Committee Report : JCI-TC052A

An Overview of the Activities and Achievements of the Technical Committee on Development of Ecological and Environmental Assessment for Environmentally Friendly Concrete

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Abstract

Since 2005, the Technical Committee on Development of Ecological and Environmental Assessment for Environmentally Friendly Concrete (EFC) has investigated the efforts made by the industry to mitigate the environmental impact with respect to environmentally friendly concrete, normal concrete, and other durable goods. Based on the investigation, the committee proposed a comprehensive assessment method for the benefit that is provided by environmentally friendly concrete over time. The assessment method and indices are expected to serve as useful guidelines for adopting environmentally friendly concrete for actual construction and help promote the use of EFC. This paper outlines the achievements of the committee activities.

Keywords: environmentally friendly concrete, environmental assessment method, environmental improvement index, age comparison factor.

1. Introduction

Concrete is widely used as a structural material for its high strength, durability, degree of freedom in design, and economic efficiency. Also, a variety of concretes in terms of "environmentally friendly" have been developed. These include the following: inclusion of industrial byproducts as admixtures; addition of such functions as water purification and greening; durable material to extent a service life; reduction of pollutants (i.e. hexavalent chromium elution); use of resources with low environmental impact (use of eco-cement); processes with low environmental impact (reduction of environmental impact by equipment); high recyclability; and capability of purifying the environment (water purification, etc.).

Based on its investigation into the current state of the industry's efforts to mitigate environmental impact in regard to normal concrete and other durable goods, the committee proposed comprehensive assessment method for environmentally friendly concrete (EFC) exerted over time (commitment to the environment). The members of the Committee are listed in **Table 1**.

Table 1 Member of the committee

Chairman	Minoru KUNIEDA (Nagoya University)
Co-chairman	Tsuyoshi HORIGUCHI (Neo-jaguras)
Secretary	Yoshitaka ISHIKAWA (J Power)
	Takahisa OKAMOTO (Ritsumeikan University)
	Mariko HANDA (Organ. for Landscape and Urban Green Tech. Development)
	Akira HOYANO (Tokyo Institute of Technology)
Members	Isamu UJIKE (Ehime University)
	Tetsuzo OZAWA (Nippon Expressway Research Institute)
	Satoshi KAJIO (Taiheiyo Cement)
	Fumio KANEKO (Taisei Corporation)
	Hideo SAEKI (Japan Const. Mat. & Housing Equipment Industries Fed.)
	Takafumi SUGIYAMA (Hokkaido University)
	Koji Takazawa (Kyowa Concrete Industry Co., Ltd)
	Tomohiro Takano (Kyowa Concrete Industry Co., Ltd)
	Masaki TAMURA (Tokyo Metropolitan University)
	Makoto HISADA (Tohoku University)
	Sumio HORIGUCHI (Shimizu Corporation)
	Naoki MASUI (Obayashi Corporation)
	Satoru MATSUOKA (Landes)
	Yukihisa YUASA (Mie Pref. Science and Technology Promotion Center)
	Hiroko WATANABE (Tsukinoizumi Professional Engineer's Bureau)

Table 2 gives the contents of the committee report, which consists of seven chapters. Chapters **1** to **3** brief the social background related to environmental responsiveness. A survey was conducted on the environmental schemes of other industries to explore their applicability to the concrete field, particularly the trend of the automobile industry including the accreditation system for low emissions and the formulation of a system whereby users acknowledge the manufacturers' commitment to the environment and reward their efforts.

Chapters **4** to **6** propose specific indices and methods for a comprehensive assessment for EFC.

This paper characterizes the environment-related factors of EFC, and reports on an example of riverbank, in which EFC is used as a material for realizing environmental improvement, as well as a comprehensive assessment method for such concrete.

2. Definition of EFC and its performance requirements

2.1 Definition

EFC is a concrete intended to mitigate/reduce the deterioration of a natural environment and improve/enhance its quality by being provided beforehand with material performances necessary for conserving the properties and functions inherent in the natural environment, while being fully or partially integrated in the environment over time.

