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EFFECT OF OHS CRITERIA ON SELECTION OF CONCRETE ADDITIVES IN MINE ORE CONSTRUCTION WORKS

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Abstract: Construction, mining or tunneling projects in Türkiye are defined as workplaces in the very dangerous class due to their physical power needs. For this reason, metal ore mining, mining supporting service activities, sewage, external construction, special construction activities, construction and landscaping activities are the sectors where occupational accidents are most common. While determining the necessary materials or work equipment during the planning phase of the works in these sectors, making decisions by evaluating the effect of "occupational health and safety" will contribute to the reduction of accidents. This research consists of two parts. In the first part, accident frequency rates were calculated by using data related to metal ore mining, mining supporting service activities, sewerage, external structure, special construction activities, building and landscaping projects between 2012 and 2019. Thus, the relationship between occupational accidents experienced as of the adoption of the Occupational Health and Safety Law has been determined. In the second part, it is tried to gain a different perspective by adding occupational health and safety factor to the Analytical Hierarchy Process (AHP), which is one of the multi-criteria decision-making methods. As a result of the research, it has been determined that "occupational health and safety" criteria are given priority according to cost and engineering advantages in alternative product/material comparisons in mines or construction works.

Keywords: Analytical hierarchy process, Multi criteria decision making method, Occupational accident frequency rate, Occupational health and safety

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1. Introduction

Due to the usage of construction equipment and the requirement for physical strength, mining and tunnel projects are classified as very dangerous workplaces (Bayraktar et al., 2018; Bayrak, 2018). Türkiye's construction industry and mining companies both contribute to the nation's economy, with employment prospects rising by 10% annually. However, when the Social Security Institution (SSI) data for the years 2012 and 2019 are studied, the construction industry and mining businesses are found to have the greatest rates of occupational accidents (As one of the industries with a high rate of occupational accidents, metal mining, mining-related service activities, sewerage, outdoor structure construction, private construction, buildings, and landscaping activities should be investigated or methods developed to reduce occupational accidents in workplaces (Bingöl, 2010). The primary preventive measure to reduce occupational accidents is to determine an alternative working style or method. Among OHS practices, the first priority is to completely eliminate the situation that may cause a work accident. If the situation that may cause a work accident is caused by a material or equipment that must be used. It is necessary to investigate substitute methods or materials that provide occupational safety advantages. In short, the secondary preventive measure to reduce occupational accidents is to determine an alternative working method or materials.

Occupational health and safety (OHS) is a scientific term that encompasses all systematic research into the effective integration and implementation of all essential workplace procedures. From this perspective, alternative techniques need to be investigated in cases where appropriate safety measures cannot be taken in the machines and equipment used to perform a task. In workplaces classified as very hazardous, it can sometimes be difficult to decide on the most advantageous method and material in terms of OHS. Generally, employers in this field only consider the engineering contribution and financial advantage they bring to the project when choosing the materials and equipment they will use on the construction site. OHS professionals, on the other hand, focus on the advantage of occupational health and safety in the selection of materials and equipment to be used. As a result, MCDM is an application that helps in selecting the most advantageous materials and methods by evaluating all the criteria together for a safe workplace idea.

In this research, the occupational accident statistics published by the SSI were used as a data source, and the occupational accident frequency rate was calculated according to the occupational accidents experienced between 2012 and 2019. Secondly, the Analytical Hierarchy Process (AHP) method was applied to two different concrete reinforcement additives that are widely used in mines and the construction industry. Thus, while choosing between alternatives, priorities are listed among the criteria that affect the decision (Lyu et al, 2020; Banerjee et al, 2021). The original aspect of this research was to determine the ideal choice by adding the occupational health and safety contribution as a criterion while choosing the most suitable concrete reinforcement material among the alternatives. In addition, this research is a pioneering study emphasizing the inclusion of "Occupational Health and Safety Criteria" in all processes in material or equipment selection in similar sectors where occupational accident rates are high.

1.1 Sectors Where Macro Synthetic Fibers Are Used for 2012-2019

Occupational Health and Safety (OHS) is the umbrella term for all systematic research done to ensure that all relevant workplace procedures are effectively integrated and put into place. According to this viewpoint, substitution (alternative) solutions should be looked for when suitable safety precautions cannot be established in the apparatus and equipment used to carry out a job. Employers working on large-scale projects in these sectors only consider the engineering contribution and cost savings a piece of equipment or material will bring to the project when selecting it. It is important to take occupational health and safety into account when selecting the materials and equipment to be utilized. Consequently, the idea of a safe workplace In workplaces such as those involved in the extraction of metal ore, mining support services, sewage, the construction of non-building structures, special construction activities, etc., the likelihood of an employee developing a work accident or occupational disease is significant due to the work machinery employed, the erratic working environment, and the requirement for physical strength. As a result, these workplaces fall under the category of very dangerous (Tehlike Sınıfları Tebliği, 2012). The primary OHS procedures in extremely risky jobs;

- Vocational training, certification, and employee inspections ought to be done.
- To offer basic OHS training for at least 16 hours each year.
- One employee out of every 30 should receive emergency training, and one employee out of every 10 should receive first aid training.
- Emergency plans and risk assessment reports should be renewed every two years at the maximum (barring circumstances prescribed by law).

