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COMPREHENSIVE RECYCLING SYSTEM

ON EXPRESSWAY CONSTRUCTION & MAINTENANCE

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Introduction

For the realization of sustainable development, developed countries are surely envisaged to be responsible for reduction in CO_2 emission, considering that they have aggressively continued reclaiming nature and emitting greenhouse gas since the Industrial Revolution, which are illustrated as "North-South problem" on Environmental issues. In order to turn sustainable development in reality, however, a recycling-based society is essential to the 21st century, and it is indispensable to harmonize economy with environment in social development. Keeping these factors in mind, we, who engage in road development, ought to renovate the existing economic-oriented system into a recyclable system. In addition, we also have to be responsible to demonstrate sustainable development models to developing countries that the model could assist the achievement of their further growth.

The Japan Highway Public Corporation (hereinafter "JH") has long been engaged in development and management of expressways that contributed to the people's life and economy in Japan. At present (as of May 2002), JH is in charge of approximately 2,100 km of new expressway construction and some 7,000 km of its operation. In construction and operation, JH aims to establish sustainable development of the expressway network in harmony with natural and living environment.

For reduction of environmental impact, several measures are taken: those are to reduce resource consumption, to promote reuse and recycling of natural resources, and to strive for preservation of natural environment. Organizational activities are discussed in this paper on recycling systems of discharged materials from expressway implemented by the whole JH (Head Office, 11 Regional Bureaus, 85 Construction Offices and 98 Operation Offices: as of April 2002,), and the effects and impact of them as follows.

1. Cycle of resources

In order to understand the outline of resources recycle in Japan, an example of yearly material balance of production activities as of 1995 is shown in Fig.1. One cycle of resources is composed of seven steps: (1) resource input, (2) production, (3) consumption, (4) accumulation, (5) emission of waste, (6) recycle and (7) final disposal. Approximately two billion tons of resource input is transformed into some 1.3 billion tons of output (products).

In the meantime, the production activities require a little more than 0.3 billion tons of energy and emits 0.4 billion tons of waste in 1995. Among the 1.3 billion tons of products, some 1.1 billion is turned into social infrastructures, such as roads, structures and buildings. Several decades later, these stocks will come out as industrial waste to discard. Therefore there are about 1.1 billion tons of future wastes accumulated yearly. Although at the present, the percentage of recycled resources to the total amount of input resources remains approximately 10% only,

the current waste amount to be recycled (domestic reserves 1.1 billions tons/year) will surely be transformed into stable and promising resources through recycling in the future.

