A STUDY ON COST REDUCTION OF CLOSED SYSTEM DISPOSAL FACILITIES

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ABSTRACT

The Research Committee for Closed System Disposal Facilities has proposed closed system disposal facilities (henceforth "CSDF") as landfill sites which can correspond to improvements in safety, environmental preservation functions, and information communication with residents, etc. An example of CSDF is shown in Photo 1, and the committee is currently performing an investigation, a study, and publicity work to increase the popularity of such facilities.

In order for the CSDF to be cut off from the outside environment, covering facilities, seepage control facilities, and other incidental facilities are needed. This necessity has created the impression that construction costs are high when compared with conventional opened type landfill sites (henceforth "OPLS").

Therefore Models of CSDF and OPLS having 10,000m^3 disposal capacity were set up, and construction costs, maintenance management costs and the benefit of constructing landfill sites were calculated. Then the cost effectiveness of CSDF and OPLS was compared, and the advantages of CSDF were confirmed by these examinations. However, many assumptions were introduced into the examination process and this left some problems such as how to monetarize the benefits.

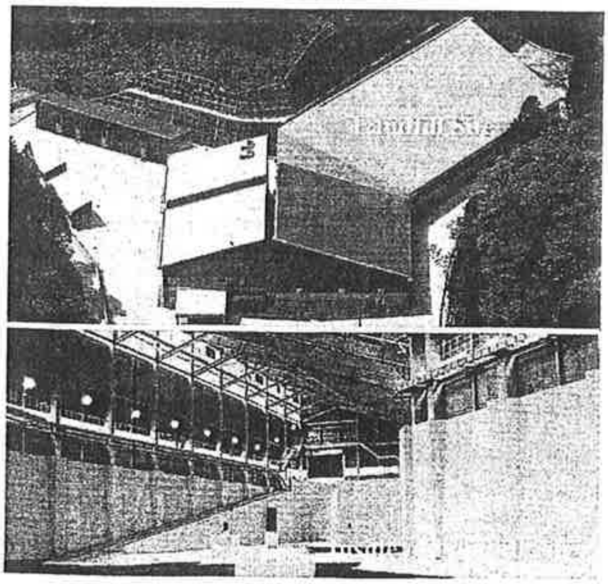


Photo 1 Example of Closed System Disposal Facilities

INTRODUCTION

The CSDF, in which a landfill is covered with covering facilities, has the following features:

- It is easier to obtain the consent of residents about the construction of a landfill site.
- It can conform to various conditions of the location.
- A reduction of construction costs is possible by reducing the scale of water treatment facilities and maintenance management expenses.

- The scattering of waste and diffusion of bad smells can be prevented.
- Neither the amount of leachate nor reclamation work is influenced by the weather.
- It can also be used as a storage facility for recycling.
- There is a wide variety of possible uses for the ultimate land.

Even though CSDF have such clear advantages, the factor of increased constructions costs due to the need for previously unnecessary (in the case of OPLS) covering and incidental facilities must be taken into account.

In this study, first a model of CSDF is set up and the construction costs of the main facilities are calculated. Second, the benefits obtained by building CSDF are examined. Finally, the advantages of building CSDF are confirmed by comparing the cost effectiveness of CSDF and OPLS.

CONSTRUCTION COSTS OF MAIN FACILITIES

Model of Closed System Disposal Facilities

The model of CSDF (henceforth "Model CSDF") was set up to calculate the construction costs of CSDF and to examine the benefits, etc. The specifications of Model CSDF are shown in Table 1, and a cross-sectional view is shown in Fig. 1.

Covering Facilities

Because covering facilities are unnecessary for OPLS, they are the factors which cause the construction costs of CSDF to increase. Therefore, the construction costs of covering facilities are important for the planning of CSDF.

In this section, the kinds and features of covering facilities are described, and considerations regarding laws and regulations are examined. Further, construction costs are roughly calculated for the typical covering facility structures.

(1) Kinds and Features of Covering Facilities

The typical structural forms of covering facilities are the arch type, rigid-frame type, truss type, hybrid type, shell type, space frame type, and air support type. Among these, many rigid-frame types and truss types made from steel frame structures are often adopted.

