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Development of an Evaluation System for Comprehensive Environmental Performance of Finishing Materials

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ABSTRACT

To allow the designers effective selection of finishing materials with a high environmental performance, the authors have developed an evaluation system for the comprehensive environmental performance of finishing materials. Using the present system, they may compare the environmental performance of individual finishing materials of a building on a construction part-basis from the standpoints of eight criteria. First, the eight evaluation criteria were established based on such building comprehensive environmental performance evaluation systems as BREEAM, LEED and CASBEE. Then, evaluation method was selected such as a point system and standards set on a building part-basis. Evaluation standards were finalized for each building part by a questionnaire survey to the manufacturers of the finishing materials. This evaluation system has been applied to proposing "Eco"-friendly materials in, for example, competitions. A future plan includes improvement of the system making more effective and accurate evaluations possible by incorporating feedbacks from the designers.

Keywords. "Eco"-friendly material, Finishing materials, Evaluation system, Environmental performance, Questionnaire survey

1. INTRODUCTION

To cope with growing concerns on global warming, Evaluation Systems for Comprehensive Environmental Performance (ESCEP, hereafter) for the building such as BREEAM, LEED and CASBEE have appeared. The designers are required to select construction materials with comprehensively high environmental performance in addition to improving the conventional amenity. In Japan, evaluation systems for the environmental performance of construction materials, such as Ecomark and Green Purchasing law are present. However, the majority of them are merely certification systems for usage of recycled materials and, furthermore, evaluation criteria and standards vary from an evaluation system to another. As a result, the designers often face difficulties with effectively choosing construction materials with comprehensively high environmental performance, especially those used for finishing. Among the conventional construction materials, skeleton materials are said to bear the major portions of the environmental load. On the other hand, CO_2 emission from finishing materials has been found to reach approximately 18% of the total CO_2 emission from the entire construction materials in RC structure, whereas it occupies approximately 24% in steel structure. Therefore, to allow the designers to effectively select finishing materials with comprehensively high environmental performance for every building part, the authors have developed ESCEP for finishing materials. This system has three characteristics: comprehensive environmental performance evaluation, point system evaluation, and standards on a building-part basis, as shown in Figure 1. The system consists of an input sheet and a result sheet for every one of 8 building-parts. The designers input points for minor criteria in the input sheet based on the physical properties of candidate finishing materials (STEP1 in Figure 1), and then the points of secondary and primary criteria are calculated automatically (STEP2 in Figure 1). Finally, the designers may compare the environmental performance of individual finishing materials of a building on a construction part-basis from the standpoints of eight criteria and select finishing materials with comprehensively high environmental performance (STEP3 in Figure 1).An example for the system usage is shown in Figure 2. The designer selected Paint A and Tile B as candidates for outer wall surface. As a result of evaluation with ESCEP for finishing materials, the primary points of Paint A and Tile B are, respectively, 0.85 and 0.98; hence, the designer will select Tile B as outer wall surface. The development procedure is shown schematically in Figure 3. In the next section, eight evaluation criteria based on those used by the present ESCEP of the building are described. In section 3, evaluation methods applied to the system are described, such as a point system evaluation and eight candidate building parts where standards are set up. In section 4, evaluation standards for the eight criteria are established individually for building parts based on environmental performance of general finishing materials derived from a questionnaire survey to the finishing material manufacturers.