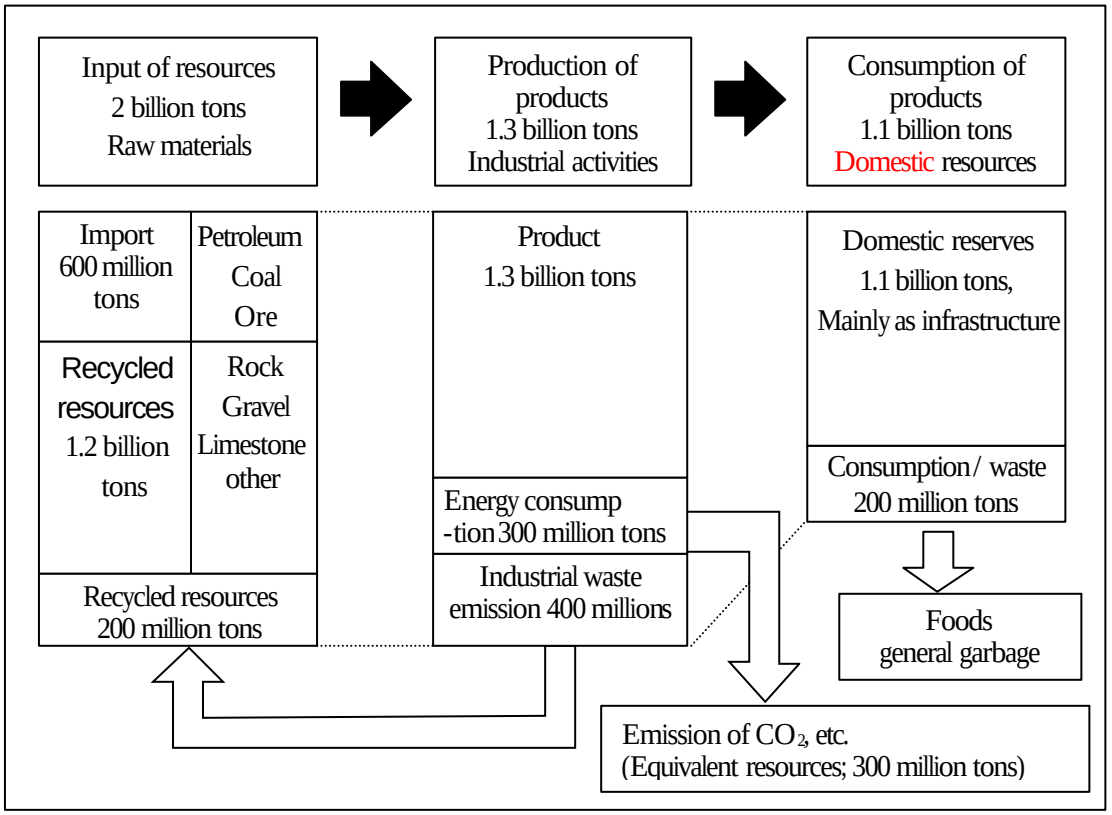


Fig.1 Material balance in Japan (1995)

As for JH's efforts of tackling to resource recycling, although the businesses of JH account for a small percentage in the national scale, expressway construction should be deemed as part of the domestic resources reserves, and in the future, will become waste in the same sense. In the case of expressways, concrete and asphalt waste are foreseen to become main recyclable resources, and recycling of such waste resources is a rightful action JH should take.

Under the governmental policy support for resource recycling, JH's recycling system can be considered sufficiently feasible for adoption in many fields of public works.

2. Overview of the recycling system

As a recycling system, there are three types of systems constructed for the reduction of waste, reuse and recycle of the waste of construction by-products or waste which is generated by construction and maintenance of expressways. Promotion of this system contributes to reduction of CO_2 emission and fixing of CO_2 for the control of energy emission and prevention of global warming, helping create a recycle-based society.

Three systems mentioned above are

(1) Construction by-products recycling system
(2) Green recycling system
(3) Recycling system of materials generated in construction.

In addition, other systems are introduced for the reduction of environmental impacts, such as recycling of garbage generated at rest facilities for the use as fuel (RDF: refuse-derived fuel), and the use of treated wastewater for toilets. These efforts exhibit good results in the whole corporation of JH; especially the construction by-product

recycling system becomes more effective with regional recycle activities, in addition to those by JH.

3. By-product recycling system

The by-product recycling system is designed to control the emission of construction by-products (soil, concrete waste, etc.) generated through construction and maintenance activities, and to reuse them systematically at appropriate JH sites across the country.

3-1 Problems arisen in creating a recycling system and implementation policy for their examination

In response to the policy of the national government, JH started its efforts to create a construction by-product recycling system in 1992. Though JH has made efforts to use resources effectively, before starting the promotion of the recycling scheme, the expressway construction projects were implemented mainly placing importance on the economy. For example, concrete wastes were not effectively used as recycled aggregate, but most of them had been utilized for the construction of expressway embankments. In other words, useful materials were not used in appropriate places for rightful purposes.

Considering these circumstances, JH set forth four major policies for the thorough implementation of effective reuse of materials and wastes that originate from expressway projects.

(1) Importance shall be placed rather on reduction of the environmental impact than the economical efficiency. Use of recycled materials shall be promoted for some work categories with attention to the life-cycle cost, even if such measures may be more costly on early stages.