Establishing OHS committees and holding regular meetings each month, renewing employee health examinations on a regular basis each year, and assigning each employee an occupational safety specialist who will work for at least 40 minutes each month and a workplace doctor who will work for 15 minutes (Türk Tabipleri Birliği, 2021).

Metal ore mining, mining support services, sewage, the construction of non-building structures, specialized construction activities, buildings, and landscaping activities were chosen as typical workplaces where two distinct concrete reinforcement materials may be used. When looking at Figure 1, it has been determined that between 2012 and 2019, in Türkiye, there were 973,192 workplaces and 10,636,427 workers in these industries (SGK, 2021). Examining the statistics in Figure 1, it can be seen that these industries support the economy of the nation by adding 9% additional jobs annually on average.

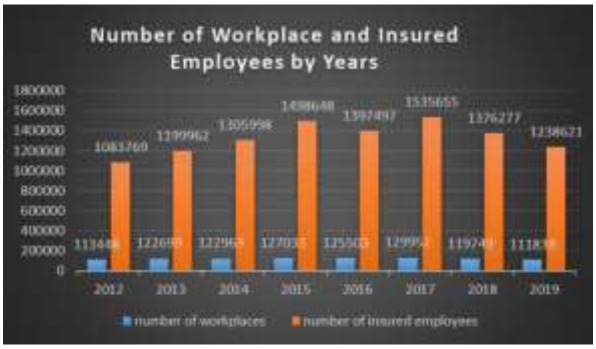

Figure 1. Number of workplace and insured employees between 2012 and 2019 (SGK, 2021).

When the data in Figure 2 in the years 2012 to 2019 with the adoption of the OHS Law is examined, it appears that 259,866 people had occupational accidents out of the 10,636,427 people employed in metal ore mining, mining support service activities, sewerage, construction of non-building structures, private construction activities, buildings, and landscaping activities (SGK, 2021). Even while this condition really offers employment prospects, it demonstrates that 2.44% of those who have been employed for seven years had experienced a workplace injury.

Figure 2. Number of occupational accidents in metal ore mining, mining support service activities, sewerage, construction of outdoor structures, special construction activities, buildings and landscaping activities between 2012 and 2019 (SGK, 2021).

As shown by the data in Figure 2, the fact that 24% of employees experience work-related accidents highlights the importance of occupational health and safety for the industry. It's crucial that workplace safety and employee welfare continue to exist (Bilim ve Çelik, 2018). Employers should do a risk assessment pertaining to the use of tools and machinery needed for the job and look for alternatives for this reason. When making a decision, taking occupational health and safety into account will ensure business continuity. In terms of OHS, substitute methods encompass all the work done to reduce the effects of potentially harmful circumstances that may develop as a result of work that cannot be canceled in the course of a process. In a nutshell, the decrease of the success of alternative solutions makes it possible to reduce occupational accidents in various industries.

It is claimed that occupational accidents during the construction of outdoor constructions account for 8–15% of the project cost in his paper titled "Safety Risk Assessment Using Analytic Hierarchy Process (AHP) During Planning and Budgeting of Construction Projects" (Aminbakhsh et al, 2013; Soyalan, 2020). It is not just about occupational health and safety when it comes to occupational diseases or accidents, particularly in the construction industry. Occupational accidents also have an indirect impact on the nation's economy (Aminbakhsh et al, 2013). Occupational safety standards coordinated with the activity will therefore contribute to the project's success since mines and building projects are frequently seen as large-scale endeavors. OHS experts need to be involved from the planning stage of the project onward. Only engineering or cost advantage should not be taken into account during the planning phase when choosing the materials or work equipment to be utilized for the job in the absence of OHS professionals. Making the best decisions and including "occupational health and safety criteria" in the selection criteria will aid in preventing work accidents that might happen as the project progresses. Additionally, it will benefit the OHS procedures needed in the workplace. Macro synthetic fiber materials can be used as concrete reinforcement materials instead of conventional reinforcements in a specific area of work in metal ore mining, mining support service activities, sewerage, external structure construction, special construction activities, building, and landscaping projects. These concrete additives, which are polymer-based, ecologically friendly, and more useful compounds that can be utilized as an alternative to conventional reinforcements, have been introduced to the market as a result of evolving technology [14]. However, when it comes to strengthening reinforced concrete structures, traditional reinforcements are the first steel elements that come to mind. Macro Synthetic Fibers (MSF) and conventional reinforcements have similar engineering characteristics, but in some situations, it may be preferable to use one over the other (Dağdeviren and Tamer, 2001).