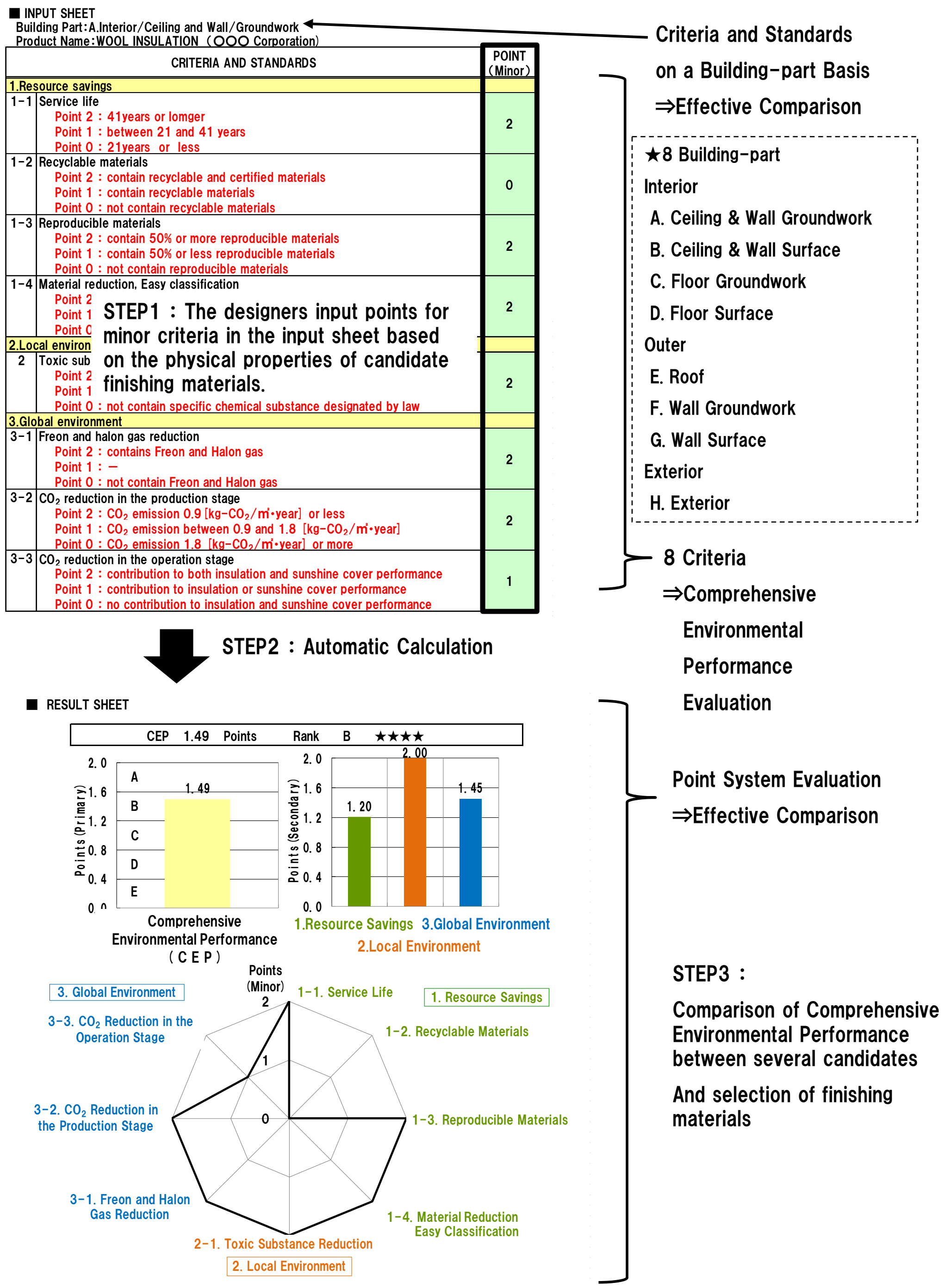
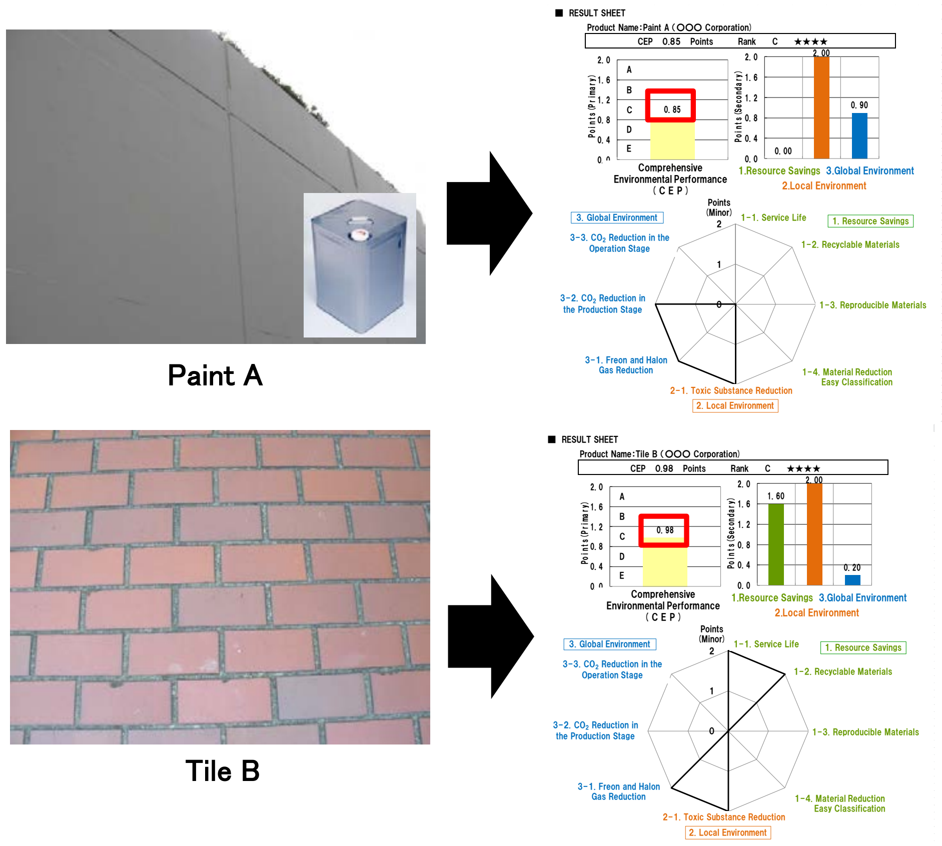


