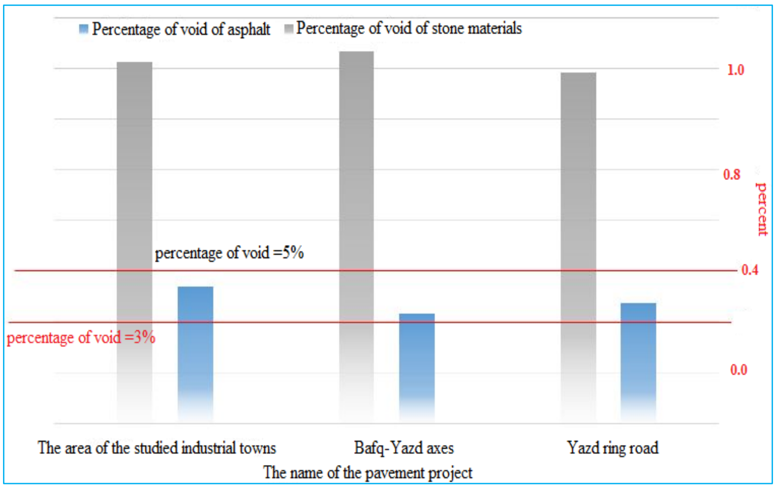


Fig. 3. The average void percent of asphalt and void percent of stone materials of the investigated projects

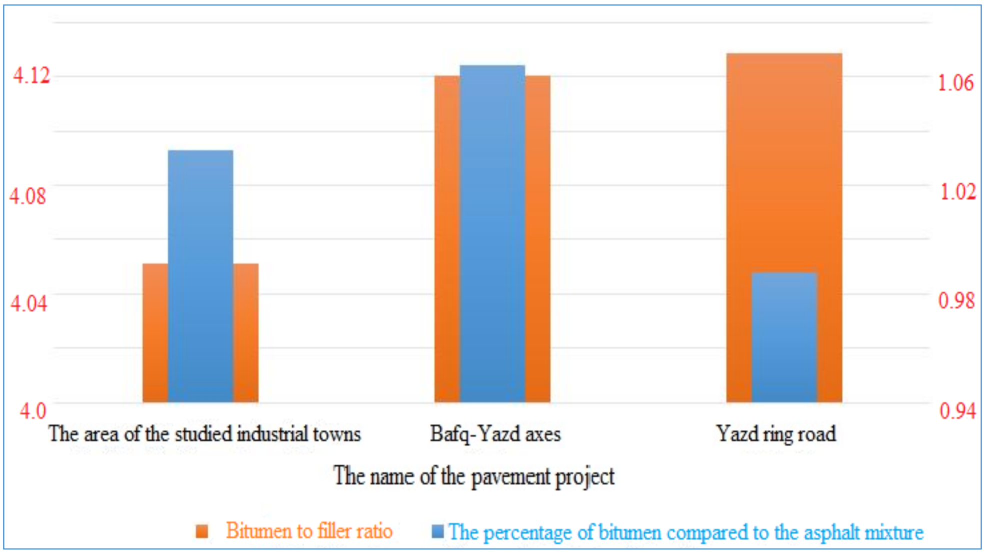


Fig. 4. The average percent of bitumen in asphalt and the ratio of bitumen to filler in the studied projects

Tab. 1
Displaying the amount of bleeding in Design Expert software

Display in Design Expert software	Bleeding intensity
0	No bleeding
1	Little bleeding
2	Moderate bleeding
3	Severe bleeding

