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MATERIALS OR SYSTEMS EVALUATION AND SELECTION

Materials evaluation and selection can be done via unstructured or structured approaches. The former is more common and is based mainly on the experience of the individual guided by the stated or implied requirements which are then matched with the properties of the available materials. By a process of elimination a set of viable options are arrived at and the final selection made by more refined considerations. Frequently however, the final choice is made merely on the individual's familiarity with the optional materials. The structured approach to materials evaluation and selection parallels the modern process of tender evaluation and selection of contractors. This approach is more amenable to computer automation and can therefore result in a faster, more reliable, and consistent process. The software can range in sophistication from a set of simple spreadsheets, to a comprehensive application incorporating a database and quantitative management tools such as Decision Theory.

Materials evaluation and selection is really concerned with two major areas: (1) the evaluation of a new material and (2) the evaluation and selection of materials for use in a new project.
New materials can actually be separated into two distinct categories: (a) those that are manufactured to meet an existing standard and (b) those that are unique in that no standard exists against which they can be measured and therefore require an investigation and assessment as to the claims of the manufacturer.

New materials that fall into the first category are readily evaluated against a product standard. Good product standards are the result of systematic technical research efforts combined with committee work such as ASTM and ANSI American standards, and the BSI and EN standards for the UK and Europe. These standards establish suitable physical and/or chemical properties that for the most part have a direct relation to performance. Through use these standards are upgraded as additional knowledge of a product's performance is obtained from the field. New products that are claimed by the manufacturer as meeting a product standard can therefore be quite readily evaluated against the product standard.

New products marketed without comprehensive reference to product standards require a more generalised evaluation and/or selection methodology. There is, however, a basic tool that can be utilized to establish a rational approach for the investigation and evaluation of materials, products, and systems for which there are either no known standards, nor a set of comprehensive standards that entire cover the material. This tool is the performance concept in which performance requirements are listed in terms of properties or characteristics.

In this section, basic general considerations towards the formulation of a structured approach to materials evaluation and selection is presented for the more general case of a new material or product not manufactured to meet specific standards.

General Procedure for Materials Evaluation and Selection

The general procedure can be described as:

1. Identify performance required
2. Establish evaluation criteria
3. Acquire test results where not available
4. Acquire historical information
5. Select a range of optional materials or products
6. Develop an evaluation matrix for each optional material
7. From 6, develop a rating matrix for each optional material or product.

In the next section item 6 is expanded on. At this point it is important to note that the evaluation and selection processes, though having different objectives are similar.

When evaluating a material for a specific application, the objective is to determine the relevant capabilities of the material in terms of the required properties. Hence the essence of the evaluation process is determining how the material responds to tests in terms of the required properties. For example, for using concrete roofing, a property deemed necessary for checking may be its thermal transmittance. This property can then be evaluated via an appropriate test. Hence one may be able to say that a concrete roof has poor thermal transmittance properties thereby concluding the evaluation (for that property).

When selecting a material for a specific application the essence of the process is comparing the evaluated properties of the material with threshold values that represent necessary performance levels.

Evaluation Matrix

As we examine the concept of performance we recognize that a structured approach to materials evaluation and selection can be achieved based on the development of matrices. The system for rational evaluation consists of two basic ingredients: (1) a checklist consisting of several broad qualitative headings or performance requirements that are then expanded to a series of subordinate properties or characteristics and (2) a method of assessing and measuring the performance characteristics or criteria. A matrix can then be prepared that permits the user to subject any new material to comprehensive investigation and evaluation. The checklist's broad qualitative headings can be reduced to eleven major performance requirements as follows:

1. Structural serviceability
2. Fire safety
3. Habitability
4. Durability
5. Practicability
6. Compatibility
7. Maintainability
8. Code Acceptability
9. Economics
10. Local availability
11. Functionality

To understand each of these major performance requirements or "attributes" the following generalizations can be made for each category.

1. *Structural Serviceability.* Includes resistance to natural forces such as wind and earthquake; structural adequacy and physical properties such as strength, compression, tensile forces, shear, and behavior against impact and indentation.

Note: For specific "materials" where structural serviceability is not a factor, the investigation into this performance requirement is not applicable.

2. *Fire Safety.* Includes resistance against the effects of fire such as flame propagation, burn through, smoke, toxic gases, etc.