Table 2 Contents of the committee report

Foreword

1. Environmental commitment and background

- 1.1 Basic framework of environment
- 1.2 Process to awareness of environment
- 1.3 Environment and social system
- 1.4 Commitment to environment

2. Policies and technical measures related to environment and environmental assessments

- 2.1 Overview
- 2.2 Current state of policies related to environment
- 2.3 Technical measures related to environment
- 2.4 Environmental assessments and their issues

3. Environmental efforts in other industries and possibility of application to concrete field

- 3.1 Overview
- 3.2 Characteristics of individual company's efforts
- 3.3 Possibility of application to concrete field

4. Definition of environmentally friendly concrete (EFC)

- 4.1 Definition of EFC
- 4.2 Examples of EFC
- 4.3 Necessity of environmental assessment of EFC

5. Performance requirements and assessment of EFC

- 5.1 Performance requirements of EFC
- 5.2 Greening/planting
- 5.3 Water purification
- 5.4 Thermal conditioning
- 5.5 Moisture conditioning
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- 5.8 Landscape
- 5.9 Summary of performance requirements and development of assessment method

6. Application examples of EFC to structures and assessment items

- 6.1 Overview
- 6.2 Riverbank
- 6.3 Pavement
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- 6.5 Slope(Bank)
- 6.6 Building
- 6.7 Comprehensive assessment of EFC applied to structures

7. General statement

- 7.1 Comprehensive assessment of EFC
- 7.2 Future issues
- 7.3 Concluding remarks

In other words, as shown in **Fig. 1**, EFC can be regarded as a material that positively contributes to and enhances the surrounding environment over time during its service life, while having all the fundamental characteristics of ordinary concrete, such as strength, durability, and economic efficiency, during the production stage.