(2) In order to grasp what kind of materials are recyclable on all the routes and manage them for recycling, JH shall beforehand implement a survey on information of recyclable materials. And special importance shall be placed on the exchange of information with the projects in the vicinity and on the coordination for effective use of resources.

(3) The recycling plan and how it should be accomplished shall be officially announced so that it may be used in contracting out the projects.

(4) JH shall make all the parties (manufacturers, designers, and constructors) related with the project thoroughly understand their respective roles in the project.

3-2 Classification of construction by-products

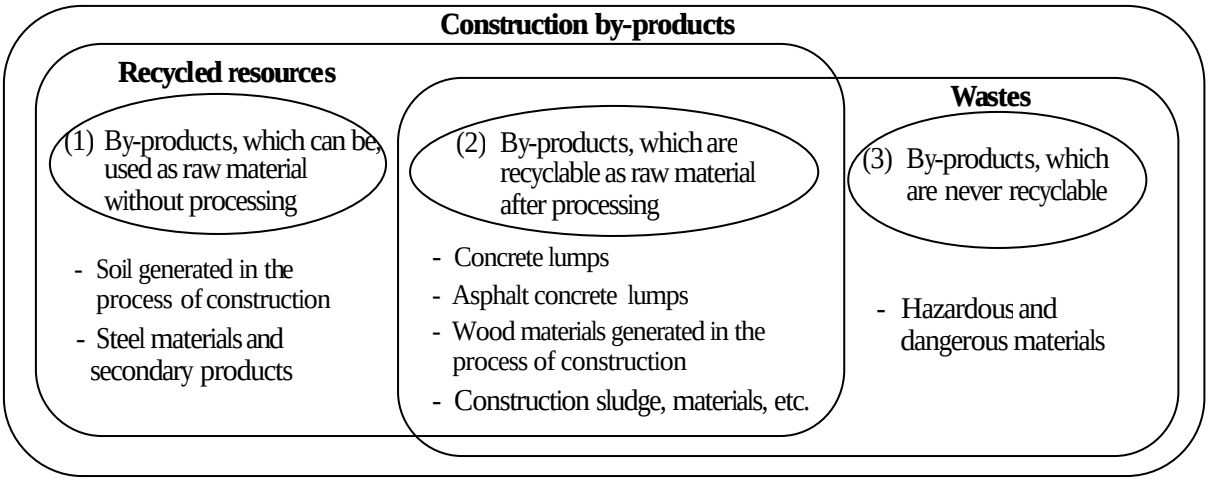


Fig.2 Classification of construction by-products

As shown in Figure 2, construction by-products are classified into three categories: (1) by-products, which can be used as raw material without processing. (2) by-products which are recyclable as raw material after processing (3) by-products which are never recyclable.

3-3 Basic principles of recycling construction by-product

The priority flow for recycling is shown in Fig.3. The basic principles for each step are described below.

(1) Emission control:(Reduce)

Planning and designing for road development must be done to control the generation of construction by-products. For example, controlling the emission of surplus soil by considering soil volume balance, or finding a method that generates no surplus soil or sludge in the phase of planning.

(2) Reuse:

The soil generated from other construction sites or useful materials such as steel materials and secondary products generated from JH works shall be reused for other purposes.

(3) Recycling of materials and use of recycled materials:

It shall be promoted to recycle waste from construction projects at a recycling plant and reuse the materials recycled. For instance, as we discuss later, use of recycled aggregates made from crushed concrete lumps and of compost made from green wastes.

(4) Volume reduction and proper treatment of waste:

For the wastes that cannot be recycled, it should be strived to reduce their weight or volume with measures such as dehydration of construction sludge which observing the laws and regulations for proper disposal.