A typical material used for roofs is metal or membrane. In the case of metal, since construction is easy, a folded-plate is used in most cases. Although membrane material is effective when building large-sized covering facilities, there are also laws that regulate the use of membrane material.

The features of these rigid-frame type and truss type by steel frame structure covering facilities are shown in Table 2.

Table 1 Specifications of Model CSDF

Reclamation capacity	10,000 m^3
Width of landfill (earth surface)	20 m
Width of landfill (bottom)	10 m
Gradient of slope of landfill	1 : 0.5
Depth of landfill	10 m
Length of landfill (earth surface)	70 m
Area of landfill	1,400 m^2
Capability of water treatment facility	2.0 m^3/day

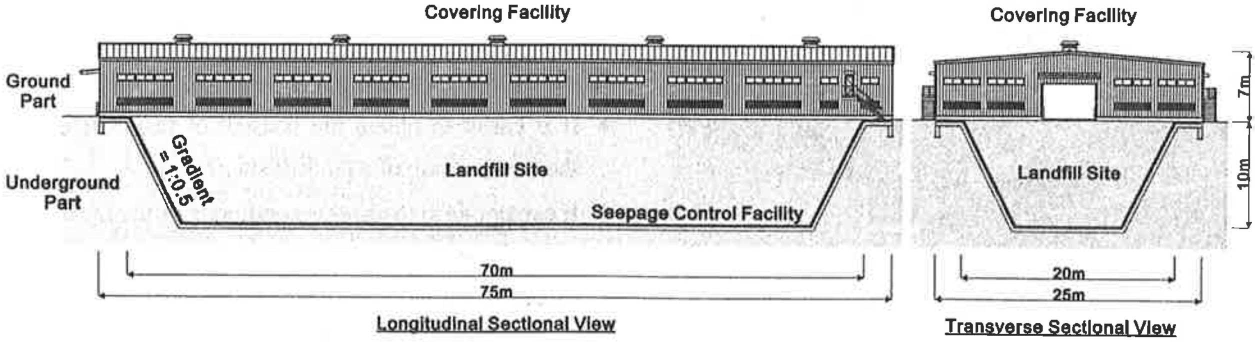


Fig.1 Cross-Sectional View of Model CSDF

Table 2 Features of Covering Facilities

	Rigid-frame type (Full web structure)	Truss type (Lattice beam structure)
Merit	Adoption of standardized goods is possible. Design term is short. Effective when small-scale.	The correspondence to a large span is easy. Effective when large-scale.
Demerit	Inside columns are required for correspondence to a large span.	An individual design is required. There are few elements of construction-cost reduction.

(2) Important Notice about Laws

Covering facilities are buildings and therefore the Building Standard Law is applied. Moreover, the Fire Service Law is also applied. The important points of each law are shown below.

Regarding the Building Standard Law:

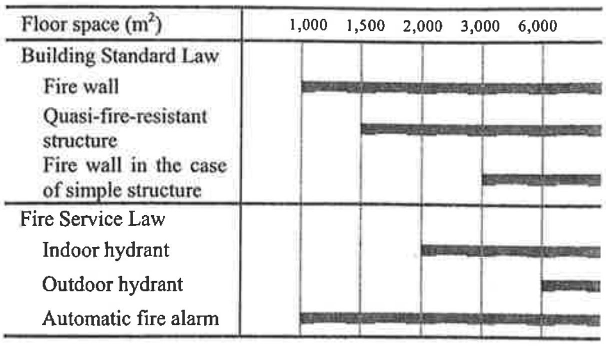
According to the Building Standard Law, if covering facilities are treated as general buildings, a fire wall is needed for every 1,000m^2. However, if covering facilities are fireproof buildings or quasi-fireproof buildings, a partition by the fire wall is unnecessary. In addition, covering facilities can be treated as simple structure buildings, and if the floor space is less than 3,000m^2, the above-mentioned regulation may not be applied.

Regarding the Fire Service Law:

Covering facilities are classified into "others" according to the Fire Service Law in many cases. If covering facilities are "others" and "not a non-window floor," a fire extinguisher is needed for every 300m^2. If the area is more than 1,000m^2, an automatic fire alarm is also needed. Furthermore, in the case of covering facilities being made of quasi-fire-resistant structure, if the area is more than 2,000m^2 then indoor hydrant equipment is needed, and if the area is more than 6,000m^2 then outdoors hydrant equipment is needed. However, the facility can be exempted from the installation of such hydrant equipment by installing a power-driven fire pump.