Figure 1. Characteristics and operation procedure of ESCEP for finishing materials

Which is the proper selection for the outer wall surface, Paint A or Tile B?
Paint A : not contain specific chemical substance designated by law !
Tile B : contain recyclable and certified materials !



Comprehensive Environmental performance
Paint A : 0.85 points
Tile B : 0.98 points ←◎Higher, therefore to be selected

Figure 2. A usage example of ESCEP of finishing materials

2 SETTING CRITERIA
↓
3 SETTING EVALUATION METHOD
  3.1 Point system evaluation method
  3.2 Standards on a building part-basis
↓
4 SETTING STANDARDS TO EACH BUILDING PART AND CRITERION
  4.1 Listing-up finishing materials for every building part
  4.2 Questionnaire survey to the finishing material manufacturers
  (on the environmental performance of the finishing materials)
  4.3 Analysis of the survey results for setting evaluation standards

Figure 3. Flowchart of the development procedure

2. SETTING CRITERIA

From the criteria for finishing materials in ESCEP for the building, the eight new criteria are set as in Table 1. They are based mainly on the standpoint of the environmental load reduction which is seriously related to environmental problems outside the building such as global warming. ESCEP for finishing materials constitutes the primary criterion, while conservation of resources, local environment and global environment are assigned as the secondary criteria. For minor criteria, the following eight are selected: 1-1. service life, 1-2. recyclable materials, 1-3. reproducible materials, 1-4. material reduction, 2-1. toxic-substance reduction, 3-1. Freon and halon gas reduction, 3-2. CO_2 reduction in the production stage, and 3-3. CO_2 reduction in the operation stage.

Table 1. New criteria selected

Primary	Secondary	Minor
Comprehensive environmental load reduction	1.Resource savings	1-1.Service life
		1-2.Recyclable materials
		1-3.Reproducible materials
		1-4.Material reduction, Easy classification
	2.Local environment	2-1.Toxic substance reduction
	3.Global environment	3-1.Freon and halon gas reduction
		3-2.CO_2 reduction in the production stage
		3-3.CO_2 reduction in the operation stage

3. EVALUATION METHOD

3.1 Point system evaluation method

In order to facilitate comparison of finishing materials, a point system evaluation method is used. Specifically, the raters such as the designers assign a point ranging from 0 to 2 points to each minor criterion (see Table 1). Consequently, points for the secondary and primary criteria are calculated automatically.

3.2 Standards on a building part-basis

Although evaluation standards for each finishing materials or building parts may be set individually, it is a common practice of the designers to choose finishing materials to every building part. In addition, their performance varies depending on the specific building parts used even for same finishing materials. Hence, we decided to set standards on a building part-basis. The classification of a building part for setting standards are provided in Table 2. The building parts are divided into eight by referring to JASS26: Interior Decoration

Construction. First, building parts are grouped by interior, outward, and exterior. Then, the "interior" is further sub-divided into ceiling and wall ground work, ceiling and wall surface, and floor ground work and floor surface. Similarly, the "outward" is split to roof, and wall groundwork and wall surface.

Table 2. Classification of the building parts

No.	Building Parts			No.	Building Parts		
A	Interior	Ceiling Wall	Groundwork	E	Outer	Roof	
B			Surface	F		Wall	Groundwork
C		Floor	Groundwork	G			Surface
D			Surface	H	Exterior		

4 SETTING STANDARDS TO EVERY BUILDING PART AND CRITERION

4.1 Listing-up finishing materials for every building part

Since the characteristics of finishing materials differ by their applications in the building, 661 finishing materials are initially picked up by studying 20 real buildings for 10 sets of usage plans and specifications, as shown in detail in Table 3. Furthermore, a total of 302 finishing materials are extracted as the general finishing materials out of the 661 products, see Table 4 for more information.