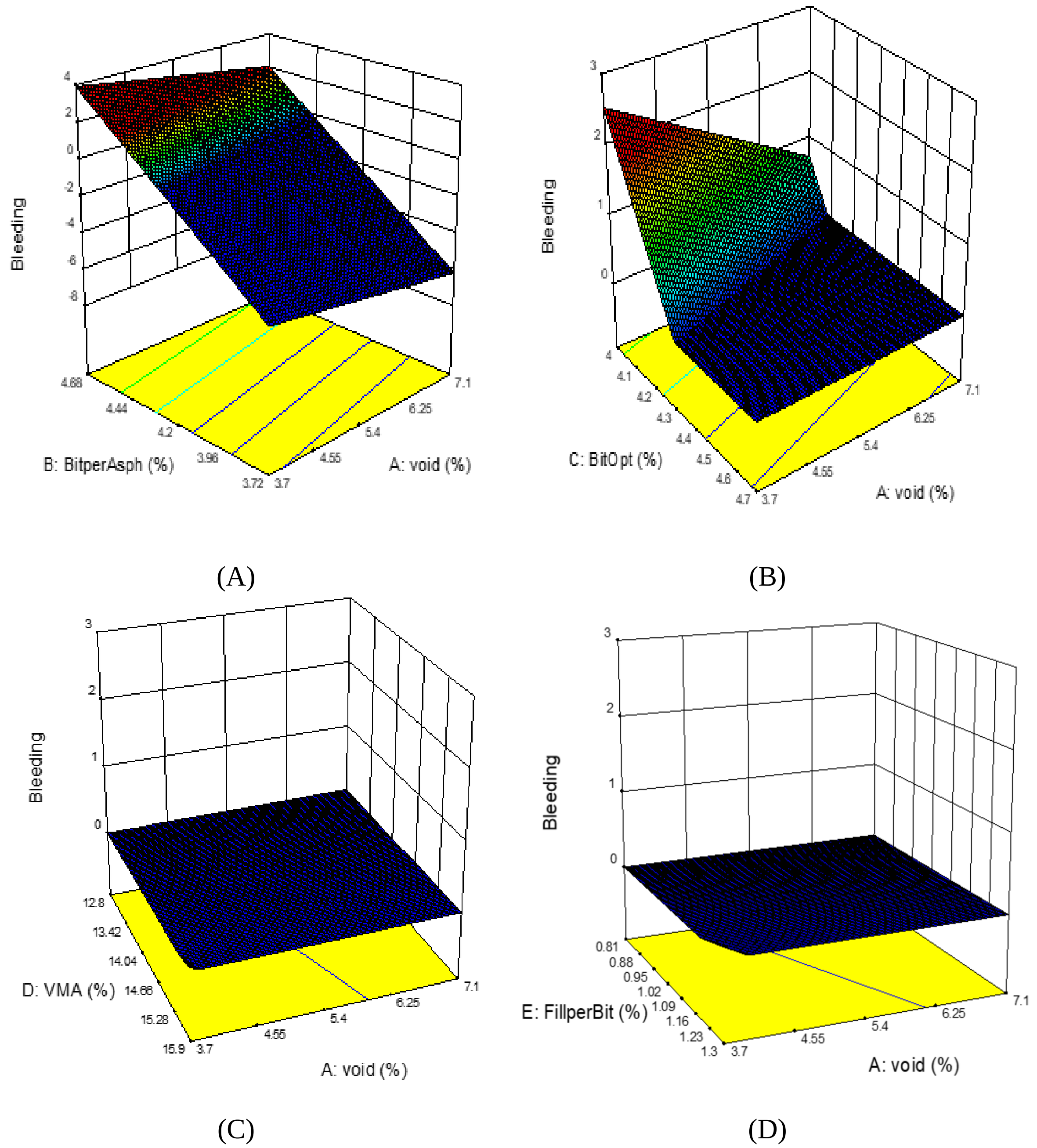


Fig. 5. Diagrams of the effect of the void percent and the ratio of bitumen to asphalt mixture on the bleeding level of Bafq-Yazd axes (A), the effect of the void percent and the percent of optimal bitumen on the Bafq-Yazd axes (B), the effect of the void percent and the void percent of stone materials in Bafq-Yazd axes (C), the effect of the void percent and the weight percent of filler on the weight percent of the bitumen of the Bafq-Yazd axes (D)

As can be seen from the diagrams in Figures 6 and 7, the ratio parameter of bitumen to asphalt mixture is the most effective factor in the amount of bleeding; in fact, it can be said that the amount of bitumen in the asphalt mixture, which is also effective on the void percent in the asphalt mixture, is the determining factor for the amount of bleeding; so, the more the amount of bitumen in the asphalt mixture is higher than the optimal bitumen amount, the more likely it is to cause bleeding. Of course, this does not mean that other parameters do not have an effect on the amount of bleeding, because as it is clear from the diagrams, the probability of bleeding and its intensity increases with the decrease of the void percent of asphalt mixture and the void percent of stone materials; however, according to the diagrams, with the increase in the ratio of the weight percent of filler to the weight percent of bitumen, due to the increase in the amount of filler and as a result, the decrease in the void percent stone void, the probability of bleeding and its severity increases, which is consistent with the results of the research of Brown et al. [27].

