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A Model Proposal for Wall Material Selection Decisions by Using Analytic Hierarchy Process (AHP)

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Analytical hierarchy process, developed by Saaty, is a multi-criteria decision making method. It creates a hierarchy using the goal, decision criteria and decision alternatives, and sorts the various alternatives according to their relative importance. The aim in AHP is to choose the most suitable and important alternative, by making an arrangement from the most important to the least. In this study, a real life material selection application in a hotel building is described by using AHP method. Wall materials such as brick blocks, pumice concrete block, sand autoclaved aerated concrete blocks are decision alternatives and mechanical properties, physical properties, ease of application and costs of these materials are the decision factors. The analysis was performed based on the opinion of an expert and the most suitable alternative is selected. Also, it is concluded that the order related to the alternatives is reliable for the decision markers. Thus, a decision supporting method for a construction company using AHP applications is developed.

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PACS/topics: multi-criteria decision making, analytical hierarchy process, expert choice, building material selection

1. Introduction

It is well understood that materials play an important role in engineering design. Material selection is one of the most challenging issues in the design and development of products, and it is also critical for the success and competitiveness of the manufacturing organizations [1–3]. The selection of an optimal material for an engineering design from among two or more alternative materials on the basis of two or more attributes is a multiple attribute decision making (MADM) problem [4]. Liao [5] presented a fuzzy multi-criteria decision making method for material selection. Ashby [6] proposed multi-objective optimization in materials design and selection using "utility" functions. Ashby et al. [7] provided a comprehensive review of the strategies or methods for materials selection, from which three types of materials selection methodology had been identified. For the free-searching method, there are already a number of well-documented methods, the most famous being the graphical engineering selection method or the ranking method [8, 9].

A checklist/questionnaire method had been proposed by a number of researchers, the recent being described by Edwards [10], where the author had developed a structured set of questions to improve the likelihood of achieving an optimal design solution. Some of representative examples include a knowledge based system for materials management that include materials selection [11], a knowledge based system for materials selection [12], integrated information technology approach [13], fuzzy knowledge based decision support system for selection of manufacturing processes and materials [14] and a case-based reasoning method [15].

This paper shows that a model proposal which was developed for wall material selection decisions by using AHP is useful tool for this area. Designers, constructors, or employers will be able to use this method for similar construction materials selections. They will be able to earn time and make more qualified evaluations. Studies on decision making are for specifically processes regarding ranking or selecting the best alternative according to cognitive information [16–20].

2. Application

In this application, the aim of the handled decision problem is determination of the most suitable wall material to be used in a hotel construction by AHP. After the aim has been determined, the criteria were determined for this aim and were incorporated to hierarchic structure. The criteria were selected among the properties placed by material producers in their product introductions. As decision alternatives, brick, pumice concrete and autoclaved aerated concrete (AAC) were determined. The hierarchic structure formed in this context was given in Fig. 1.

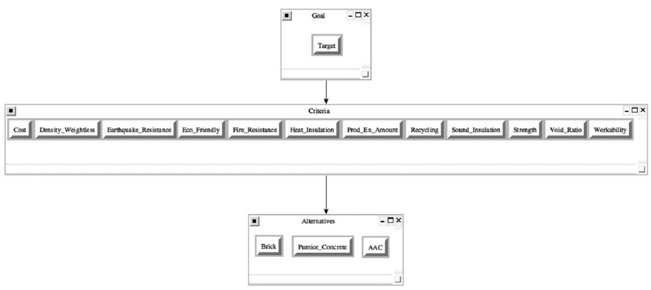


Fig. 1. Problem hierarchic structure.

The criteria used in a decision problem are compared with each other for each level and the obtained values are saved into matrix form. In comparison, mostly the Saaty scale and the values between 1 and 9 defined in this scale are used. The comparison values between criteria are saved in supra diagonal cells of the matrix. The

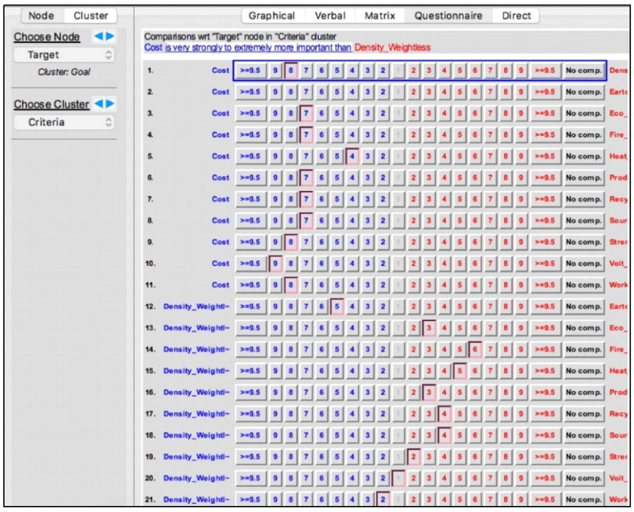


Fig. 2. Conversion of the information received from experts into group decision.

values under the diagonal will be saved as 1/supra diagonal value. Accordingly, if the supra diagonal elements are X_{ij}, the elements below the diagonal will be calculated as $X_{ji} = 1/X_{ij}$. For mathematically combining the preferences made by 5 experts and converting them into a group decision, geometric average of the binary comparison matrix elements was taken. For the solution of the established decision model and determination of the best alternative, SuperDecisions program was used. Converting the information received from the expert into a group decision was realized as shown in Fig. 2. With the help of these information, inconsistency ratio of the model can be calculated. In case the inconsistency value is greater than 0.01, the people who filled the survey are asked to refill the survey.