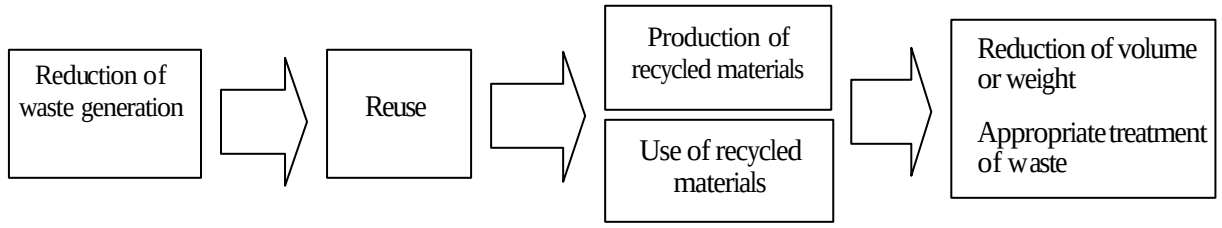


Fig.3 Priority sequence for recycling

3-4 Examples of recycling construction by-products

Recycled resources include soil carried in from construction sites of other projects, and resources processed and manufactured in recycling facilities. Some examples are shown in Table 1.

Table 1 Examples of recycling construction by-products

Construction by-products	Recycling method	Recycled resources
Concrete lumps	Crushing	Recycled aggregate (crushed stone, sand), etc.
Asphalt concrete lumps	Crushing, addition of materials	Recycled hot-mixed asphalt mix, recycled base course material, etc.
Woods available at the site	Chipping, compost production, carbonization (green recycle)	Mulching, compost, soil improving material, etc.
Soil available at the site	No processing, soil property improvement	Embankment material, backfilling material, etc.

(1) Examples of utilization

Photo 1 shows an example where rocks produced in a tunneling project of JH were effectively used in another JH project. About 80, 000 m^3 of rocks from the tunneling were crushed, and used as

Photo-1 Mobile crushing facility

foundation material and sub base course material in the work of the same line.

Photo 2 is an example that the soil from projects of other fields was utilized in an expressway project. In this expressway construction site that required about 8 million m^3 of embankment, high quality material (dredged sand) produced in a port dredging work and soil from cutting of a diversion channel (cohesive soil of high moisture content) were mixed and used as embankment material amounting to about 2.4 million m^3.

Photo-2 Yard for mixing by-product soils

Photo 3 is an example where about 80, 000 m^3 of waste sand from foundry factories was used for the embankment of expressways. The waste sand was used as mold of casting work. At that time the disposal of waste sand was a serious problem for foundry companies. Therefore, the recycling contributed to cost reduction both in foundry companies and JH. The waste sand is a safe material, which meets the legal standards and conforms to the quality standards of JH for embankment.

Photo-3 Construction of an embankment using waste casting sand

3.5 Roles of concerned persons

In order to utilize this recycle system properly, it is necessary that all persons concerned should develop collaboration and efforts in the promotion of all recycling measures relating to expressway projects.

(1) Executive Agency (JH)

In controlling the generation of construction by-products, since measures available in the construction phase are limited, the executive agency needs to develop required activities earlier, that is, in the phase of planning and design. Therefore, JH implements necessary surveys in the planning and design phase to grasp the generation of construction by-products, and based upon such surveys, establishes a plan for limiting by-product generation as well as for their reuse, and integrates it into the design. At the time of tendering a project, JH provides a contract document specifying required conditions and makes potential bidders offer necessary cost for these measures.

(2) Material manufacturers

JH requires material manufacturers (1) to provide quality labels on their supply, and refrain from use of materials that cannot be separated into what can be recycled and what must be disposed of (2) JH requests manufacturers to develop and manufacture construction materials containing as much recyclable material as possible; precutting of materials in the factory, and (3) improvement of durability of construction materials.

(3) Designers

As approaches to be taken in the design phase, especially for selecting construction materials, designers shall consider the following conditions: (1) the materials as much simply structured for separating demolition as possible, (2) improvement in durability of structural building frames, β) use of design to ensure a long life of structure, considering LCC (Life Cycle Cost), and (4) examination of construction procedures and selection of construction materials so as to reduce the emission of waste.