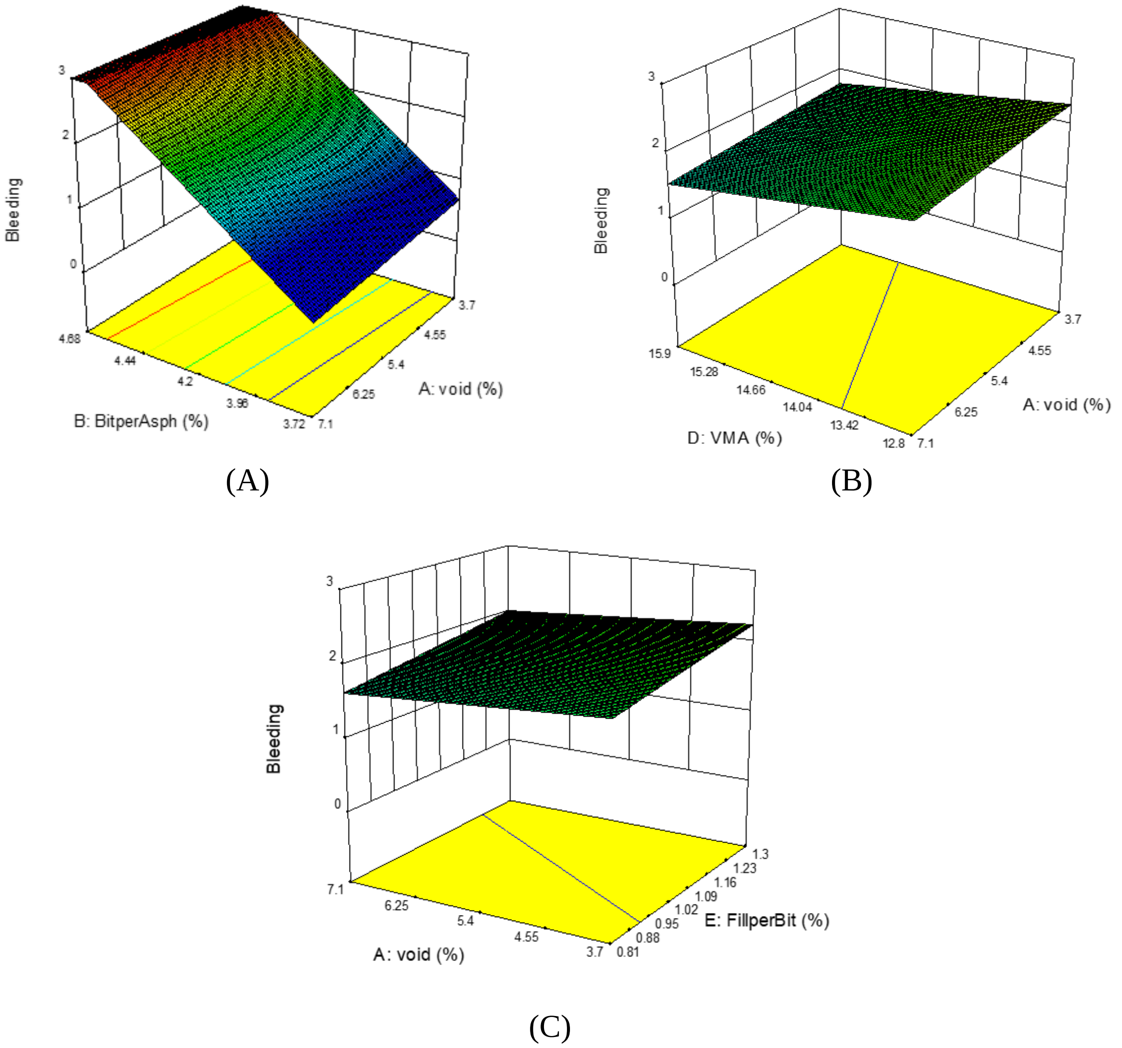


Fig. 6. Diagrams of the effect of the void percent and the ratio of bitumen to asphalt mixture on the amount of bleeding in Yazd ring road (A), the effect of the void percent and the void percent of stone materials in Yazd ring road (B), the effect of the void percent and the weight percent of filler on the weight percent of bitumen in Yazd ring road (C)

