Selection Model For Plaster Materials On Construction Sites Using AHP

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Abstract: Material selection is an essential factor in construction industry which has a large impact on all stake holders as well as the environment. The precise choice of materials for a project requires considerations of aesthetic appeal, initial and maintenance costs, life cycle assessment considerations such as material performance, availability, impact on the environment and the ability to reuse, recycle or dispose the material at the end of its life. The Analytical Hierarchy Process (AHP) is a tool designed to solve Multi Criteria Decision Making (MCDM) problems. AHP enables us to investigate the relative importance of the criteria and alternatives for the identification of the best suited option for application to a particular project. This paper aims to demonstrate the application of AHP in selection of plaster material. Plastering process uses sand, cement and water in large quantities which may affect the environment adversely and other alternatives may cause unwanted outcomes and increased costs during the life cycle. In the present paper The AHP has been applied to the selection of proper plastering material from various alternatives for a residential building.

Index Terms: Analytical Hierarchy Process (AHP), Material Management, Material Selection, Multi Criteria Decision Making (MCDM), Plaster Material.

1 Introduction

AT the start of a building project, a frequently ignored factor is the choice of components to be used to finish the design. Selection of an effective material involves various criteria. Multi Criteria Decision Making (MCDM) is a sub-discipline of Operations Research that explicitly evaluates multiple conflicting criteria in decision making. MCDM is concerned with structuring and solving decision and planning problems involving multiple criteria which enable more informed and better decisions. Typically there is no 'one-size-fits-all' solution to such issues and it is essential to consider various stakeholder preferences to distinguish among alternatives. Tools like Analytic Hierarchy Process (AHP) provide clear idea to the management with regards to their requirements and goals.

Each criterion has its own importance therefore its relative importance is analyzed for solution of this problem. Plastering alternatives may use river sand, cement, and water in large quantities thus having a substantial environmental impact. Internal plastering for residential buildings as widely observed in Indian conditions is done using the following three alternatives: Sand Cement Plaster, Lime Plaster and Gypsum Plaster. This study focuses on the plaster material selection for a particular residential project in Pune, India.

2 Objectives

1) To identify various criteria for assessment of plaster material selection.
2) Obtain relative importance of criteria with respect to the alternatives.
3) To demonstrate use of AHP application for effective plaster material selection.

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3 Selection of Alternatives and Criteria for Internal Plastering

The alternatives for internal plastering must be easily available in the local market, must be within budget and easy to apply. Internal plastering for residential buildings as widely observed in Indian conditions is done using the following three alternatives:

Conventional Cement Sand Plaster

The conventional plaster uses a mix of sand and cement to provide finishing layer on the wall surface, create moldings and internal decoration purpose. Cement plaster is most commonly used due to low cost and easy availability of cement and labor.

Lime Plaster

Lime Plaster is a fascinating material that has been around for a considerable length of time. It is ideal for internal plastering as it is profoundly strong. Lime mortar is adequately strong and impervious to natural components to be utilized for plastering. The high pH of lime in the mortar works as a fungicide and does not allow mold to develop in the mortar. Lime is called a "breathable" material meaning that it allows air and humidity to pass freely. This ensures moisture buildup is avoided.

Gypsum Plaster

Gypsum is a yielding sulphate mineral that consists of Calcium sulphate di hydrate ($CaSO_4$, $2H_2O$). It is very light and has a chalk like texture. Plaster of Paris is obtained by pulverizing the gypsum where it is heated to temperatures beyond 150°C. It is extremely simple to apply and mold gypsum mortar. Gypsum reaction delivers less heat while curing as opposed to cement which causes less shrinkage splits. It sets rapidly so painting could begin within 72 hours after application of plaster.

3.1 Assessment Criteria Identification:

Selection of the best plaster finish cannot be done considering only a few aspects and criteria. Thus Multi

Criteria Decision Making methods analyze the importance of different criteria and offer a best possible solution for the selection problem. The criteria for ideal material are chosen from extensive literature review, study of market conditions and the preferences of project stakeholders. To present the best alternative, the following criteria are chosen:

1) Cost
2) Durability
3) Curing
4) Availability of Raw Materials (AoRM)
5) Impact on Environment (IoE)

A brief detail of various criteria is presented in Table 1 below.

TABLE 1
CRITERIA SPECIFICATIONS AGAINST ALTERNATIVES

	Lime Plaster	Gypsum Plaster	Cement Sand Plaster
Cost	It is cheaper than Gypsum and Cement sand plaster	It is costlier than Lime	It is costlier than Gypsum plaster and Lime plaster due to non-availability of river sand.
Durability	Less shrinkage compared to both and resistant to cracks.	It has a life span of excess of 50 years.	Lifespan of cement sand plaster is about 25 or 30 years. Shrinkage cracks occur quite frequently.
Curing	Lime mix should be kept wet for minimum 72 hours and allowed to dry out slowly.	Gypsum plaster does not need water for curing.	After plastering it is advised to cure the cement with water for at least 15 days.
AoRM	It is composed of lime and aggregate such as sand, mixed with water. Availability of river sand is concern.	Gypsum plaster does not need sand. So it is easily available.	It is a uniform mix of cement and sand with water. Natural river sand is not easily available in cities like Pune.
IoE	Excessive quarrying can harm natural habitats.	Disposing gypsum in landfills can pollute soil and ground water resources.	The cement industry causes NO2 and CO2 emissions. It has high embodied energy.