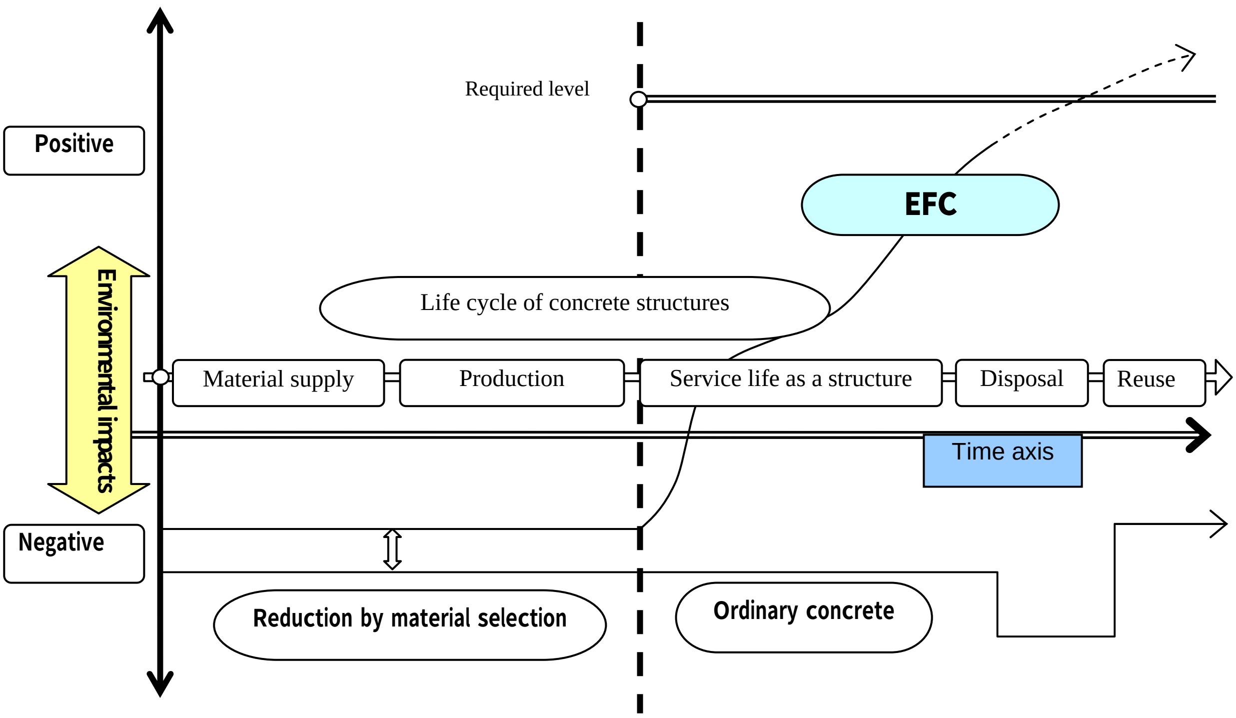

Figure 1 Schematic image of environmental conservation/improvement of ordinary concrete and EFC

EFC may sometimes convert its functions (evolve) so as to achieve symbiosis with the environment. This is considered to be one of the principal characteristics of EFC demonstrated during the service stage.

This committee also defined the performance requirements of EFC as the factors of the environment that are affected and enhanced by EFC (factors of the environment that the environment requires EFC to affect and enhance).

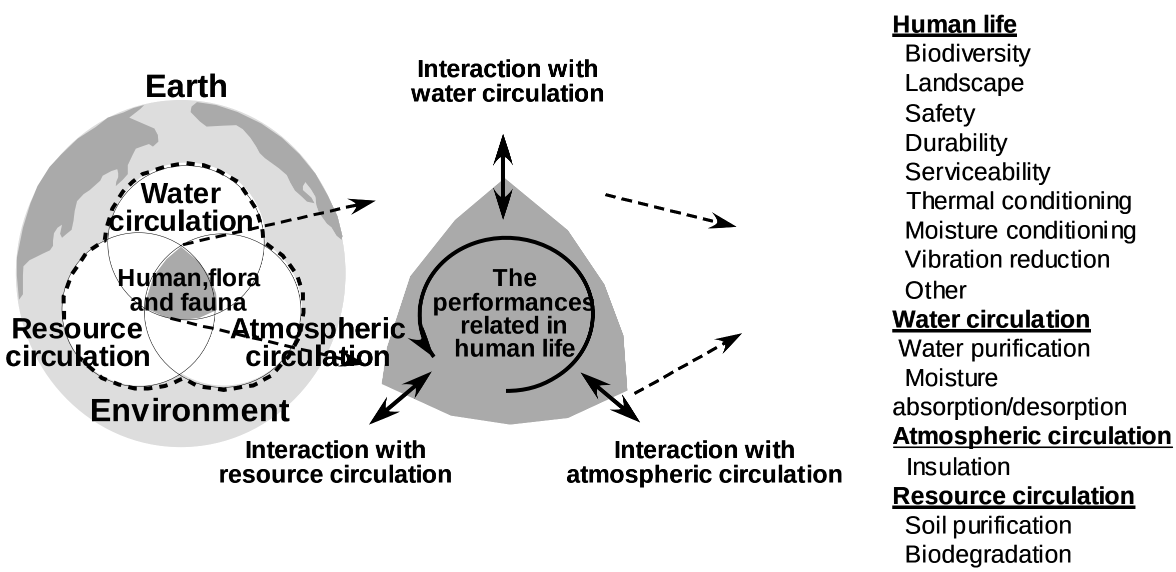

Figure 2 Segmentation of environmental performances in this study

2.2 What are performance requirements for EFC?

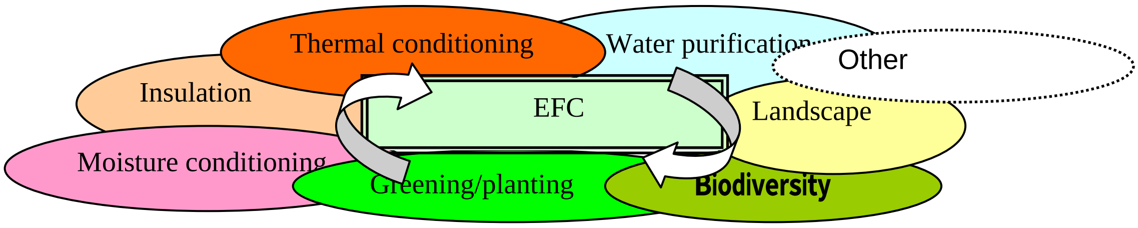

Figure 3 Performance requirements of EFC

When viewed from the requirement areas of environmental performances, the performance requirements for EFC from the natural environment can be basic performance requirements at various levels and sectors as shown in **Fig. 2**.