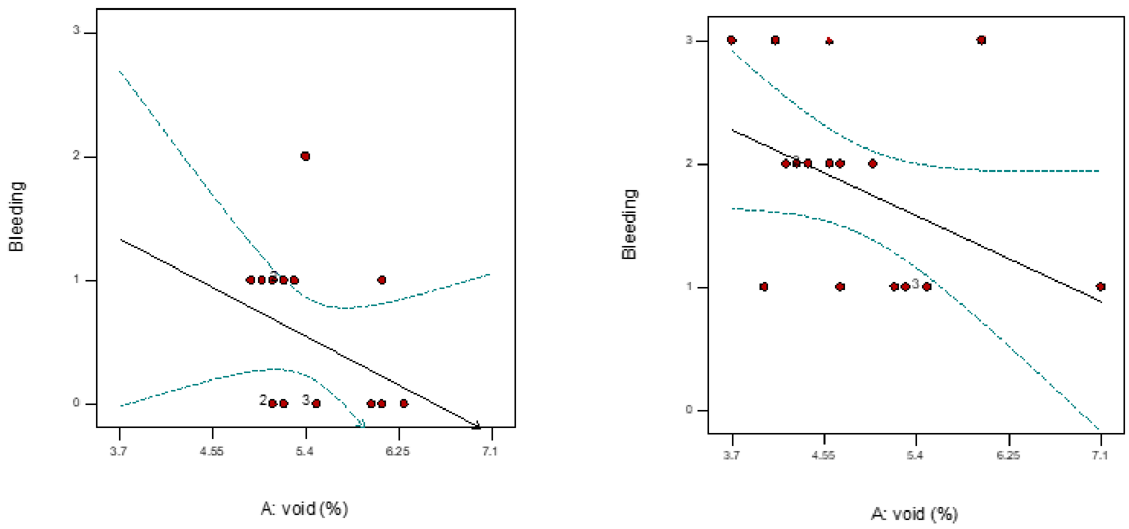
Since the void percent is the most important parameter in the bleeding phenomenon, the influence of the parameter of the void percent on the amount of bleeding will be investigated in the following. Figure 8 shows the diagrams related to the void percent and the amount of bleeding.

Using the Design Expert software, the relationship between the parameter of void percent and the amount of bleeding for the Bafq-Yazd axes is presented in relation 1 and for the Yazd ring road in relation 2. In relations 1 and 2, Bleeding and void express the intensity of bleeding and the void percent, respectively.

$$\text{Bleeding} = +3.047 - 0.46285 * \text{ void} \tag{1}$$

$$\text{Bleeding} = +3.78 - 0.40918 * \text{ void} \tag{2}$$

As it is clear from Fig. 7 and relations 1 and 2, the bleeding phenomenon is strongly influenced by the void and there is an inverse relationship between the void percent parameter and the bleeding phenomenon; this means that by reducing the void percent, the possibility of bleeding phenomenon and its severity increases and vice versa. This is why it is emphasized in the asphalt mixing design that this amount should be within the limit of 3 to 5 percent and try to avoid the minimum void percent in the design due to the increase in the probability of the phenomenon of bleeding and its severity.



(A) (B)

Fig. 7. The amounts of bleeding in terms of the void percent on the Bafq-Yazd axes (A), bleeding according to the void percent in Yazd ring road (B)

4.3. Examining the samples of successful projects in the absence of bleeding

In this section, the parameters of the mixing design of the roads in which the bleeding phenomenon did not occur are discussed. Since the void percent is the most important parameter on the phenomenon of bleeding; in this step, the effect of the parameters of the mixing design on the void percent is examined.