Table 3. The number of the finishing materials broken down into usage and building parts used in the studied buildings

Usage	The number of studied buildings	The number of the finishing materials grouped by usage and parts			
		A	B	C	D
		Interior Ceiling,Wall Groundwork	Interior Ceiling,Wall Surface	Interior Floor Groundwork	Interior Floor Surface
Hospital	2	13	17	2	26
Temple	2	4	9	2	8
House	2	2	21	0	21
Leisure facility	1	1	10	3	12
Hotel	1	1	12	1	12
R&D Lab.	3	11	28	3	27
Factory	5	17	20	5	30
Distribution facility	2	7	9	0	8
Office	2	25	37	10	38
Sub total	20	81	163	26	182

Usage	The number of studied buildings	The number of the finishing materials grouped by usage and parts			
		E	F	G	H
		Outer Roof	Outer Wall Groundwork	Outer Wall Surface	Exterior
Hospital	2	2	2	14	2
Temple	2	0	0	7	1
House	2	3	0	11	3
Leisure facility	1	7	4	10	2
Hotel	1	3	0	5	1
R&D Lab.	3	5	0	8	2
Factory	5	11	3	9	4
Distribution facility	2	6	1	8	4
Office	2	16	4	28	23
Sub total	20	53	14	100	42
				Ground Total	661

Table 4. The number of the general finishing materials for each building part

Building part	A Interior Ceiling,Wall Groundwork	B Interior Ceiling,Wall Surface	C Interior Floor Groundwork	D Interior Floor Surface
The number of the finishing materials	43	53	16	74
Building part	**E Outer Roof**	**F Outer Wall Groundwork**	**G Outer Wall Surface**	**H Exterior**
The number of the finishing materials	30	5	62	19
			Total	302

4.2 Questionnaire survey to the finishing material manufacturers

To find out the environmental performance of the general finishing materials extracted in the previous subsection 4.1, a questionnaire survey is conducted based on the eight criteria set in section 2 by contacting 123 finishing material manufacturers. See Table 5 and 6 for the content of the questionnaire survey. In addition, calculation is made of the amount of CO_2 emission in 3-2. (CO_2 reduction in the production stage) by a process method based on the energy consumption in the factory.

Table 5. Questionnaire items to the finishing material manufacturers (Resource conservation and Local environment)

1　Resource conservation
1−1　Service life
(1) Normal service life (Period of time without malfunctions, necessary repair, or renewal) (2) Possible reasons and time periods if service life is shortened or prolonged (3) Basis for the stated service life　(example) Outdoor exposure testing
1−2　Recyclable materials
(1) Contains recyclable materials? (2) Certified materials?　(example) Ecomark, Green Purchasing Law (3) Product name and content ratio (with calculation method) of recyclable materials
1−3　Reproducible materials
(1) Contains reproducible materials, such as certified woods? (2) Product name and content ratio (with calculation method) of reproducible materials
1−4　Material reduction, Easy classification
(1) Any contrubition to reducing materials? (2) Any contrubition to easy classification? (3) Any other noteworthy points?
2　Local environment
2−1　Toxic substance reduction
(1) Any specific chemical substance designated by law*? (2) Product name and content ratio (with calculation method) of spacific substance (3) Any other toxic substances of health hazards?

*Act on Confirmation, etc. of Release Amounts of Specific Chemical Substances in the Environment and Promotion of Improvements to the Management Thereof

Table 6. Questionnaire items to the finishing material manufacturers (Global environment)

3	Global environment
3-1	Freon and halon gas reduction
(1) Contains Freon and halon gas?	
(2) Product name of GDP and/or GWP	
3-2	CO_2 reduction in the production stage
(1) Annnual production by volume or weight	
(2) Annual primary energy consumption	
3-3	.CO_2 reduction in the operation stage
(1) Contribution to insulation and/or sunshine cover performance	
(2) Quantitative information on improvement	

The answer rate for individual parts and criteria are listed in Table 7. It ranges for 50-88.4% except for item 3-2 mentioned above, which turns out to be low answer rates of 21.6-40%.