Regulation by the Building Standard Law and the Fire Service Law is shown in Table 3.

Table 3 Regulation by Laws



(3) Construction Costs of Covering Facilities

Construction costs were calculated for the rigid-frame type (full web structure) and truss type (lattice beam structure) of steel frame structures, which are typical structural forms for covering facilities.

The relationship between the construction costs of covering facilities and the scale of facilities is shown in Fig. 2. If the rigid-frame type (full web structure) is adopted as the covering facilities of Model CSDF, the construction costs are ¥78,000,000.

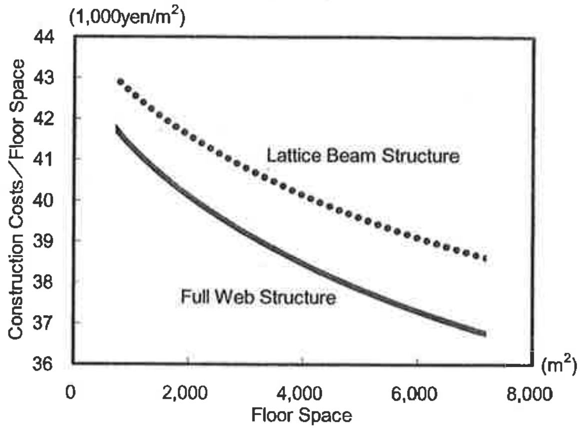


Fig.2 Construction Costs of Covering Facilities

__Incidental Equipment__

The principal incidental equipment of the CSDF is introduced in this section, and the cost of each piece of equipment is calculated.

(1) Equipment for Reclamation

Equipment for reclamation is also required in the OPLS.

Usually, a gentle slope road is prepared, and waste is carried in and deposited by vehicles. However, it may be difficult to prepare the gentle slope road depending on some structures and the size of the landfill.

In this subsection, the slider landfill system and the machine landfill system are introduced as suitable for CSDF, which has a comparatively small-scale landfill.

Slider Landfill System:
Waste is thrown in from vehicles through a slider, and the thrown-in waste is leveled and compacted with heavy machinery in the landfill.

Machine Landfill System:
Waste is thrown in from the equipment used for reclamation by the bridge type crane equipped with a hopper. In the case of this system, full automation of reclamation work by the devices of the reclamation procedure or method is possible.

The cost is ¥8,500,000 if the slider landfill system is adopted as the equipment for reclamation in the Model CSDF.

(2) Lighting Equipment

By the Labor Security and Hygiene Law, 70*lx* or more of the illumination of the work place where a laborer works must be secured. Generally, mercury lamps are used for landfills and fluorescent lamps are used for management passages.

The specifications and costs of lighting equipment of Model CSDF are shown in Table 4.

Table 4 Specifications and Cost of Lighting Equipment

	Specification	Cost
Landfill	Mercury lamps (with lifts)	¥5,200,000
Management passage	Fluorescent lamps (70m, 2 lines)	¥140,000
Total		¥5,340,000

(3) Watering Equipment

Watering equipment is installed for promoting the stabilization of waste and control of coarse particulates. Watering systems include a rain-gun system, a mist system, and a rain system. In actual situations, however, precise watering standards for promoting the stabilization of waste are not established.

In this subsection, the mist system, which greatly helps control coarse particulate, is examined. In the mist system, the generation of coarse particulate is efficiently controlled by easing the surface tension of water with chemicals. The specifications and costs of such watering equipment for Model CSDF are shown in Table 5.

Table 5 Specifications and Costs of Watering Equipment

	Specification	Cost
Watering system	Mist system	Cost of equipment: ¥6,800,000 Running cost: ¥120,000 /year
Watering range	Whole surface of landfill	
Water used	Water of flood control reservoir	
Watering time	1.0 hour/day	
The amount of watering	300 *l*/hour	

(4) Ventilation Equipment

Ventilation equipment is installed for the preservation of the environment inside a landfill site. In the ventilation system, there is natural ventilation represented by a louver and mechanical ventilation represented by a roof fan. Moreover, there is a blower system for ventilation of purposes other than for preserving the environment within a landfill site. An example is the promotion by the blower system of the stabilization of waste by aerobic reclamation management.