The results of the analysis with Design Expert software show that the void percent is related to these four parameters with relation 3. Fig. 8 also shows the ratio of the actual value of the void percent and the values predicted by the model. In relation 3, parameters of Void, BitperAsph, BitOpt, VMA, FillperBit respectively express the percent of void, the percent of bitumen compared to the asphalt mixture, the percent of optimal bitumen, the void percent of stone materials (VMA), the ratio of the weight percent of filler to the weight percent of bitumen.

Fig. 9 shows the effect of parameters of bitumen percent compared to asphalt mixture, optimal bitumen percent, stone material void percent (VMA), ratio of weight percent of filler to weight percent of bitumen on void percent.

$$\text{Void}=-107.5-107.1*\text{BitperAsph}+69.13*\text{BitOpt}+19.66*\text{VMA}+85.59*\text{FillperBit}+14.04*\text{BitperAsph}*\text{BitOpt}+3.35*\text{BitperAsph}*\text{VMA}-0.11*\text{BitperAsph}*\text{FillperBit}-7.57*\text{BitOpt}*\text{VMA}-15.77*\text{BitOpt}*\text{FillperBit}-1.46*\text{VMA}*\text{FillperBit} \quad (3)$$

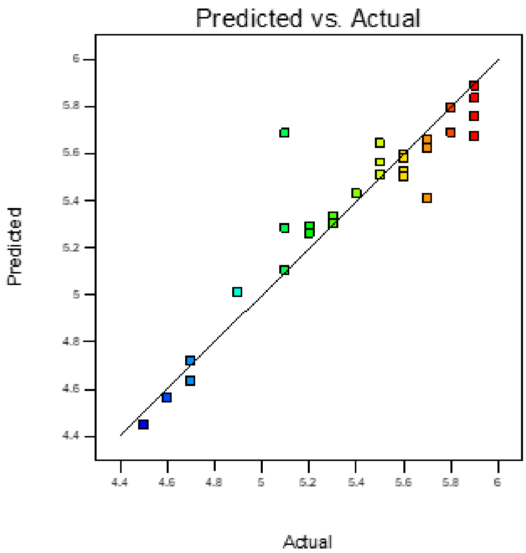
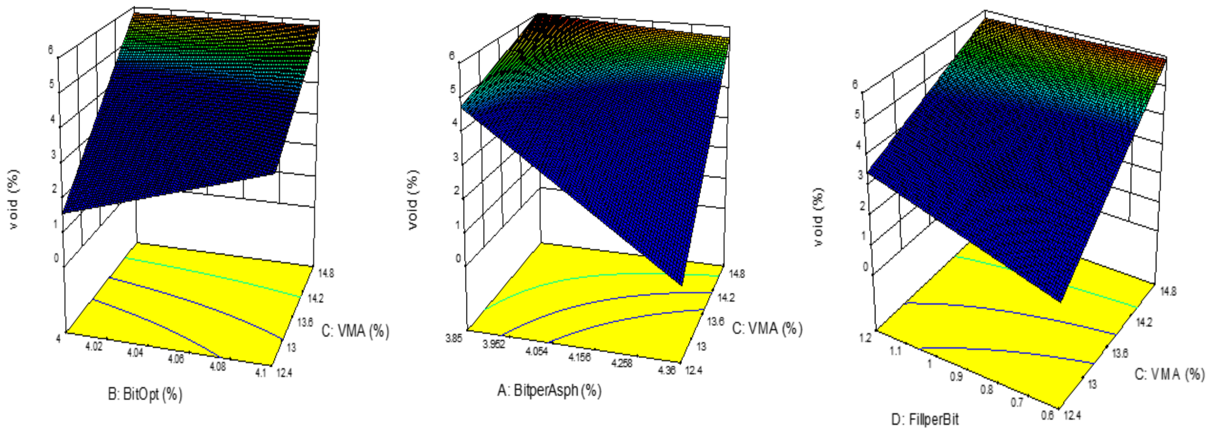


Fig. 8. The ratio of the actual value of the void percent values and the values predicted by the model



(A) (B) (C)