Özcan (2018) study claims that variations in engineering strength are brought on by the corrosion effect of traditional reinforcements along with the passage of time. MSFs should be prioritized in the use decisions made for projects since they continue to function at their peak capacity even after being used (Dağdeviren and Tamer, 2001). Additionally, while comparing the two options, procedures like transporting, merging, and using conventional equipment necessitate the use of labor and professional expertise. In other words, workplace accidents or occupational diseases will inevitably occur whenever physical strength is successfully utilized in the workplace. The examination of each material's contribution to workplace health and safety when deciding between them would thus indirectly help the substitution approach in terms of OHS in these industries where both materials can be utilized interchangeably. Therefore, even a slight reduction in the number of work accidents that occur relative to the employment rate will be beneficial.

Enterprises frequently choose alternatives using Multi-Criteria Decision Method (MCDM) methodologies. In order to choose the best supplier, Dadeviren and Tamer identified four key criteria. Using these criteria, they used the AHP approach to establish the priorities of four vendors (Badri et al, 2011). In order to create and better organize the safety culture in a mining sector project, Badri, Nadeau, and Gbodossou used the MCDM method to identify OHS concerns (Bao et al, 2016). According to six primary criteria, Bao, Zhang, Li, Liu, and Shi used the fuzzy AHP technique to assess the societal benefits of the OHS management system in two separate mining operations in China and Switzerland (Bao et al, 2017). In order to guide the establishment of OHS management systems in mining firms, this study was conducted. According to six primary criteria, Bao et al. (2016) used the fuzzy AHP technique to assess the societal benefits of the OHS management system in two separate mining operations in China and Switzerland (Bao et al., 2017). The goal of this study is to guide the development of OHS management systems in mining businesses. For the prevention, efficient analysis, and ongoing improvement of occupational diseases in the mining industry, Bao et al. (2017) developed an FMEA-based technique (fault mode and impact analysis) and an enhanced AHP (analytical hierarchy process) model (Korkusuz et al, 2019). It has been demonstrated that this approach can be used to manage business processes. The level of OHS performance among hospitals was compared using the Korkusuz et al. (2019) study, which used AHP, Promethee, and GRA methodologies (Dağdeviren, 2008). By using MCDM techniques, a groundbreaking advancement in the field of OHS was made in the research, which incorporated "OHS Performance" as a criterion for evaluating hospital performance. Dağdeviren (2008) claimed that used the PROMETHEE approach to make the best choice and the AHP method to structure the criteria needed for the selection of appropriate equipment (Denizhan et al, 2017). This study's research topic is comparable to our own, but our study differs in that it takes occupational health and safety parameters into account while choosing the right equipment.

However, there isn't a model study that highlights the importance of choosing the tools or supplies to use in the workplace while accounting for OHS contributions. In this study, "Occupational Health and Safety" has been incorporated as a selection factor along with the "Cost, Engineering, and Time Management Advantage" while choosing concrete reinforcement material by utilizing the AHP approach. This study's main goal is to increase public knowledge about the need to use OHS benefits as a selection factor when purchasing machinery or other items that will be used in workplaces. The use of MCDM techniques in workplace OHS procedures is the secondary goal. The third objective is to develop an efficient OHS infrastructure in the workplace by reducing the initial investment expenditures for OHS that companies avoid at the start of the job.

In this study, using the MCDM, in addition to the cost and engineering advantage of the proposed macro synthetic fiber material, the contribution of its use in OHS applications was added as a criterion. Thus, it was emphasized that enterprises can benefit from the AHP method by adding the OHS criterion in the selection of materials to be used to reduce investment costs in OHS applications.

The AHP method is one of the oldest and frequently used methods in various application areas. For this reason, in this article, this method was chosen among the MCDM methods and this method was used in the grading of the criteria.

2. Materials and Methods

In this investigation, two evaluations were conducted. First, for the industries covered by the Turkish Social Security Agency's research, the frequency of occupational accidents between 2012 and 2019 was estimated.

In the second, the decision-making factors were given priority using the AHP approach while deciding between the concrete reinforcement materials that are frequently utilized in these industries.