(4) Contractors

Contractors shall study construction procedures, materials to be used and conditions of the site and its surroundings to establish the most appropriate construction plan. Since they generate construction by-products, they must, as their own responsibility, make efforts for controlling the generation of such waste, their recycling and in the use of recycled materials, and have the obligation of their appropriate treatment in close coordination with JH. Specifically, for the volumes of materials to be carried in and out for each project, constructors should prepare a plan for utilization of recyclable resources to be input in the construction program.

3-6 Recycling Achievement of JH

Table 2 shows recycling of construction by-products of JH in 2000. The total amount of materials recycled across JH projects is approximately 1.5 million tons per annum. The recycle rate to the amount of all construction by-products generated is 95%. Concerning the soil and sand, the amount reached 45 millions tons and 99% of it was recycled.

Table 2 Recycleratios of construction by-products in JH (achievement of the year 2000)

Construction by-products	(Unit)	Production amount	Recycled amount	Recycling ratio		Nationwide (2000)	
Concrete lumps	(1,000 t)	262	247	94.2%	94.6%	96.0%	85.0%
Asphalt concrete lumps	(1,000 t)	1,169	1,127	96.4%		98.0%	
Construction wood waste	(1,000 t)	53	48	91.3%		38.0%	
Sludge from construction	(1,000 t)	94	71	75.0%		35.0%	
Soil from construction	(1,000m^3)	45,536	45,260	99.4%		54.0%	

3-7 Evaluation of the construction by-products recycling system

JH has been recycling construction by-products since 1992, achieving a stable resource-recycling ratio around 95% for the last 3 years. This figure is higher than 85%,which is the recycle ratio of the entire the construction waste in Japan, demonstrating the higher performance of JH's system. For soil from construction, JH has been aggressively tackling effective use of recycled resources, probably resulting in a satisfactory recycle ratio of 99%.

As for the 75% recycle rate for construction sludge, there are several kinds such as dehydrated sludge produced from the treatment in tunnels and sludge generated at the moment of driving piles. Their recycling should be promoted further in future.

These effective uses of recycled resources contribute not only to the reduction of environmental impact which is most important, but also noticeably contribute to decreased cost of JH's projects by reducing disposal cost of industrial wastes, and further saving of new material cost for construction.

4. Green Recycle System

JH has established the "Green Recycle System" for conservation of both the roadside environment and the global environment. In the system, green wastes such as, weeding, mowed grass, chopped branches, etc. through expressway construction and maintenance work are recycled to green materials for forestation of road slopes.

4-1 Background

In the implementation of construction work, JH makes efforts to conserve the existing vegetation in

planning area, taking suitable measures such as preserving or transplanting for roadside green. When unavoidable, some amounts of plant are cut down. In the process of expressway maintenance mowing grass, trimming branches for safety drive and healthy vegetation. In the past, part of mowed grass was supplied as agricultural material to farmers, but a larger part of the rest including woody plant materials was used for landfill or disposed by burning, etc.

However, in response to more stringent legal regulations imposed on wastes, and as the issue of carbon dioxide generated by burning has become serious, lower loading measures have been desired, both in disposal and effective utilization of green waste.

4-2 Investigation into the utilization of green waste

Since around 1988, JH has been studying flow of green wastes and the ways of multiple utilizations, which have been increasing in amount year by year. As the first step, forestation of expressway slopes is executed to reduce the emission of green waste. The next issue is reuse of such green waste, and currently the amount of green waste received by farmers is decreasing as the demand for green waste declines because of an aging society problem of farmers and farming business depression. To overcome this difficulty, we promote recycling of green waste as planting materials. Although mowed grass or trimmed branches cannot be used without any processing, but we have successfully developed techniques for composting, chipping and carbonization of green waste for recycling.

4-3 Recycle of green waste

(1) Composting

Green waste is cut or broken into small pieces, and allowed to fermentation into compost. The mature compost produced in this way is mixed in soil to grow plants.

(2) Chipping

The chipping process is to pulverize woody plant waste into small pieces 5 to 10 cm long. Chips are used as mulching for planting trees in order to prevent overgrowth of grass and drying up of soil surface.