Fig 9. The effect of different parameters of the asphalt mixing design on the void percent; (A) the void percent of stone materials and the percent of optimal bitumen, (B) the percent of bitumen compared to the asphalt mixture and the void percent of stone materials, (C) the void percent of stone materials and the weight percent of filler weight percent of bitumen

As it can be seen in Figure 9, with the increase in the percent of optimal bitumen and the percent of bitumen compared to the asphalt mixture, the percent of void decreases because with the increase of bitumen, the holes filled with bitumen increase and finally the void percent decreases; meanwhile, compared to the asphalt mixture, it has a significant effect on the void percent compared to the optimal bitumen percent parameter. On the other hand, by increasing the void percent of materials and the weight percent of filler to the weight percent of bitumen, the void percent increases; meanwhile, the void percent of materials has a significant effect on the void percent. By altering the gradding and choosing a coarser gradding and then increasing the void percent of stone materials, the void percent of the total asphalt will clearly increase. On the other hand, by increasing the ratio of filler to bitumen, the void percent increases with the amount of filler being constant and decreasing the amount of bitumen.

Figure 10 shows the decision tree related to checking the effective parameters of the void percent. Based on the drawn decision tree, the parameters of bitumen percent compared to asphalt mixture, material void percent and filler weight percent to bitumen weight percent are the most effective parameters on the amount of bitumen; in this order, the void percent is divided into two groups based on the percent of bitumen compared to the asphalt mixture, if this parameter is less than 4.06, the percent of void is equal to 5.612 percent and if this parameter is more than 4.06, the value of the percent of void is equal to 5.075%, which are divided into two groups based on the weight percent of filler and the weight percent of bitumen; if this parameter is less than or equal to 1.18, the void percent is equal to 5.233, and if it is greater than 1.18, the void percent is equal to 4.6. In the same way, this division continues based on the void percent of stone materials.

5. CONCLUSION

This research was conducted with the aim of investigating the parameters of the mixing design in creating the phenomenon of bleeding and its severity. For this purpose, the parameters of the effective mixing design in the bleeding phenomenon were collected from laboratory sheets and investigated. The studied area includes the Yazd-Bafq axes, the Yazd ring road, as well as the landscaping projects of Nain town, the implementation of the entrance and exit of Najafabad industrial town and the roads of Kohpayeh industrial town and the amount of bleeding of these projects was determined by field sampling. Then, the collected data was analyzed with the Design Expert and SPSS software. In general, the results of this research are as follows:

- All five parameters are optimal bitumen percent, bitumen percent compared to asphalt mixture, void percent Marshall's sample, volume percent of void of stone materials and the ratio of filler to bitumen are effective in creating bleeding phenomenon and its intensity. Among the mentioned parameters, two parameters, the percent of bitumen compared to the asphalt mixture and the void percent of the Marshall sample, have a greater effect on the severity of the bleeding phenomenon.
- Also, the results show that several factors are effective on the void percent of asphalt; among these factors, we can mention the optimal bitumen percent, the percent of bitumen compared to the asphalt mixture, the volume percent of the void of stone materials and the ratio of filler to bitumen; but the results of this research show that the most important parameter affecting the percent of void is the bitumen percent parameter compared to the asphalt mixture.