The AHP approach was chosen as the MCDM method because it has a wealth of literature applications and is one of the most effective criterion weighting methods (Dağdeviren, 2008). Denizhan et al. (2017), study used fuzzy AHP and AHP methods to choose the best provider out of two options and found that the application had no effect on the criteria's ranking (Arıtan and Ataman, 2017). It was shown that in studies where two different options were evaluated, the results did not change in accordance with the fuzzy AHP approach; instead, the weight of the criteria with high relevance grew even more, and the weight of the criteria with low importance was reduced. Due to their difficulty in application, fuzzy numbers were not selected when choosing between conventional reinforcement and macro-synthetic fiber reinforcement material.

2.1. Accident Frequency Rate

The insured person's rate of occupational accidents during working hours is expressed as a percentage (Yılmaz Oral and Ünal, 2020). For the years 2012 to 2019, occupational accident frequency rates were calculated using data on occupational accidents that the Turkish Social Security Agency had collected in the mining of metal ore, mining-related service activities, sewage, construction of non-building structures, private construction activities, and building and landscaping activities. As a result, it offers insight into how various industries approach workplace safety.

The Equation 1 is used to calculate the occupational accident frequency rate for each year (Kuruüzüm and Atsan, 2001).

$$KSO = TNWA / [(TWD-NWD) \times RDWT] \times 10.000 \quad (1)$$

TNWA= total number of work accidents, TWD= total working days, NWD= non-working day, RDWT= refers to the daily working time, expresses.

2.2. Analytical Hierarchy Process (AHP)

The AHP method, which was developed by Saaty in 1977, considers the main factors affecting the decision as the main decision criteria and divides them into sub-decision criteria that affect the main decision criteria (Lin and Kou, 2021). Briefly, the AHP method calculates the order of importance among the features that are effective in comparing the alternatives with each other (Keçek and Yıldırım, 2010). Thus, it provides a detailed comparison analysis for the right choice based on the opinions of people who have sufficient knowledge and equipment to solve the problem.

The AHP method is generally preferred for solving problems such as the most useful product or resource selection in projects, cost calculations, and employee performance evaluations (Saaty, 1987).

2.2.1. AHP method implementation stages

The four solution procedures that make up the AHP Method's solution are the construction of the hierarchical structure, the development of the comparison matrices, the development of the priority vector in light of the comparison matrices, and the determination of the consistency ratio.

In the initial phase of the study, a hierarchical structure is made with comparison standards developed using the opinions of specialists. In order to gather the required data sources for the problem's AHP method solution, comparison matrices are obtained using the AHP questionnaire forms. The priority vector, which is the next stage of the solution, is derived from the verbal responses provided by the survey respondents and converted into the numerical values shown in Table 1.

The meaning of a_{ij} value in the comparison matrix represents the comparison value between i diagonal criterion and j diagonal criterion and the comparison matrix representation created according to Table 1 is as given in (Equation 2). The value of the diagonal elements of the matrix is equal to 1 and the mutual values within the matrix are equal to $a_{ij} = 1 / a_{ji}$‘.

Table 1. Significance values and numerical correspondence of AHP method comparison criteria (Çetin, 2019)

Importance Values	Significance value definitions
1	Equally important
3	Moderately important
5	Strongly important
7	Very strongly important
9	Absolutely important
2,4,6,8	Intermediate values

$$A=\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \qquad (2)$$

The 'normalization' process (Equation 3) is carried out to produce the priority vector by dividing the total value of each row of the acquired comparison matrix by the sum of all rows. Row totals are divided by the total number of criteria weights in the priority vector to get the criteria weights.

$$b_{ij}=\frac{a_{ij}}{\sum_{i=1}^{n}a_{ij}} \qquad (3)$$

Calculating the consistency ratio is necessary in order to analyze the comparable criteria for solving problems. It is required that the consistency ratio (CR) value be less than 0.10. The () value is determined by dividing the comparison matrix's row totals, which are derived by multiplying the matrix elements in each column of the decision matrix by the criterion weights. Reading from Table 2 yields the Random Consistency Index (RI) value, which is another parameter needed to calculate the CR value, and the n value is determined by how many criteria were considered. The consistency indicator (CI) value and the consistency rate (CR) value are calculated using the Equation (4), and a comparison of 0.10 is made.

$$CI=\frac{\lambda-n}{n-1},\ CR=\frac{CI}{RI} \qquad (4)$$

Table 2. RI Value Table (Çetin, 2019)

n	RI
1	0
2	0
3	0.52
4	0.89
5	1.11
6	1.25
7	1.35
8	1.4
9	1.45
10	1.49

If a consistency ratio is given, the criterion with the largest numerical value in relation to the outcome of the transaction is regarded as having the greatest influence on the choice (Çetin, 2019).