3. *Habitability.* Includes livability relative to thermal efficiency, acoustic properties, water permeability, optical properties, hygiene, comfort, light and ventilation, etc.

4. *Durability*. Includes ability to withstand wear, weather resistance such as ozone and UV, dimensional stability, etc.

5. *Practicability*. Ability to surmount field conditions such as transportation, storage, handling, tolerances, connections, site hazards, etc.

Note.- Transportation of huge prefabricated elements will require investigation with respect to roads, bridges, and tunnels to assure passage. Investigation of tolerances of dissimilar elements such as a concrete frame or a structural steel frame to receive precast concrete or metal and glass curtain walls.

6. *Compatibility.* Ability to withstand reaction with adjacent materials in terms of chemical interaction, galvanic action, ability to be coated, etc.

Note: In using a sealant will it stain adjacent surfaces, will there be any chemical interaction with other backup materials?

7. *Maintainability.* Ease of cleaning, repairability of punctures, gouges and tear, recoating etc.

Note: For factory baked-on paint finishes, are there any satisfactory retouching materials to cover scratches or other minor defects resulting from installation or use?

8. *Code Acceptability*. Includes review of code and manufacture's claims as to code compliance. This includes sustainability codes such as LEED, BREEAM, etc.

9. *Economics.* Includes installed costs, maintenance costs, budgetary limitations. May also include results of cost/benefit analysis, NPV, or other economic evaluation indices.

10. *Local Availability.* Considers whether the material must be imported and if so, the lead time required.

11. *Functionality.* Considers its ease of use or user-friendliness.

Each of these groups can be expanded in terms of properties of give a comprehensive list. In actual use, the list may be shortened to suit the specific case.

A matrix can then be developed comprising of the aforementioned headings 1 to 11 in column-1, the properties in column-2, the test method in column-3, the test result in column-4, the threshold value in column-5, and an indication that the test result satisfies the threshold value (e.g. a "tick" mark), in column-6.

If a simple evaluation is being performed (i.e. not part of a selection process), only columns 1 to 4 are required. Otherwise, add columns 5 and 6.

EXAMPLE 1
The following is an example evaluation for a product called "Siporex" (a lightweight concrete) for use as an exterior wall.

Evaluation of Siporex as a an External Wall

Performance Requirement	*Property*	*Test Method*	*Result*	*Desired Value*	*Pass/Fail*
1. Structural Stability	1.1 Impact resistance	ASTM E-72, Section 13			
	1.2 Modulus of rupture	ASTM C683			
	1.3 Support for attached loads	Bookshelf at 40 lb/lin. ft			
	1.4 Wind resistance	Apply 50 lb/sq. ft for I min and report damage			
	1.5 Compressive load	ASTM E-72, Section 7			
	1.6 Pull-out resistance	Analysis or physical simulation			
	1.7 Seismic resistance	Analysis or computation			
	1.8 Cut-out for service elements-mechanical electrical	Analysis or physical simulation			
	1.9 Puncture resistance				
	1.10 Resistance to point impact	Fed. Test Method Std. 406, Method 1074.			
2. Fire Safety	2.1 Fire endurance	ASTM E19	8 in. block-4 hrs.		
	2.2 Flame spread	ASTM E84			
	2.3 Smoke developed	ASTM E84			
	2.4 Toxicity	Animal inhalation test			
3. Habitability	3.1 Thermal Properties				
	3. 1.1 Thermal conductivity	"K" factor ASTM C177	0.81		
	3.1.2 Thermal expansion	ASTM E228	4.5 x 10-6		
	3.1.3 Thermal shock	Rapid heating and cooling			
	3.2 Acoustic Properties				
	3.2.1 Sound transmission	ASTM E90			
	3.2.2 Sound reverberation	ASTM C423			
	3.2.3 Sound absorption	ASTM C423			
	3.3 Water Permeability				
	3.3.1 Water absorption	ASTM C140			
	3.3.2 Permeability	Fed. Spec. TT-P-0035 (E514)			
	3.3.3 Water vapor transmission	ASTM C355			
	3.3.4 Moisture Expansion and Drying shrinkage	ASTM C426	0.07		

Note: Since the material will take on water it is essential to protect elements from condensed moisture that could impair structural adequacy through deterioration. Provide adequate vapor barriers, ventilation, breathing coatings, etc. to keep moisture out or to expel moisture.