(Source: Compiled by author)

4 AHP APPLICATION FOR PLASTER MATERIAL SELECTION

A questionnaire is formed to record the expert judgment of the project management team and obtain relative importance of various criteria under consideration. The data collected from these questionnaires is presented in tabular form, ANNEXURE). The Geometric mean for all criteria is calculated and the derived values are used to form a pair wise comparison matrix (see, Table 2).

TABLE 2
PAIR WISE COMPARISON MATRIX FOR CRITERIA

	Cost	Durability	Curing	AoRM	IoE
Cost	1.00	4.7177	5.5934	1.4422	6.8919
Durability	0.2120	1.00	1.5704	0.2341	2.4662
Curing	0.1788	0.6368	1.00	0.4055	2.2649
AoRM	0.6934	4.2716	2.4662	1.00	3.1369
IoE	0.1451	0.4055	0.4415	0.3188	1.00
TOTAL	2.2292	11.0316	11.0716	3.4006	15.76

(Source : APPENDIX)

The pair wise scores of every individual criterion are divided by the sum total of all scores of that row to obtain a Normalized Pair Wise matrix (see Table 3). The average of sum of all scores for each criterion gives the Criteria weights (CW).

TABLE 3
NORMALIZED PAIR WISE COMPARISON MATRIX FOR CRITERIA

	Cost	Durability	Curing	AoRM	IoE	TOTAL	CW
Cost	0.4485	0.4276	0.5052	0.4241	0.4373	2.242	0.4485
Durability	0.0950	0.0906	0.1418	0.0688	0.1564	0.552	0.1105
Curing	0.0801	0.0577	0.0903	0.1192	0.1437	0.491	0.0982
AoRM	0.3110	0.3872	0.2227	0.2940	0.1990	1.414	0.2828
IoE	0.0650	0.0367	0.0398	0.0937	0.0634	0.298	0.0597

Further, pair wise comparison of every individual alternative is done against each criteria and a normalized matrix is generated to obtain its weights. The pair wise comparison and normalized matrix for overall cost gives the score of cost criteria for all alternatives. (See Table 4 & 5)

TABLE 4
PAIR-WISE COMPARISON MATRIX FOR OVERALL COST

	Sand Cement Plaster	Lime plaster	Gypsum plaster
Sand Cement Plaster	1.0000	0.1947	0.5848
Lime plaster	5.1369	1.0000	2.3956
Gypsum plaster	1.7100	0.4174	1.0000
TOTAL	7.8469	1.6121	3.9804

(Source: APPENDIX)

TABLE 5
NORMALIZED PAIR-WISE COMPARISON MATRIX FOR OVERALL COST

	Sand Cement Plaster	Lime plaster	Gypsum plaster	TOTAL	Avg. Score
Sand Cement Plaster	0.1274385	0.1207542	0.1469214	0.395114	0.13170
Lime plaster	0.6546444	0.6203072	0.6018463	1.876798	0.62559
Gypsum plaster	0.2179169	0.2589384	0.2512322	0.728088	0.24269

The pair wise comparison and normalized matrix for durability gives the score of durability criteria for all alternatives. (See Table 6 & 7)

TABLE 6
PAIR-WISE COMPARISON MATRIX FOR DURABILITY

	Sand Cement Plaster	Lime plaster	Gypsum plaster
Sand Cement Plaster	1.0000	0.1470	0.2582
Lime plaster	6.8041	1.0000	3.5569
Gypsum plaster	3.8730	0.2811	1.0000
TOTAL	11.6771	1.4281	4.8151

(Source: APPENDIX)

TABLE 7
NORMALIZED PAIR-WISE COMPARISON MATRIX FOR DURABILITY

	Sand Cement Plaster	Lime plaster	Gypsum plaster	TOTAL	Avg. Score
Sand Cement Plaster	0.08563788	0.1029121	0.0536228	0.242173	0.08072
Lime plaster	0.58268803	0.7002239	0.7386968	2.021609	0.67387
Gypsum plaster	0.33167408	0.1968639	0.2076803	0.736218	0.24541

The pair wise comparison and normalized matrix for curing gives the score of Curing criteria for all alternatives. (See Table 8 & 9)

TABLE 8
PAIR-WISE COMPARISON MATRIX FOR CURING

	Sand Cement Plaster	Lime plaster	Gypsum plaster
Sand Cement Plaster	1.0000	0.3376	0.1278
Lime plaster	2.9618	1.0000	0.2582
Gypsum plaster	7.8254	3.8730	1.0000
TOTAL	11.7872	5.2106	1.3860

(Source: APPENDIX)