Elements like the technical qualities and advantages of the alternatives are compared with the AHP technique and are grouped based on the judgments of the experts. The order of priority is established using the AHP approach, where each group value is used as a reference in the subheadings that are pulled from inside themselves. It makes decision-making more specific, particularly in circumstances where it is difficult to compare alternatives objectively.

3. Results

3.1. Occupational Accidents in Sectors Where Macro Synthetic Fibers Are Used

Data on occupational accidents that are specific to the industry for which the calculation of the occupational accident frequency rate is intended are needed, as well as details about daily working hours and weekends. Work is done six days a week in industries like mining for metal ore, providing mining support services, cleaning sewage, building buildings, landscaping, and creating outdoor constructions.

Table 3. Number of occupational accidents in 2012-2019 (SGK, 2021)

2012	5867
2013	17113
2014	23880
2015	28747
2016	37738
2017	45412
2018	56023
2019	45086

For the research's target industries, a total working day (TWD) of 45 hours per week was established. Weekends, paid time off, and public holidays are computed based on the calendar of the current year. The ranking is based on 10,000 hours as well, for clarity's sake. According to the number of work accidents listed in Table 3, occupational accident frequency data are derived for each year and are shown in Table 4.

Examining Table 4 and Figure 3, it can be seen that there is a linear increase in the likelihood of an occupational injury for insured individuals employed between 2012 and 2016. The increase in insured personnel by 138,158 over the prior year is assumed to be the cause of the fall in accident frequency rate in 2017. The significance of OHS practices is demonstrated by the increase in accident frequency over time. OHS's primary goal is to entirely eliminate work accidents, which unfortunately does not align with the existing scenario.

Table 4. Accident frequency rates by years

Years	2012	2013	2014	2015	2016	2017	2018	2019
TNWA	5867	17113	23990	28747	37738	45412	56023	45086
TWD-NWD	307	287	297	289	288	289	283	287
RDWT	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Number of Employees	1083769	1199962	1305998	1498648	1397497	1535655	1376277	1238621
Time Calculation	10000	10000	10000	10000	10000	10000	10000	10000
AFR	0.04	0.13	0.18	0.22	0.29	0.14	0.19	0.17
Average Value	4%	13%	18%	22%	29%	14%	19%	17%

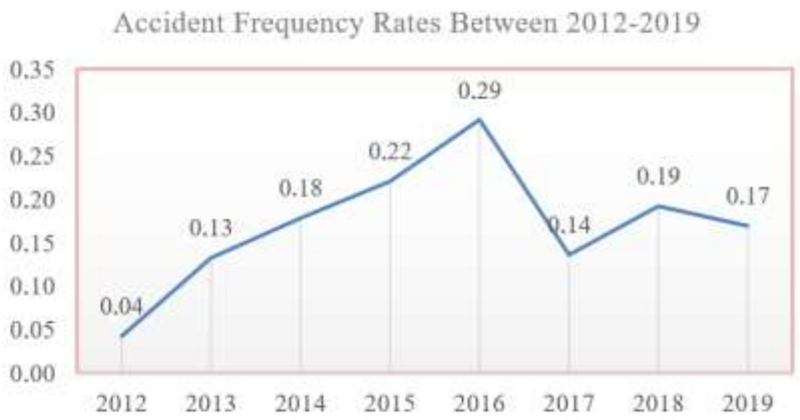

Figure 3. Number of occupational accidents in metal ore mining, mining support service activities, sewerage, construction of outdoor structures, special construction activities, buildings and landscaping activities between 2012-2019.