(3) Carbonization

Carbonization produces charcoal from woody plant waste. Charcoal has been conventionally used as a fuel. It can be used, however, in a variety of ways, for example, improvement of soil quality for planting, additive for composting process mentioned above, as purification and deodorant of water and materials. JH is also studying other applications.

(4) Recycle volume

In the scope of the maintenance work of JH in fiscal 2000, of about 320,000 m³ of green waste, 73%, 233,000m³ were recycled. Among this recycled material, approximately 46% of the whole, i.e. 146,400 m³ was used for production of compost (Fig.4). In the scope of construction projects, from about 89,500 m³ of green waste, 3,800 m³ of compost and, about 9,900 m³ of chips were produced.

Photo-4 Compost-manufacturing process

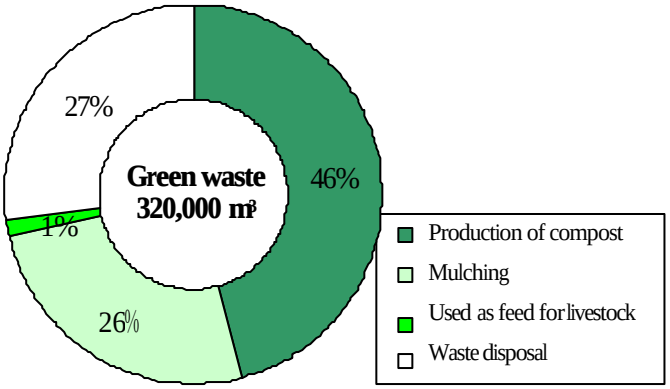
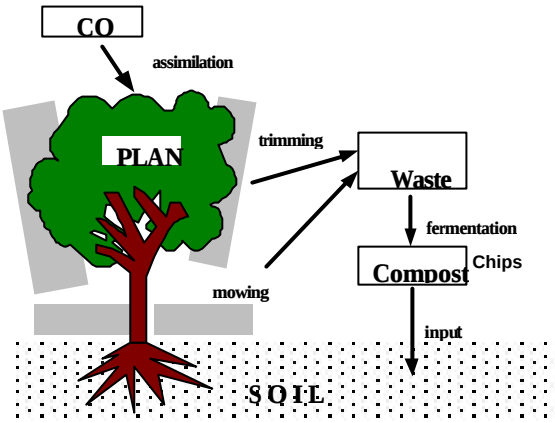


Fig.4 Recycle rate (year 2000)

(5) Effects of green recycle

Green recycling, as discussed below, will create the following effects; fixing of CO_2 contributing to global warming, reduction of disposal cost of green waste.. More over, it reduces the cost for purchasing planting materials to be used for the management of construction on expressway vegetation.



i .Composting and chipping

Compost is decomposed by microorganism and soil animals, and become small pieces, which make good soil for plants. Chips are also decomposed by microorganism and soil animals. Through the decomposition, they generate CO_2, and its process takes a much longer time than burning, so composting and chipping are more excellent than burning in temporally fixing CO_2.

ii. Carbonization

Carbonization changes woody waste to solid and stable carbon, therefore, the carbon in soil as charcoal is preserved permanently in expressway.

iii. Full use of recycled resources (forestation)

Recycled resources can be used for the forestation as of slopes of expressways. There are 8,400 hectares (2002) of expressway slopes where planting is possible under the management of JH.

The trees and plants accumulate CO_2 in the process of growing to form their stems, so fixing of CO_2 takes place during the process of growing with the estimated capacity of fixing approximately 250,000 tons of CO_2 per year.

Forestation of expressway slopes helps expand biotopes habitats wild lives, and reduce the impact of vehicle light and noise from expressways, and contribute to the conservation of natural surroundings.

Photo-5 Slopes with forestation

5. System for recycling the wastes from construction projects (hereinafter referred to as work-generated material)

Provisional work materials such as steel materials, and materials removed in the process of remodeling works (work-generated materials) may be generated during construction. These materials may be useful for recycling.