As a result of the comparisons made, inconsistency ratio of the model was calculated by the weight values of the criteria and the results were given in Table I. When these values are examined, it is observed that most important factor in wall material selection for decision makers is cost with a value of 0.360. This is followed by fire resistance (0.141), heat insulation (0.124), and sound insulation (0.123). The least important factor among the decision criteria was observed to be earthquake resistance (0.009). The inconsistency value of the model was found to be 0.092 by the program and as this value is lower than 0.1, the analysis result was found to be sufficient and consistent.

TABLE I
Weight values of the criteria and inconsistency ratio.

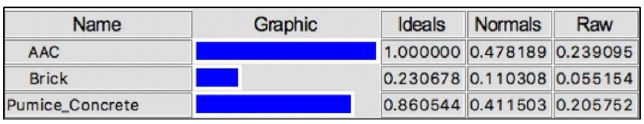
Inconsistency	0.092	
name	normalized	idealized
cost	0.360	1.000
density weightless	0.025	0.069
earthquake resistance	0.009	0.026
eco friendly	0.057	0.158
fire resistance	0.141	0.393
heat insulation	0.124	0.344
prod. en. amount	0.040	0.111
recycling	0.038	0.106
sound insulation	0.123	0.342
strength	0.026	0.071
void ratio	0.024	0.066
workability	0.032	0.090

The super matrix showing the importance comparison of the decision alternatives in terms of criteria is given in Table II. When the data here is examined it is observed that AAC has higher importance value compared to other alternatives in terms of all criteria.

Unweighted supermatrix criteria. TABLE II

	Cost	Density weightless	Earth. resist.	Eco friendly	Fire resist.	Heat insul.	Prod. en. amount	Recyc.	Sound ins.	Strength	Void ratio	Work.
AAC	0.385	0.760	0.685	0.472	0.665	0.454	0.433	0.454	0.368	0.528	0.779	0.767
brick	0.153	0.048	0.080	0.084	0.093	0.090	0.100	0.090	0.082	0.140	0.041	0.061
pumice concrete	0.461	0.191	0.234	0.444	0.245	0.454	0.467	0.454	0.550	0.332	0.180	0.171

When the super matrix above and Fig. 3 showing the importance level of the alternatives are combined, it was determined that AAC, with a value of 0.478, is the alternative that should be selected.



Name	Graphic	Ideals	Normals	Raw
AAC		1.000000	0.478189	0.239095
Brick		0.230678	0.110308	0.055154
Pumice_Concrete		0.860544	0.411503	0.205752

Fig. 3. Priority values of alternatives.

In Fig. 4, sensitivity analysis of the model was shown. By this analysis the effect of small changes in input values to the result can be observed. In the graph, vertical axis shows the priority values of the three alternatives and the horizontal axis shows the cost information.

By sensitivity analysis, the way how the best alternative changes can be examined when each criterion takes a different priority value. As seen in left part Fig. 4, threshold value is reached at approximately 66% value of cost criteria and in terms of AAC and pumice concrete.

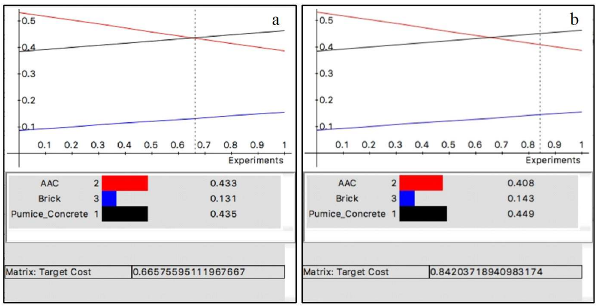


Fig. 4. Sensitivity analysis.

Below this threshold AAC and above this threshold pumice concrete takes the first place in terms of cost (Fig. 4, right).

3. Conclusion

Selection of the construction material that is compliant with the usage purpose of the structure and which will perform duty at an expected quality during the economic lifetime of the structure is one of the important problems of the construction sector. Construction material production sector is developing day by day and provides almost unlimited options to the sector. For selection of the material to be used in the structure although generally previous experiences are used, the high variety of the material options presented to the sector, necessitates the evaluation of the material with all its technical details during decision stage. In this study, analytical hierarchy method was used for the selection of wall material among brick, pumice concrete and AAC blocks to be used in a hotel construction. As a result of the analysis made with the help of evaluations made by experts of the subject it was concluded that the suitable material was AAC in terms of the criteria taken into consideration. At the end of the study, it was observed that AHP method can be applied in project basis with its application speed, ease of analysis and ability to reflect the opinion of many decision makers. For this reason it was concluded that AHP method can be effectively used in construction material selection. With this method, more detailed analyses can be made than other multi-criteria decision making methods. It is possible to compare each sub criteria with each other with AHP.

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