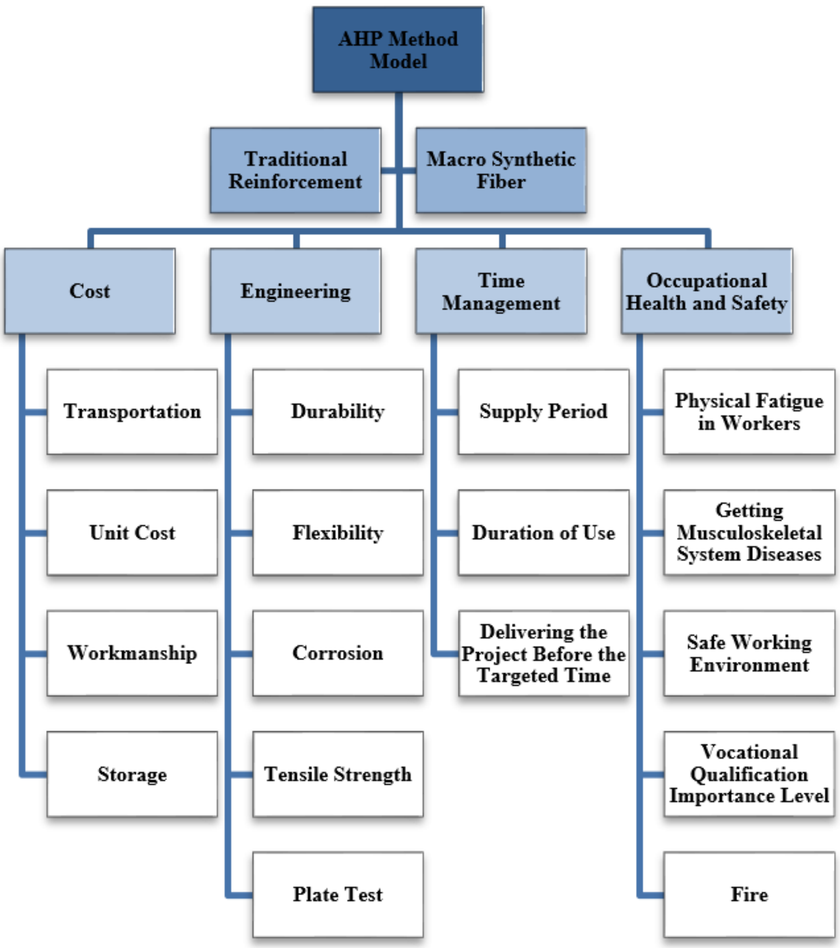

Figure 4. AHP method model.

3.2. AHP Method Application Results

The AHP technique used interviews with employers or expert engineers from 10 different businesses to determine the criteria. DM profiles consist of 10 experts in their fields, including employers or employers' representatives, site supervisors and expert civil engineers working in 10 different mining enterprises. The most important feature of these 10 people is; they have the authority to decide on the choice of alternative materials and the technical equipment to compare the products.

AHP questionnaires and major and sub-criteria were designed using the interviews with this expert panel (Figure 4). Also referred to as this expert team are the decision-makers. The evaluation of the questionnaire responses led to the calculation of the ranking of the selection criteria. On August 19, 2020, Uskudar University received the study's ethics committee's permission.

3.2.1. Evaluation of data with ahp method

Stage 1: Determination of decision criteria

Following interviews with key decision-makers, four main criteria—cost, engineering, time management, and occupational health and safety—and a total of 17 sub-criteria were established for comparing the two materials. The established major and sub-criteria were used to build the AHP questionnaire forms.

Stage 2: Developing criterion weights and binary comparison matrices

The AHP approach was used to transform the verbal data into their numerical equivalents and create comparison matrix values for the primary criteria listed in Table 5.

Stage 3: Normalized binary comparison matrices for key criteria

A single unit matrix was created by taking the geometric mean of the answers given by the survey participants, and the normalized comparison matrix is given in Table 6.

Table 5. Comparison matrix

Main Criteria	Cost	Engineering	Time Management	Occupational Health and Safety
Cost	1.0000	0.5213	0.9587	1.0000
Engineering	1.9184	1.0000	0.6834	0.7569
Time Management	1.0431	1.4633	1.0000	0.5444
Occupational Health and Safety	1.0000	1.3211	1.8369	1.0000

Table 6. Normalized comparison matrix

Main Criteria	Cost	Engineering	Time Management	Occupational Health and Safety
Cost	0.2016	0.1211	0.2140	0.3029
Engineering	0.3867	0.2323	0.1526	0.2293
Time Management	0.2102	0.3398	0.2233	0.1649
Occupational Health and Safety	0.2016	0.3068	0.4101	0.3029

Stage 4: Creating the priorities vector

The priority values of the main criteria of cost, engineering, occupational health and safety, time management, which are effective in determining the alternatives, were calculated and the values in Table 7 were obtained.

Table 7. Priority values

Main Criteria	Priority values
Cost	0.209894
Engineering	0.250191
Time Management	0.234561
Occupational Health and Safety	0.305354

When the values given in Table 7 are examined, it has been determined that the "Occupational Health and Safety" criterion is the most effective criterion in alternative selection, since it has the highest value.

Stage 5: Calculation of consistency analysis parameters

In order to calculate the consistency analysis parameters, the λ values of the main criteria were calculated as given in Table 8.

Table 8. Calculation of λ value

Main Criteria	Priority Matrix Total
Cost	4.147534
Engineering	4.173902
Time Management	4.202837
Occupational Health and Safety	4.180898
Lambda (λ)	4.176293087

Stage 6: Calculation of the CR value

CR = 0.06529 for main criteria. Since it satisfies the CR <0.1 rule, it is possible to mention that the results of the criteria weights obtained are consistent.

Stage 7: Creating the hierarchy

By providing the consistency analysis, the hierarchical ranking for the main criteria was calculated as Occupational Health and Safety 0.3053, Engineering 0.2501, Time Management 0.2345, Cost = 0.2098.