As shown in **Fig. 2**, a performance requirement may be considered in different sectors on the same level, while another performance requirement may be simultaneously considered on various levels, such as a region/city level, building/structure level, and interior level.

The Committee focused on the seven performance requirements shown in **Fig. 3** among those shown **in Fig. 2** as being important for their impact on the environmental aspect, and proposed a specific assessment method for these performances. These are as follows: (1) greening/planting performance: (2) water purification performance; (3) thermal conditioning performance; (4) humidity conditioning performance; (5) insulation performance; (6) biodiversity performance; (7) landscape performance; and (8) other performances.

3. Proposal for a comprehensive assessment of EFC (draft)

In view of the assessment of each performance requirement for EFC described in Section **2**, a comprehensive assessment method for EFC (draft) is proposed as to the process of thinking for carrying out a comprehensive assessment of the performance of EFC.

3.1 Structures to be covered and performance requirements

The performance requirements for EFC vary depending on the structure to be covered. For a riverbank, for instance, greening/planting, biodiversity, and landscaping performances among the seven performance requirements described in section **2.2** are the priority performance requirements, whereas water purification and thermal conditioning are the basic performance requirements. Requirements other than those given in **Table 3** for the given structures have also been discussed, but the committee limited the number of performance requirements for simplicity. The performance requirements depending on the type of survey structure as shown in **Table 3** should be selected appropriately.

Table 3 Survey structures and performance

Performance \ Survey structure	Riverbank	Pavement	Bridge	Breakwater	Slope (Bank)	Building
Greening/ planting	◎	○	○	−	◎	○
Water purification	○	−	−	◎	−	−
Thermal conditioning	○	◎	−	−	○	◎
Moisture conditioning	−	−	−	−	−	◎
Insulation	−	◎	○	−	○	◎
Biodiversity	◎	−	−	◎	◎	−
Landscape	◎	◎	◎	◎	◎	◎

3.2 Performance assessment and selection of assessment items

The following sections describe the key points of comprehensive assessment regarding performance requirements of EFC for selected survey structures.

(1) Importance of time-dependent assessment

The assessment concerning the chronological aspect is important for assessing EFC. When assessing the environment-protective effect of a structure at riverbank, for instance, its material characteristics, or whether its shapes and materials are effective as a greening base material, are important. The importance then shifts to the time-dependent assessment as to how long it takes to restore the assumed nature.

(2) Selection of performance requirements and assessment items

As stated in section **3.1**, the performance requirements and their assessment items widely vary from one survey structure to another. Those of similar buildings can differ, if closely investigated, depending on their construction conditions. The assessment items should therefore be selected in consideration of these conditions.

(3) Determination of target area and reference area

The target area for assessment should be determined in regard to each performance requirement of the survey structure in consideration of the state of the neighborhood. Also, an assessment reference area should be set beforehand. For a riverbank structure, for instance, a reference area should be one relatively unaffected by human-induced action, particularly one having similar natural conditions, in the vicinity of the survey area. A reference area should also be selected separately for comparison with the survey area. Various selections are possible for this reference area, such as for comparison between numbers of years after completion and methods of construction.

3.3 Definition of performance assessment for environmental friendliness – Environmental improvement index and age comparing factor

The performance assessment of environmental friendliness is to determine the degree of friendliness of a concrete structure to the surrounding natural environment (or the set environment) during the course of assimilation with the environment, while maintaining the inherent performances required of the concrete structure, such as safety, serviceability, and durability.