Table 7. Answer rate per part and criterion

Building Part		A Interior Ceiling,Wall Groundwork	B Interior Ceiling,Wall Surface	C Interior Floor Groundwork	D Interior Floor Surface
1.Resource savings					
1-1	Service life	72.1	54.7	50.0	52.7
1-2	Recyclable materials	88.4	69.8	62.5	81.1
1-3	Reproducible materials	88.4	71.7	56.3	82.4
1-4	Material reduction, Easy classification	83.7	62.3	62.5	67.6
2.Local environment					
2-1	Toxic substance reduction	88.4	73.6	62.5	82.4
3.Global environment					
3-1	Freon and halon gas reduction	88.4	73.6	62.5	82.4
3-2	CO_2 reduction in the production stage	34.9	32.1	31.3	21.6
3-3	CO_2 reduction in the operation stage	86.0	69.8	62.5	79.7

Building Part		E Outer Roof	F Outer Wall Groundwork	G Outer Wall Surface	H Exterior
1.Resource savings					
1-1	Service life	80.0	80.0	79.0	73.7
1-2	Recyclable materials	83.3	80.0	82.3	68.4
1-3	Reproducible materials	76.7	80.0	79.0	73.7
1-4	Material reduction, Easy classification	83.3	80.0	79.0	68.4
2.Local environment					
2-1	Toxic substance reduction	83.3	80.0	83.9	73.7
3.Global environment					
3-1	Freon and halon gas reduction	80.0	80.0	82.3	73.7
3-2	CO_2 reduction in the production stage	36.7	40.0	37.1	47.4
3-3	CO_2 reduction in the operation stage	83.3	80.0	74.2	68.4

4.3 Analysis of the survey results for setting evaluation standards

By analyzing the results of questionnaire survey described in sub-section 4.2, evaluation standards are set to every one of the eight building parts and criteria. An example of the results analyzed is presented in Figure 4 for the building part A. interior wall and ceiling surface and the Criterion: 1-1. Service life.

As a result of the questionnaire survey, service life is found to range widely from less than five years to over 41 years. The point system employed here is designed to add points in three classes, i.e., 0, 1 or 2 points. Each of them may correspond to an applicable service life span when the entire range is divided into three sections; namely, 2 points for a superior service life of 36 years or longer, 1 point for a normal service life of over 16 years, and 0 point for an inferior service life of 15 years or less. Please refer to Table 8 for detained information on the evaluation standards.

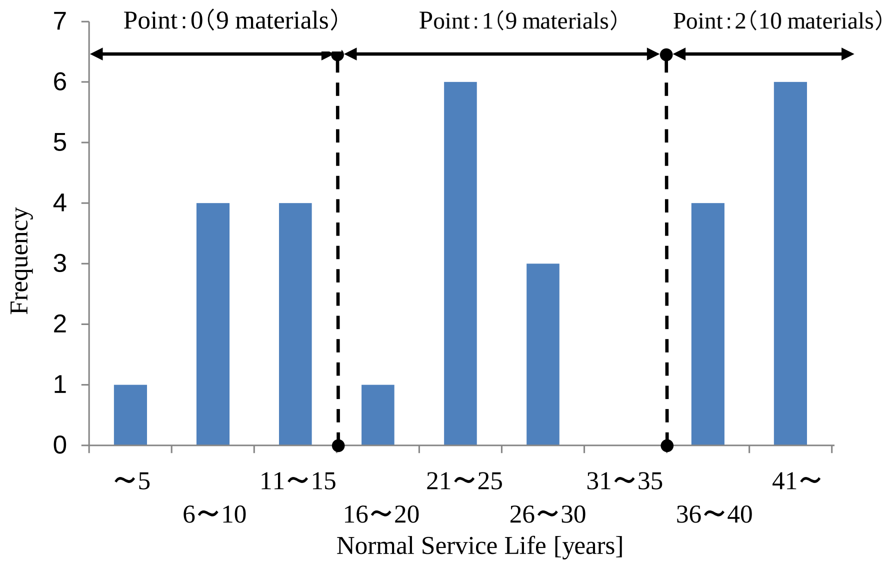


Figure 4. Example of analysis on the questionnaire survey results
Building part: A. interior wall and ceiling surface / Criterion: 1-1.Service life

Table 8. Example of the standard based on analysis
Building part: A. interior wall and ceiling surface / Criterion: 1-1.Service life

1-1	Service life
Purpose	Reducting non-reproducible materials consumption and waste to final disposal sites
Method	Normal service life
Criteria	Point 2 : 36 years or longer Point 1 : between 16 and 35 years Point 0 : 15 years or less

5. SUMMARY

In the present study, detailed development procedure of ESCEP for finishing materials was reported. The system enables the designers to effectively select eco-friendly finishing materials. It has actually been applied to proposing eco materials in design competitions. A future plan includes improvement of the system making more effective and accurate evaluations possible by incorporating feedbacks from the designers.

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