Stage 8: Determination of priority values for main criteria, sub-criteria and alternatives

In all calculations of the sub criteria, the CR <0.1 rule has been provided and the results obtained are given in Tables 9 and 10 below.

Table 9. Major criteria, sub-criteria and criteria weights of alternatives

Main Criteria	Criterion Weights	Sub Criteria	Criterion Weights	Alternatives	Priority Values
Cost	0.2098	Transportation	0.2208	Traditional Reinforcement	0.3640
				Macro Synthetic Fiber	0.6359
		Unit Cost	0.3245	Traditional Reinforcement	0.2311
				Macro Synthetic Fiber	0.7688
		Workmanship	0.3552	Traditional Reinforcement	0.4452
				Macro Synthetic Fiber	0.5547
		Storage	0.0993	Traditional Reinforcement	0.2984
				Macro Synthetic Fiber	0.7015
Engineering	0.2501	Durability	0.1993	Traditional Reinforcement	0.1729
				Macro Synthetic Fiber	0.8270
		Flexibility	0.1099	Traditional Reinforcement	0.1577
				Macro Synthetic Fiber	0.8422
		Corrosion	0.2291	Traditional Reinforcement	0.8455
				Macro Synthetic Fiber	0.1544
		Tensile Strength	0.1651	Traditional Reinforcement	0.7594
				Macro Synthetic Fiber	0.2405
		Plate Test	0.2964	Traditional Reinforcement	0.4577
				Macro Synthetic Fiber	0.5422

Table 10. Major criteria, sub-criteria and criteria weights of alternatives (more)

Main Criteria	Criteria Weights	Sub-Criteria	Criterion Weights	Alternatives	Priority Values
Time Management	0.2345	Supply Period	0.1936	Traditional Reinforcement	0.4452
				Macro Synthetic Fiber	0.5547
		Duration of Use	0.1365	Traditional Reinforcement	0.3815
				Macro Synthetic Fiber	0.6184
		Delivering the Project Before the Targeted Time	0.6697	Traditional Reinforcement	0.1078
				Macro Synthetic Fiber	0.8921
Occupational Health and Safety	0.3053	Physical Fatigue in Workers	0.1327	Traditional Reinforcement	0.5710
				Macro Synthetic Fiber	0.4289
		Getting Musculoskeletal System Diseases	0.2421	Traditional Reinforcement	0.8593
				Macro Synthetic Fiber	0.1406
		Safe Working Environment	0.3323	Traditional Reinforcement	0.4099
				Macro Synthetic Fiber	0.5900
		Vocational Qualification Importance Level	0.1145	Traditional Reinforcement	0.8785
				Macro Synthetic Fiber	0.1214
		Fire	0.1782	Traditional Reinforcement	0.3129
				Macro Synthetic Fiber	0.6870

The calculation's findings indicate that occupational health, with a weight value of 0.3053 before cost, engineering criteria, and safety, is the most crucial factor influencing the decision between the alternatives in projects involving dams, mine galleries and tunnel shotcrete projects, field concrete, and industrial floors where the use of both materials is common. The contribution that must be given in relation to OHS in the projects of the construction of dams, mine galleries and tunnel shotcrete, field concrete, and industrial floors has been emphasized in this place in comparison to the financial and engineering advantages of the employers.

4. Discussion

Construction of the mine or tunnel is associated with a high number of workplace accidents as work is done in the project area, and this is not just a problem in Türkiye, according to surveys of work accidents conducted throughout the world. 800 workplace accidents in Taiwan's construction sector were analyzed by Cheng et al. (2010) and Hola and Szostak (2017).

As a result of the analysis, he emphasized that occupational accidents occurring in small-scale construction projects are more common than in large-scale construction projects. As a result of this analysis, it was emphasized that work accidents that occurred in small-scale construction projects were more common than in large-scale construction projects. In small-scale construction projects, they found that 41% of them were due to poor health and safety management. Hola and Szostak (2017), in Poland, 485 work accidents in the construction sector were examined, and the people who had a work accident were analyzed (Bayraktar et al., 2018). The study's findings revealed that 40% of workplace accidents were brought on by unsafe working conditions, and the significance of restrictive measures in accident prevention was underlined.

In their study "Statistical Analysis of Occupational Accidents in the Turkish Mining Sector," Bayraktar et al. (2018), also looked at the occupational accident data in the mining industry (Özcan et al., 2019). It was found that, despite having a safe workplace and giving employees training for the job, fatal occupational accidents have increased year over year. According to a report by Dede and Baltacı (2019) from which included 361 members of the construction industry, the workers were aware of the need for OHS training, but they expressed safety concerns about the tools and machinery they utilized.