EFC applied to an environment is assessed in terms of the ratio of the natural conditions restored over time (or the conditions of the set environment at that time) to the target natural conditions (or set environment). This is defined as the environmental improvement index (EI index). The performance of EFC is assessed by investigating each item of performance requirements and comprehensively considering the results. An EI index is calculated as [assessments at survey area of n-th year / assessments at reference area].

In the case of basically assessing the EI index year by year, an age comparing factor (AC factor (n-m) (n>m)) is separately defined to compare the assessments of the n-th year and m-th year as an index to the speed and sustainability of environmental improvement. An AC factor is calculated as [assessments at survey area of n-th year / assessments at survey area of m-th year].

4. Example of comprehensive assessment of EFC

In view of section **3.3**, the proposed method for comprehensive assessment of EFC is explained using a specific example.

4.1 Survey structure, assessment items, and assessment areas

(1) Survey structure and its characteristics

Riverbank made of porous concrete shown in **Fig. 4** is taken up as an example of a survey structure for performance assessment of EFC. Reveting river banks with porous concrete is a method using a porous material that can impart a planting function to the structural framing of the concrete riverbank. It has been attracting attention as an effective method of natureful river improvement aiming for protecting the natural ecosystem and enhancing the riverscape, while providing a habitat for plants and animals, including microorganisms, in addition to the water-controlling function.

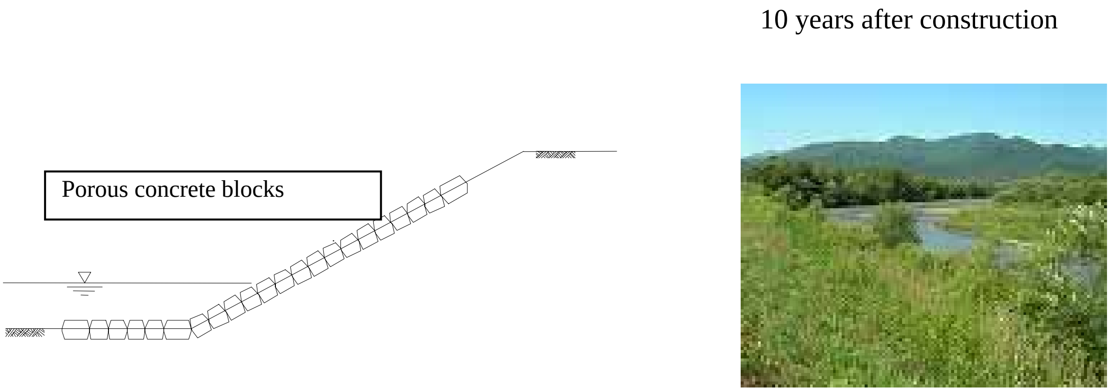

Figure 4 Application of EFC to riverbank

(2) Survey area and assessment items

As stated in section **3**, performance requirements related to the survey structure include greening/planting performance, biodiversity performance, landscape performance, and water purification performance. Also, the assessment items are tabulated as given in **Table 4**, varying depending on the set environment in the survey area as stated in the previous section.

(3) Reference area and survey area

The current state of the surrounding nature was set as the reference. An area to which porous concrete riverbank had been applied 10 years ago was selected as the survey area (t=10 years). For time-series comparison, an area where the same blocks were applied five years ago was also selected as the survey area (t=5 years).

Table 4 Assessment items for each survey area (Greening/planting, biodiversity, water purification performances)

Performance	Assessment items			Survey area		
				Land	Waterside	Water
Greening/planting	Grass	Density		○		
		Plant body		○		
	Wood	Plant body (vitality index)		○		
Biodiversity	Flora	Terrestrial	Waterside woods/ grass on flooded land	○	○	
		Aquatic (submerged/waterside)	Emersed/submerged		○	○
	Fauna	Terrestrial	Birds	○		
			Mammals/reptiles	○		
			Terrestrial insects	○		
		Aquatic	Fish and shellfish		○	○
			Bottom animals		○	○
			Amphibians		○	○
Water purification	Water quality index	Basic item	Water temp./PH/DO			○
		Suspended matter	Transparency/visibility			○
		Organic matter	BOD or COD			○
		Eutrophication	T-N/T-P			○
	Bioindicator	Type/amount of periphyton				○