In this subsection, the combination of the louver and roof fan to preserve the environment inside the landfill site is examined. The specifications and costs of ventilation equipment of Model CSDF are shown in Table 6.

Table 6 Specifications and Costs of Ventilation Equipment

	Specification	Cost
Louver	8 places	¥2,200,000
Roof Fan	4 sets	

(5) Snow-Melting Equipment

In a district where snow falls regularly, snow-melting equipment may be needed. Such equipment consists of a watering system or a heat panel system (an electric system or warm water circulation system).

This cost is not calculated for Model CSDF because it was assumed that snow-melting equipment was unnecessary.

Seepage Control Facilities

In CSDF, since covering facilities must be constructed, it is common to make the area of the landfill as small as possible and to make a plan so that waste may be disposed of efficiently. Therefore, the vertical gradient of the landfill is often steep.

In this section, the kinds of seepage control facilities for CSDF are classified and the construction costs are calculated.

(1) Kinds of Seepage Control Facilities in CSDF

When the kinds of seepage control facilities are classified in the actual results of CSDF, it is generally as follows. In most cases, the gradient of the slope of the landfill is vertical or steep.

- Reinforced banking + Liner sheets
- Reinforced concrete retaining wall + Liner sheets
- Reinforced concrete box + Liner sheets
- Steel plates + Asphalt sheets

(2) Construction Costs of Seepage Control Facilities

The classification "Reinforced banking + Liner sheets" was chosen as the type of seepage control facilities for Model CSDF, and construction costs were then calculated. Liner sheets shall be doubly laid by the surface of the landfill with reinforced banking.

The construction costs of the seepage control facilities of Model CSDF are shown in Table 7.

Table 7 Construction Costs of Seepage Control Facilities

Item	Cost
Storage structure (reinforced banking)	¥65,600,000
Seepage control facilities (slope part)	¥34,883,000
Seepage control facilities (bottom part)	¥9,360,000
Fixed structure	¥1,175,000
Total	¥111,018,000

Water Treatment Facilities

In the CSDF, which has the ability to control the amount of watering, the construction of economical water treatment facilities is possible by adopting the optimum amount of watering and the adequate watering method according to the composition and quantity of waste.

In this section, the actual result of the construction costs of water treatment facilities is investigated, and the construction costs of the water treatment facilities of Model CSDF are calculated by introducing the trial calculation formula of construction costs.

(1) Case Investigation of Construction Costs

A case investigation was conducted in order to grasp the actual construction costs of water treatment facilities. The subjects of the investigation were 62 facilities constructed in 1998 and afterwards where capacity is below $30m^3$/day.

Although there are some variations, results showed that there is a tendency for construction costs to become high in relation to increases in capacity.

(2) Trial Calculation Formula of Construction Costs

The trial calculation formula of construction costs was examined using the results of the case investigation and Tanaka's formula, shown in Eq. 1:

$$C_W = (1+\Sigma a_m)\cdot C_{W0}\cdot (S/S_0)^{0.7} \qquad \text{[Eq.1]}$$

In this formula, C_W and C_{W0} are construction costs and standard construction costs (yen), S and S_0 are capacity and standard capacity (m^3/day), and a_m is the weight coefficient defined for each treatment process.

Through many calculations, the standard construction costs and standard capacity were finally set up with C_{W0}=200 million yen, S_0=10m^3/day.

(3) Construction Costs of Water Treatment Facility

The specifications and construction costs of the water treatment facility of Model CSDF are shown in Table 8.

Table 8 Specifications and Costs of Water Treatment Facility

	Specification	Cost
Treatment capacity	2.0 m^3/day	Cost of equipment: ¥139,000,000 Running cost: ¥5,800,000 /year
Treatment process	Calcium removal Coagulating sedimentation Biological denitrification Sand filtration Activated carbon adsorption Desalination treatment	
Engineering & construction works	Included	

EXAMINATION OF BENEFIT

In this chapter, the monetarization of the benefit of Model CSDF was attempted. The examination items regarding the benefit fall into four categories: consensus building, maintenance management, environmental management, and land utilization.