TABLE 9
NORMALIZED PAIR-WISE COMPARISON MATRIX FOR CURING

	Sand Cement Plaster	Lime plaster	Gypsum plaster	TOTAL	Avg. Score
Sand Cement Plaster	0.084838	0.0647977	0.0922006	0.241837	0.08061
Lime plaster	0.251270	0.1919157	0.1862923	0.629478	0.20982
Gypsum plaster	0.663891	0.7432864	0.7215069	2.128685	0.70956

The pair wise comparison and normalized matrix for availability of raw materials gives the score of Availability of raw materials criteria for all alternatives. (See Table 10 & 11)

TABLE 10
PAIR-WISE COMPARISON MATRIX FOR AVAILABILITY OF RAW MATERIAL

	Sand Cement Plaster	Lime plaster	Gypsum plaster
Sand Cement Plaster	1.0000	0.3376	0.1470
Lime plaster	2.9618	1.0000	0.2004
Gypsum plaster	6.8041	4.9898	1.0000
TOTAL	10.7659	6.3275	1.3474

(Source: APPENDIX)

TABLE 11
NORMALIZED PAIR-WISE COMPARISON MATRIX FOR AVAILABILITY OF RAW MATERIAL

	Sand Cement Plaster	Lime plaster	Gypsum plaster	TOTAL	Avg. Score
Sand Cement Plaster	0.092886	0.0533605	0.109078	0.255326	0.08510
Lime plaster	0.275107	0.1580415	0.148739	0.581888	0.19396
Gypsum plaster	0.632006	0.7885979	0.742181	2.162786	0.72092

The pair wise comparison and normalized matrix for impact on environment gives the score of Impact on Environment criteria for all alternatives. (See Table 12 & 13)

TABLE 12
PAIR-WISE COMPARISON MATRIX FOR IMPACT ON ENVIRONMENT

	Sand Cement Plaster	Lime plaster	Gypsum plaster
Sand Cement Plaster	1.0000	0.5302	0.3521
Lime plaster	1.8860	1.0000	0.2811
Gypsum plaster	2.8403	3.5569	1.0000
TOTAL	5.7262	5.0871	1.6332

(Source: APPENDIX)

TABLE 13
NORMALIZED PAIR-WISE COMPARISON MATRIX FOR IMPACT ON ENVIRONMENT

	Sand Cement Plaster	Lime plaster	Gypsum plaster	TOTAL	Avg. Score
Sand Cement Plaster	0.1746345	0.1042298	0.2155731	0.494438	0.16481
Lime plaster	0.3293559	0.1965747	0.1721407	0.698071	0.23269
Gypsum plaster	0.4960095	0.699195	0.6122861	1.807491	0.60249

The scores for every alternative against individual criteria are as noted in Table 14. This score is multiplied by the weight of those particular criteria to obtain weighted scores for every alternative. This weighted score is used a gauge to select the best possible material.

TABLE 14
WEIGHTED SCORE FOR PLASTER SELECTION

CRITERIA	WEIGHT	ORIGINALSCORE			WEIGHTEDSCORE		
		Sand Cement Plaster	Lime plaster	Gypsum plaster	Sand Cement Plaster	Lime plaster	Gypsum plaster
Overall cost	0.4485	0.13170	0.62559	0.24269	0.059067	0.280577	0.108846
Durability	0.1105	0.08072	0.67387	0.24541	0.00892	0.074463	0.027118
Curing	0.0982	0.08061	0.20982	0.70956	0.007916	0.020604	0.069679
Availability of material	0.2828	0.08510	0.19396	0.72092	0.024066	0.054852	0.203876
Impact on environment	0.0597	0.16481	0.23269	0.60249	0.009839	0.013892	0.035969
Total		0.54294	1.93593	2.52107	0.109808	0.444388	0.445488

5 RESULTS

The final Analysis of all data using the AHP tool gives us the following results:

1) Lime plaster has weighted score of 0.28 for its overall cost and 0.07 for durability. Thus, on the basis of overall cost and durability it is more preferable.
2) Gypsum plaster is preferable on the basis of Curing with weighted score of 0.069, availability of materials score 0.203 and impact of environment with score 0.035
3) From sum of weighted score, lime plaster and gypsum plaster have scores 0.4443 and 0.4454 respectively. These alternatives are preferred over sand cement plaster with a score of 0.1098

6 CONCLUSION

The results obtained after analysis using AHP help to reach a balanced and well informed decision with regards to selection of the best possible alternative keeping in mind various different criteria. If Builder wants less cost and more durability, then Lime plaster is best alternative. But if sand is not available (raw material in lime plaster) then the second best alternative could be Gypsum plaster as sum weighted score of both is nearly same. For future works, using computer based applications for AHP calculations can increase precision and a large amount of data can be processed with ease. This will also allow the user to combine machine learning and Artificial Intelligence with the MCDM methodology.

ACKNOWLEDGMENT

The authors wish to thank everyone at Orange County Group, Pune. This work would not have been possible without their contributions and assistance.

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