Table 5 Ranking evaluation of wood vitality

Item	Survey area (t=10 years)	Survey area (t=5 years)	Reference area
Vitality of wood	3	2	4
Tree form	3	1	4
Extension of branch	4	1	4
Blast of blanch	4	2	4
Density of blanch	3	2	4
Leaf shape	4	1	4
Leaf size	3	2	4
Leaf color	3	2	4
Necrosis	3	1	4
Germ period	3	2	4
Leaf-fall	4	2	4
Color change	4	2	4
blossom	3	1	4
Average	3.4	1.6	4.0

Assessment criteria: 5: excellent, 4: good, 3: fair, 2: poor, 1: bad

4.2 Assessment regarding performance requirements

(1) Assessment regarding greening/planting performance

As both herbal and arboreous plants grew in the areas, their densities (coverage) and vitalities were ranked as greening performance. **Table 5** gives the assessment results for arboreous plants as an example.

(2) Assessment regarding biodiversity

The species, number of species, and population found to have emerged during field investigation are extracted. The investigation should cover terrestrial flora and fauna (mammals, terrestrial insects, birds, and reptiles).

Table 6 gives an example of the investigation results of mammals and reptiles.

Table 6 Survey results of mammals and reptiles

Species	Survey area (t=10 years)	Survey area (t=5 years)	Reference area
Weasels	2		
Nutria		2	
Brown bear			
Fox			1
Japanese raccoon	2		1
Bat	3		3
Tiger keelback	2		2
Japanese four-lined ratsnake		1	
Japanese ratsnake			1
No. of species (S)	4	2	5
Number of individuals (n)	9	3	8

(3) Assessment regarding landscaping performance

Landscaping performance should be assessed by ranking of each assessment item, e.g., by questionnaire surveys. **Table 7** gives an example of assessment results.

Table 7 Landscape performance assessment results

Performance	Assessment item	Survey area (t=10 years)	Survey area (t=5 years)	Reference area
Landscape performance	Riverhood by natural vitality	2	1	3
	Continuity of banks, flood channel, and water edges	3	1	3
	Integrity with backland neighborhood	3	1	3
	Landscape with its own ecosystem	3	1	3
Average		2.8	1.0	3.0

Assessment criteria: 3: good, 2: fair, 1: ordinary

4.3 Analytical assessment of investigation data on biodiversity

Using the biodiversity data presented in section **4.2**, the number of emerged species, their population, and diversity index are calculated for comparison and ecological structure assessment.

(1) Number of emerged species and their population

Table 8 gives comparison data regarding the number of emerged species (S) and their population (n).

Table 8 Comparison of numbers of emerged species and individuals

Class	Item	Survey area (t=10 years)	Survey area (t=5 years)	Reference area
Flora	No. of species, S	11	9	12
Terrestrial insects	No. of species, S	13	9	15
	No. of individuals, n	80	23	90
Birds	No. of species, S	14	7	19
	No. of individuals, n	33	12	37
Mammals /reptiles	No. of species, S	4	2	5
	No. of individuals, n	9	3	8

(2) Diversity index

As stated above, a diversity assessment index is used to assess the abundance of the number of species, as well as the equilibrium among species.

The Shannon-Wiener index and Simpson index are generally used. An example of analysis results by these indices is given in **Table 9**.

Shannon-Wiener index, H'

$H' = -\Sigma piLn(pi) \quad (i=1 \sim s)$

where s = type in the community

pi = ratio of the population of species i to the total individuals of all species in the community (relative priority)

Based on this, the biodiversity is also assessed in terms of the degree of equilibrium (degree of evenness of the species composition).