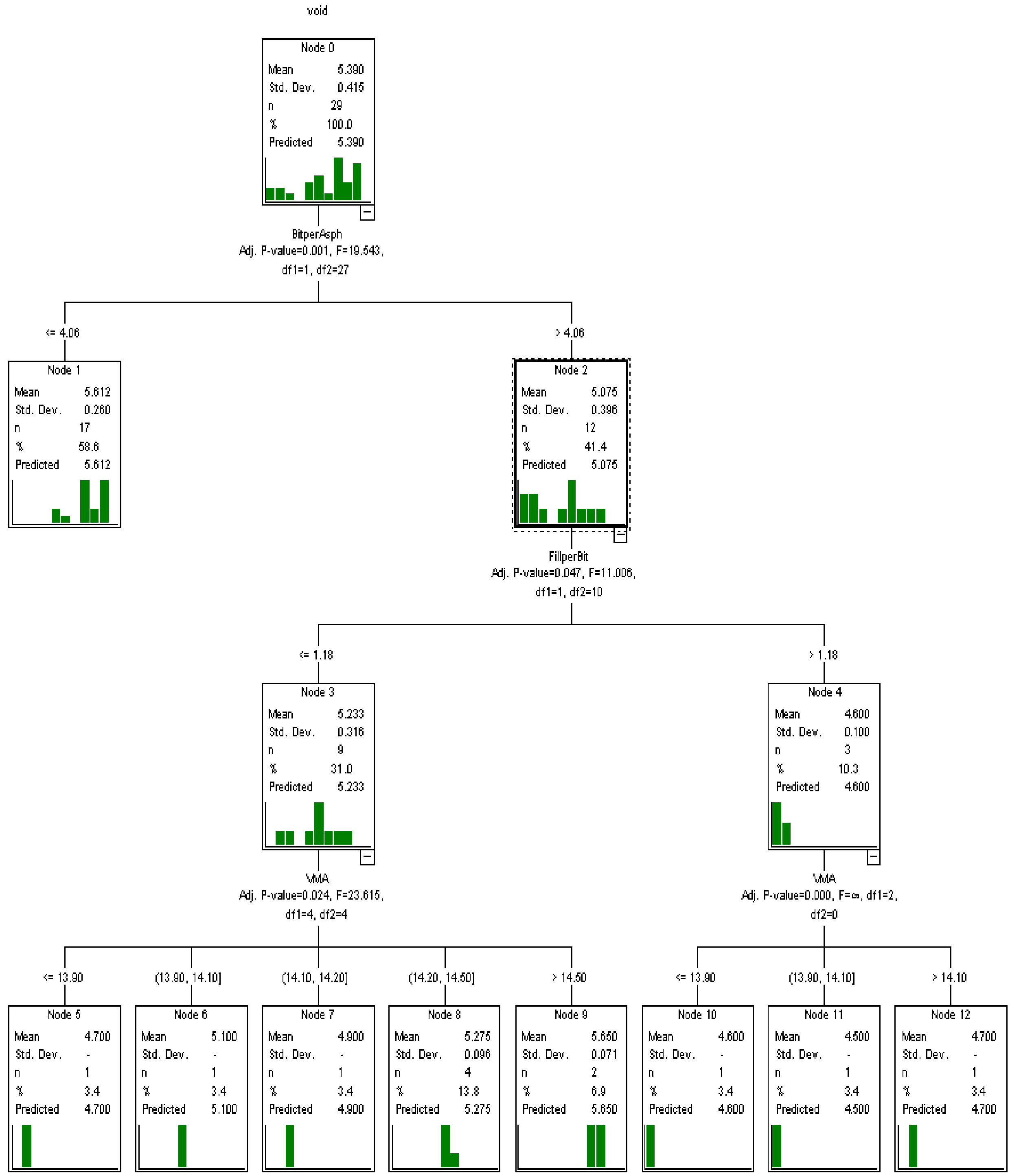


Fig. 10. Grouping of parameters of the effective mixing design on the void percent

- Regarding the void percent, it is recommended that the percent of void be optimized in order to choose the optimal bitumen percent in the Marshall mixing design in such a way that it takes into account the environmental conditions of the project area. For example, in tropical regions, with a proper engineering judgment, the percent of void should be closer to the upper limit to avoid the phenomenon of bleeding.
- Since the design and implementation of many ways is phased; in other words, at the beginning of the life of pavements, lining is implemented and used as a top; therefore, even

instead of 5% according to technical standards, the maximum void can be 6% in the mixing design.

- Based on the results of this research, it is possible to predict and prevent the occurrence of bleeding phenomenon in the stage of mixing design; the absence of bleeding will also improve road safety and reduce accidents.

Acknowledgement

This article is extracted from the national research project, entitled "The causes of bleeding in the roadway of most of the roads" based on the needs assessment of the research priorities of the Ministry of Industry, Mines and Trade in 2018. The number of this contract is 12261, dated May 22nd, 2021, with the Yazd Farsh Road Paving Company. The authors gratefully acknowledge the financial support from the Iran Ministry of Industry, Mines and Trade and Yazd University.

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Received 20.12.2022; accepted in revised form 05.03.2023