In a study by Özcan et al. (2019), primary causes of occupational accidents in the construction industry were listed using the AHP technique, and the target-oriented starting point of the activities intended to minimize the accidents was established (Barriuso et al, 2020). According to the study's findings, "reasons arising from equipment and materials" were determined to be the top factors contributing to occupational accidents. It is obvious that using MCDM approaches to make decisions that take into account occupational health and safety criteria would help to prevent potential workplace accidents, particularly when choosing the materials or equipment to be utilized during the planning stage of projects.

According to a study conducted by Barriuso et al. (2020), with 250 workers in the Spanish construction industry, management must develop replacement methods in addition to employee safety training if workplace accidents are to be reduced (Bingöl, 2018). On the other side, Bingöl stated that employers or their representatives should be informed about occupational health and safety in order to help them avoid any hazards or dangers that may be present in the line of work they are in 2018 (Abukhashabah, 2020).

In a study conducted with 300 Saudi Arabian workers in the construction business Abukhashabah et al. (2020), it was attempted to identify the reasons for occupational accidents. According to the study, 82% of the participants were affected by a hazardous work environment, workers who lacked sufficient professional expertise, and workers who were unaware of occupational safety issues (Boyacı et al, 2021). Due to the extent of building projects, Abukhashabah et al. (2020), in their study, underlined the necessity of minimizing the circumstances that result in accidents in these work zones (Boyacı et al, 2021).

Boyacı Çalış, Solmaz, and Kabak, introduced a new perspective to the Fine-Kinney approach, which is frequently used for assessing workplace risk (Kim and Park, 2021). By adding the "cost" aspect to the assessment, a multi-criteria determination was made. As a result, it did not just reduce the likelihood and severity of workplace accidents and their effects, but it also helped the employers understand the issue more realistically by including the potential costs. Kim and Park (2021) examined the effects of occupational accidents on employee performance and business image in corporate organizations. As listed above, the causes of occupational accidents in construction, mining, or tunnel projects were investigated, and the causes of the accidents were listed as lack of education, an unsafe working environment, or the machinery and equipment used. At the same time, it has been determined that occupational accidents are not only limited to negative effects on the health of employees but also cause sharp financial losses for enterprises.

The need to include "occupational health and safety" in the checklists created during the planning phase of the projects stands out as a result of the research's alternative perspective on the causes of occupational accidents in construction, mining, or tunnel projects. With the help of this illustrative study, it is clear that the materials are chosen with an eye toward improving occupational health and safety, in addition to employers' costs, time management, and engineering parameters. This is true even for the selection of concrete reinforcement admixture used in a specific area of construction, mining, or tunnel projects. To put it simply, occupational health and safety should be assessed holistically using additional criteria in these industries, where workplace accidents are quite common.

Occupational health and safety contributions will also be taken into consideration while researching the one that will provide the maximum benefit for the job in the procurement of materials or equipment included in the needs lists determined by evaluating from this point of view. In short, substitution methods will be developed to provide a safe working environment at the planning stage of the project.

5. Conclusion

In this study, "occupational health and safety" has been determined as the primary expectation in comparisons and selections between alternatives, even among concrete admixtures that will only be used in a certain part of the work in mines or construction works. Contrary to what is known, occupational health and safety have been calculated to have a higher priority than the first selection criteria that come to mind, such as cost, engineering, and time management.

The positive contribution to occupational health and safety should be considered a priority in the selection of all necessary equipment and materials for the execution of the work in areas where occupational accidents are high and the probability of their occurrence is high.

As a result, while preparing business activity reports, which were created during the planning phase of metal ore mining, mining supporting service activities, sewerage, construction of non-building structures, special construction activities, buildings, and landscaping projects, necessary machinery, materials, etc., alternative lists of such equipment must be created. It is understood that making choices among the alternatives with the priority of "occupational health and safety" criteria will contribute to the creation of a safe working environment.

With the inclusion of the OHS criteria in this study and a minimal expert team, it is at a level to direct other studies in terms of its applicability in a short time. The usage areas for working with this sample application model can be listed as follows:

- The main criteria remain the same in the selection of any material or equipment in the construction or mining sectors, and the sub-criteria are revised and implemented.
- In the root cause detection research of the work accident that occurred in a workplace with the AHP model,
- In choosing among the alternatives as a result of adapting the AHP model to different sectors,
- In making the ideal choice among the applicable methods to eliminate the hazards,
- In the future, comparisons can be made between different MCDM methods and concrete reinforcement materials in the same sector. In addition, a new study can be made by including the OHS criteria while choosing between more alternatives in the same sectors.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	T.O.	N.B.
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50
FA	50	50

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

This study was carried out with the approval of Üsküdar University Academic Ethics Committee (decision dated 19.08.2020)

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