$J' = H'/H'max$

Simpson index D'

$D' = 1 - \Sigma pi^2 \quad (i=1 \sim s)$

Table 9   Biodiversity analysis results

Class	Item	Survey area (t=10 years)	Survey area (t=5 years)	Reference area
Terrestrial insects	Shannon-Wiener index, H'	2.35	2.08	2.43
	Equilibrium index, J'	0.92	0.95	0.90
	Simpson index, I-D	0.89	0.86	0.89
Birds	Shannon-Wiener index, H'	2.46	1.86	2.79
	Equilibrium index, J'	0.93	0.96	0.95
	Simpson index, I-D	0.90	0.83	0.93
Mammals /reptiles	Shannon-Wiener index, H'	1.37	0.64	1.49
	Equilibrium index, J'	0.99	0.92	0.93
	Simpson index, I-D	0.74	0.44	0.75
Ecosystem structure	No. of species, S	31	15	49

(3) Ecosystem structure

In order to conserve the diversity of an ecosystem, it is necessary to particularly focus on endemic species that live and grow only in specific areas or environments, in addition to the assessment described in (2) above. The ecosystem structure is assessed by the abundance of species that are found to have emerged and noteworthy for its epistatic position on the ecosystem, typicality that expresses the ecosystem, and particularity representing the special environment.

Epistaticity: Species that are positioned at a high level of an ecosystem, such as those at a higher level among fish-eating fishes should be selected in a river environment, for instance.

Particularity (importance): Important endemic species from the standpoint of scientific interest and rareness should be selected.

Typicality: Species whose emergence is indicative of a good environment and environment to be conserved, though not particularly important, should be selected.

Index species to environmental deterioration: Species whose emergence is indicative of deterioration of a good environment should be selected, e.g., immigrant plants that disturb the growth of domestic endemic species. The results are given in **Table 9**.

4.4 Comprehensive assessment of EFC

The EI index of each item calculated in sections **4.2** and **4.3** is then summarized as given in **Table 10** for comprehensive assessment.

Table 10 EI index calculations

Performance		Item	Survey area (t=10years)/ ref. area EI index (t=10 years)	Survey area (t=5years)/ ref. area EI index (t=5 years)	AC factor (10-5)
Greening/planting		Grass density ratio	0.869	0.452	1.923
		Wood vitality ratio	0.846	0.404	2.095
Biodi-versity	Flora	Ratio of No. of species	0.917	0.750	1.222
	Terrestrial insects	Ratio of No. of species	0.867	0.600	1.444
		Ratio of No. of individuals	0.889	0.256	3.478
		Shannon-Wiener index ratio	0.970	0.856	1.134
		Equilibrium index ratio	1.024	1.055	0.971
		Simpson index ratio	1.006	0.974	1.033
	Birds	Ratio of No. of species	0.737	0.368	2.000
		Ratio of No. of individuals	0.892	0.324	2.750
		Shannon-Wiener index ratio	0.881	0.667	1.321
		Equilibrium index ratio	0.983	1.009	0.974
		Simpson index ratio	0.971	0.897	1.082
	Mammals/ reptiles	Ratio of No. of species	0.800	0.400	2.000
		Ratio of No. of individuals	1.125	0.375	3.000
		Shannon-Wiener index ratio	0.916	0.426	2.151
		Equilibrium index ratio	1.064	0.989	1.075
		Simpson index ratio	0.988	0.593	1.667
	Ecosystem structure	Ratio of No. of species	0.633	0.306	2.067
Landscape	Landscape		0.917	0.333	2.750

The EI index of each item is determined as [survey area (t=10years) / reference area] or [survey area (t=5years)/ reference area]. The AC factor (10-5), which is calculated by dividing the EI index 10 years after completion by the EI index 5 years after completion, represents the ratio of these EI indices to compare the values 10 and 5 years after the application of EFC.

Figure 9 shows the comprehensive assessment chart of the survey area 10 and 5 years after application. The comprehensive assessment chart shown in **Fig. 5** provides a clear view of the degree of each item's fulfillment of the target environmental improvement. This example suggests that the EI index of EFC 10 years after application approaches 1.0, having become similar to the state of nature in the surrounding environment over 10 years. The AC factors reveal that the greening/planting performance of EFC 10 years after application is twice as high as that of EFC 5 years after application. In regard to the biodiversity performance, significant performance improvements are observed for fauna, though the value for flora remains similar 10 years after application.