4. Durability	4.1	Resistance to wear	
		4.1.1 Abrasion resistance	ASTM C501
		4.1.2 Resistance to scratching	Pencil hardness test
	4.2	Weathering	
		4.2.1 Weather resistance	ASTM C217
		4.2.2 Freeze-thaw	ASTM C666
		4.2.3Acid resistance	ASTM D543
		4.2.4 Appearance after weathermeter test	ASTM G-23
	4.3	Adhesion of coatings	
		4.3.1 Delamination	ASTM C481

Note: Since resistance to wear and weathering appear to be low, applied coatings and coverings are essential. Recommended coatings and coverings must be chosen and selected to safeguard the basic material from the effects of wear and weather.

5. Practicability	5.1	Transport	
		5.1.1 Limitations with respect to size, weight, handling	Analysis/physical simulation
	5.2	Storage on site	
		5.2.1 Protective against elements	Must be protected from water
	5.3	Handling during installation	
		5.3.1 Abrasion	Patching methods essential to overcome these problems
		5.3.2 Breakage	
		5.3.3 Scaring	
	5.4	Field tolerances	
		5.4.1 Corrective measures	Material readily cut in field.
	5.5	Dimensional stability	
		5.5.1 Warpage due to: Heat Wetting	Analysis/physical situation
	5.6	Connections	
		5.6.1 Inserts	

Note.- Inserts must be corrosion resistant. Connections must develop pull-out resistance anticipated.

6**.** Maintenance	6.1 Compatibility of Coatings	
	6.1.1 Interaction	
	6.1.2 Delamination	
	6.2 Graffiti Resistance	
	6.2.1 Ability to resist and clean	
	6.3 Indentation and Puncture	
	6.3.1 Patching Materials	

Note. Recommended coatings must be investigated to ascertain compatibility and resistance to graffiti attack. Patching methods must be simple and effective.

7. Compatability	7.1 Jointing Materials	
	7.1.1 Adherance of sealants	Fed. Spec. TT-S-227
	7.1.2 Staining of sealants	
	7.2 Coatings	
	7.2.1 Ability to receive and retain coatings	ASTM C481
	7.3 Galvanic Interaction or Corrosion Resistance of inserts and attachments	
	7.3.1 Steel	Physical simulation
	7.3.2 Aluminum	tests
	7.3.3 Wood	
	7.3.4 Metallic conduit	

Note.- Applied coatings, sealants, inserts and adjacent materials must be investigated for compatibility.

EXAMPLE 2 - Evaluation of Siporex as a Floor-Ceiling-Roof and Partition

Note.- See Example 1 for the requirements for Siporex as an exterior wall material and add the following requirements.

Requirement	*Criterion*	*Test Method*	*Results*
1. Acoustic properties	1.1Impact Sound	Topping Machine ISO R140	
2. Structural	2.1Impact Resistance	ASTM E72	
	2.2Occupancy Loads		
	2.3Deflection		
	2.4Concentrated Loads		
3. Compatibility			
	3.1 Adhesive Floor Cover		
	3.2 Chemical Resistance		
4. Habitability			
	4.1Floor Coverings	Fed Spec.	
	Moisture Protection	TI-C-00555	

Final Decision

The selection process allows the formation of a group of optional materials for the case in question. To complete the aforementioned general procedure a rating matrix must be established for each option. This can be arranged to facilitate collective decision-making by including the various members of the Project Team.

Weighting factors are determined based on consultation with the Owner and a numerical rating system is determined for each performance requirement in the evaluation matrix. The rating matrix consists of two main areas – the objective evaluation based on the test results and historical information, and a subjective evaluation based on the views of the key members of the Project Team.

The total points are tallied and an average rating determined by dividing the total points by the number of main requirements headings (in our case this equals 11). A rating matrix is prepared for each material, and the one with the highest average rating is the final choice.

A rating system can be as follows:

8 = Excellent satisfaction
7 = Good satisfaction
6 = Average satisfaction
5 = Moderate satisfaction
4 = Poor satisfaction
3 = No satisfaction
2 = Very unsatisfactory
1 = Totally incompatible
0 = No relation
X = Unknown

The following is what a rating matrix can look like for the case of Brand "X" for application as a Roof Insulating Material.

Hence for "Brand X" the final rating is 576/11 = 52.36