The items examined for each category are listed, and the results of the monetarization attempt are shown.

Examined Items and their Contents

The examined items and their contents regarding the benefits of consensus building, maintenance management, environmental management, and land utilization are shown in Tables 9-12.

Table 9 Consensus Building

Items	Contents of the monetarization (example)
Shortening of term	Number of times of local explanation meeting
Reduction of local measure costs	Construction of public hall, park, etc.
Improvement of scenery	Construction of periphery wall of landfill site
Flexibility of location	Construction of hauling road
Utilization of other facilities	Effective utilization of surrounding lifeline facilities
Existence of trial	Judicial costs
Consignment treatment of waste	Consignment treatment costs of waste until agreement

Table 10 Maintenance Management

Items	Contents of the monetarization (example)
Ease of reclamation work	Operation of reclamation work at the time of heavy rain and heavy snowfall. Snow removal costs and maintenance costs of roads.
Shortening of management term	Term from completion of reclamation to closure of landfill site
Management of facilities	Maintenance costs of covering facilities, seepage control facilities or water treatment facility
Measure of floods	Spillway for heavy rain, and construction of reservoir pond
Reduction of volume of cover soil	Volume of cover soil for scattering of waste and measure of coarse particulate

Table 11 Environmental Management

Items	Contents of the monetarization (example)
Measure of scattering and coarse particulate	Construction of fence for measure of scattering
Measure of bad smell	The amount of spraying of deodorant or antiseptic
Measure of discharge of treated water	Compensation caused by discharging to fishery people and agricultural people caused by discharging
Damage to image	Fall of land prices of surrounding areas

Table 12 Land Utilization

Items	Contents of the monetarization (example)
Surrounding land utilization	Research expenditure of land utilization and compensation to surrounding land utilization being restricted
Ease of location selection	Cost for reservation of the substitute land for surrounding facilities and move
Reduction of design costs	Special design costs for geographical feature or geology
Ease of ultimate land utilization	Possibility of early land utilization, and utilization of facilities of landfill site

The Benefit of Closed System Disposal Facilities

The Model OPLS was defined in order to monetarize the benefit (refer to the following chapter). It is difficult to monetarize the benefit of a CSDF directly. Therefore, the costs for Model CSDF and a Model OPLS were calculated for each category, and the difference was considered the monetarized benefit of Model CSDF.

However, "Flexibility of location" and "Measure of floods" were not included since benefit was defined as the difference of the construction costs of the landfill sites. Moreover, "Shortening of management term" and "Ease of ultimate land utilization" were not included since the benefit was obtained after completing the reclamation of waste.

The monetarized benefit of Model CSDF is summarized in Table 13.

Table 13 Benefit of Model CSDF

Category	Benefit of Model CSDF
Consensus Building	¥63,200,000
Maintenance Management	¥1,780,000/year
Environmental Management	¥55,000,000 + ¥225,000/year
Land Utilization	¥11,400
Total	¥129,600,000 + ¥2,005,000/year

EXAMINATION OF COST EFFECTIVENESS

In this chapter, the cost effectiveness of CSDF and OPLS was compared on the basis of the results obtained by "CONSTRUCTION COSTS OF MAIN FACILITIES" and "EXAMINATION OF BENEFIT."

Examination Conditions

As shown in Table 14, a Model OPLS which has the disposal capacity of waste equivalent to that of Model CSDF was defined in order to compare the cost effectiveness of CSDF and OPLS. The comparison is based on the difference in the amount of cover soils in a reclamation term in which reclamation capacity is 12,000m^3. The disposal capacity of the waste of both landfill sites is the same.

Moreover, the construction term of a landfill site was assumed to be 2 years, and the reclamation disposal term of waste was assumed to be 15 years.

Table 14 Specifications of Model OPLS

Reclamation capacity	12,000 m^3
Width of landfill (earth surface)	47 m
Width of landfill (bottom)	27 m
Gradient of slope of landfill	1 : 2.0
Depth of landfill	5 m
Length of landfill (earth surface)	74 m
Area of landfill	3,478 m^2
Capability of water treatment facility	6.0 m^3/day

Calculation of Costs

Costs consist of the construction costs and maintenance management costs of facilities. The construction costs of facilities are shown in Table 15, and maintenance management costs are shown in Table 16.