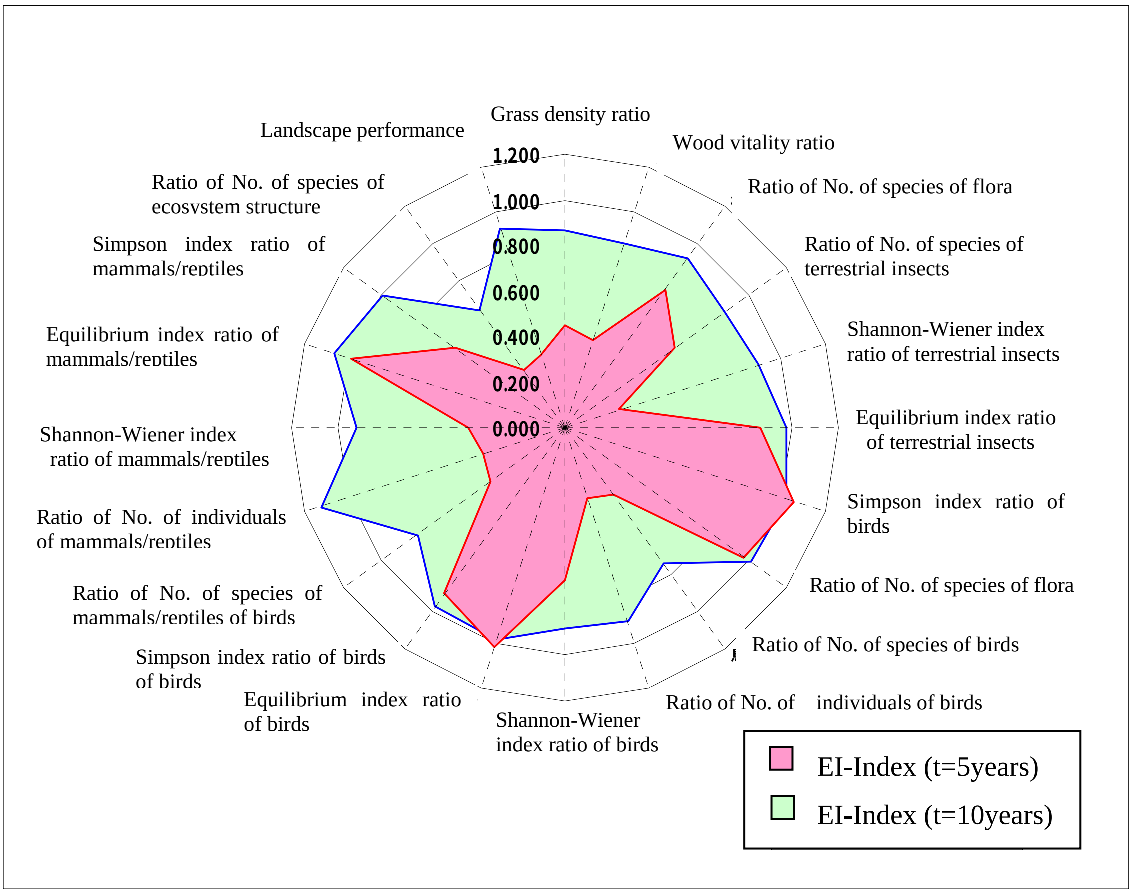

Figure 5 Comprehensive assessment chart for EI index

5. Concluding remarks

The concrete industry has not yet formulated a fundamental framework of environmental assessment consisting of the current state, future target setting based on the quantification, and communication to consumers, which has already been implemented in other industries. A proposal for an assessment method of EFC and its trial application have enormous significance as a catalyst for assessing and analyzing the current state, though various problems remain unsolved, such as unclear performances of EFC and indices for their assessment. It is now necessary to accumulate data of various structures to formulate methods of assessing environmental performance requirements suitable for various structures with EFC.