We at JH are developing a system, which has been designed to manage and distribute the information on volumes, specifications and locations of such materials across the country, aiming at effectively using them at various sites for road maintenance and related construction work.

(1) Work-generated material

Under normal circumstances, JH stores no temporary work materials for projects use. In exceptional cases, however, where a large amount of temporary work materials is necessary because of the topographic conditions

of a work site, or the work needs to be continued over a long span of time, it is up to JH to keep such materials.

After the completion of construction, they need to be treated as recyclable work-generated materials. This category of recyclable materials mainly includes for sheet piles for temporary bridges, wide flange beams, protection fences and provisional guardrails. The main items removed in remodeling projects, are acoustic panels of sound barriers. Looking at the steel materials (temporary bridge, sheet pile, wide flange beam) that were used for the construction projects of expressways in 2001, we learn that approximately 5,000 tons of waste materials were generated in one year, and 4,000 tons was recycled for the use in other sites.

(2) Waste materials generating from road facilities (facility-generated materials)

Expressway facilities include a wide range of equipment for traffic safety and for management and maintenance, and they respectively perform key roles. Due to an increase of traffic volume and the changes in social environment, road facilities have been frequently expanded and remodeled, and the facilities for traffic safety and for management and maintenance also need expansion and remodeling. For the purpose of effectively reusing the waste materials resulting from the expansion and remodeling of road facilities, JH is creating a system for the computerize management of facilities-generated materials. The main reusable equipment items in this category are tunnel jet fans, information boards and communication cables. A total of 82 jet fans were reused in the year 2000.

6. Consideration

When discussing evaluation measures for reduction of the environmental impacts, we always face problems of "how to evaluate the impact objectively and quantitatively". For instance, in case of recycle system for construction by-products discussed in this paper, the recycle rate currently used by JH is considered as an evaluation method though, it is not able to figure out energy consumption at various steps, nor to assess the level of contribution for reduction of the environmental impact.

Therefore, JH is now working to establish a procedure of evaluation of the reduction level of environmental impact objectively and quantitatively. That is, for the purpose to evaluate the effect of circulation system in operation and JH's investments on environment measures comprehensively, we are studying quantitative evaluation measures using such as the amount of CO_2 conversion, and incurred costs. We also need to examine the concept of LCA (Life Cycle Assessment) as a quantitative evaluation method of environmental impact and effect.

7. Conclusion

As expressways are infrastructure integrated huge amount of resources and high technologies in the process of their development and maintenance, creation and effective use of recycling systems of discharged materials from them is a major concern for both developed and developing countries. Especially in developed countries, active recycling in the processes of maintenance, rehabilitation and reconstruction is an urgent as well as essential issue in the coming.

JH developed and is operating one of the largest recycling systems in Japan, which achieves favorable effects on recycling construction by-products and wastes accompanying cost reduction in various aspects, such as disposing process of industrial waste and purchasing new construction materials. While green conservation is a visible recycling method, which works as CO_2 absorption or keeping natural environment for a variety of species.

JH's green recycle system creates a wide range of advantages in green conservation as; one of counter measure of global warming, protection measures of regional environment, and enhancing awareness of regional habitants toward nature. With confirming these merits, JH has to make efforts for development of more effective and productive systems.

In addition, important goal of the recycling system is a systematic approach to tackle this theme by the whole organization of JH starting from the planning/designing stage ofprojects, and the objectives and the results of recycling should be disclosed to the public. Moreover, JH should make efforts for the development of related technologies and for the expansion of demand required for recycled/treated materials.

There will be a significant step forward, once developed countries, for which recycling systems are essential as mentioned above, are able to demonstrate the orientation of a sustainable as well as economical system to developing countries. We, JH staffs, intend to continuously exchange information on technological development through close relationship and cooperation with those countries, and to proceed with integral and strategic environmental actions in a manner friendly to the earth.