Table 15 Construction Costs of Facilities

	Model CSDF	Model OPLS
Covering Facilities	¥78,000,000	¥0
Equipment for reclamation	¥8,500,000	
Lighting equipment	¥5,340,000	
Watering equipment	¥6,800,000	
Ventilation equipment	¥2,200,000	
Seepage control facilities	¥111,018,000	¥68,363,000
Water treatment facilities	¥139,000,000	¥300,000,000
Others	¥71,200,000	¥111,500,000
Expenses	¥105,515,000	¥119,966,000
Total	¥527,573,000	¥599,829,000

Table 16 Maintenance Management Costs of Facilities

	Model CSDF	Model OPLS
Watering equipment	¥120,000/year	¥0/year
Water treatment facilities	¥5,800,000/year	¥9,600,000/year
Others	¥12,000,000/year	¥14,400,000/year
Total	¥17,920,000/year	¥24,000,000/year

Calculation of Effect

In addition to the benefit examined for the preceding chapter, the following effect was taken into consideration in calculation of the effect.

- The effect of life preservation and difference of collection cost + haulage in comparison with the consignment of disposal of waste
- The effect of prevention of the pollution of groundwater and soil
- The effect of prevention of the scattering of waste and prevention of bad smell
- The effect of preservation of water quality of the public water area

The calculated effect is shown in Table 17.

Comparison of Cost Effectiveness

The cost effectiveness of Model CSDF and Model OPLS was compared using the results of the foregoing paragraphs (Fig. 3). Because B/C exceeds 1 during the reclamation, sufficient cost effectiveness can be expected regarding both of the landfill sites.

However, it is in the 9th year that B/C exceeds a value of 1.0 in Model CSDF after reclamation starts, while it is in the 14th year in Model OPLS. Therefore, in this examination condition, it turns out that Model CSDF is advantageous with respect to cost effectiveness.

Table 17 Comparison of Effect

	Model CSDF	Model OPLS
Benefit of Model CSDF	¥129,600,000 + ¥2,005,000/year	¥0
Effect of life preservation	¥33,468,000/year	¥33,468,000/year
Difference of the collection cost + haulage of waste	¥4,398,000/year	¥3,298,000/year
Effect of prevention of pollution of groundwater and soil	¥158,272,000	¥149,957,000
Effect of prevention of scattering of waste and prevention of bad smell	¥9,150,000/year	¥27,300,000/year
Effect of preservation of water quality of public water area	¥4,480,000	¥6,000,000
Total	¥292,352,000 + ¥49,021,000/year	¥155,957,000 + 64,066,000/year

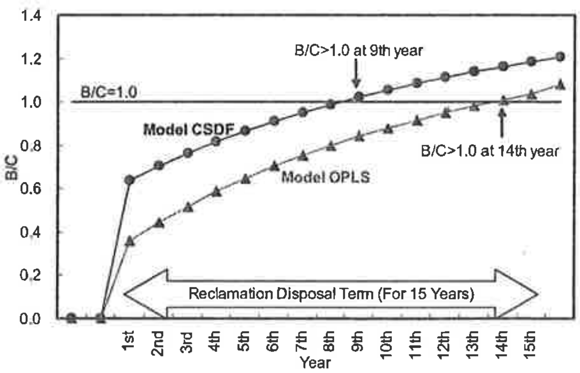


Fig.3: Comparison of Cost Effectiveness

CONCLUSIONS

Models of CSDF and OPLS having 10,000m^3 disposal capacity were set up, and construction costs and maintenance management costs were calculated. Moreover, the benefit of constructing CSDF was examined, and the cost effectiveness of CSDF and OPLS was compared. The advantages of CSDF were confirmed by these results.

However, a bold assumption was introduced through the setup of models, the calculation of construction costs and maintenance management costs, and the monetarization of the benefit. Although the examination in this study is very useful in order to understand the advantages of CSDF over OPLS, more detailed studies are necessary in the future.

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