APPLICATION OF LIFE CYCLE MANAGEMENT ON PORT DESIGN AND OPERATION

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ABSTRACT

Life Cycle Management is a new concept in design field. Life Cycle Management supports an improved quality approach. It is an optimum solution, in which we have many factors to examine.

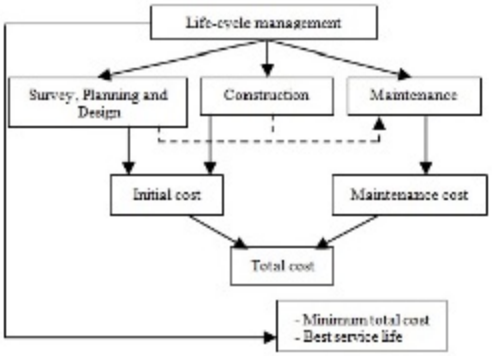
Nowadays, developed countries have applied Life Cycle Management method to design new structures or rehabilitate existing ones. However, in some developing countries, structural designers concentrated on design and construction phase with less attention to maintenance, resulting in low quality of structure. These structures have short life spans. To expand their life spans, we need a lot of maintenance and repair works, resulting in very high total costs.

This paper presents a brief of this theory and its application on port design and operation to avoid above situation.

1. INTRODUCTION

The main purpose of Life Cycle Management (LCM) is to minimize the total costs and to maximize life spans of structures. There are three main components: design phase, construction phase, and maintenance phase. They are carried out independently, however results or decisions of the previous phase always effect to rearward phase.

Initial cost is the total costs for design and construction phase, and maintenance cost includes cost for operation, maintenance and repair. The total costs that include initial cost and maintenance cost are whole expense used to maintain service life of structure from design phase to the end of its life span. General concepts of the Life Cycle Management of structure are shown in following chart.



2. THE MODEL OF LIFE CYCLE MANAGEMENT

2.1 Design stage

2.1.1 Survey

Survey is the first step in design stage. It determines location, scale and kind of structure. Survey has to be applied carefully not only to avoid failure of structures, such as subsidence, slide, or collapse …, but also to reduce construction costs.

The purpose of the surveys is to establish the baseline data and information for planning and design of the required facilities related to the port project.

There are many elements which affect to quality of survey, such as equipment, technology, test methods and especially, human reliability. Among them human factor is the most important. It dominates all of the others, and affects strongly the accuracy of survey results.

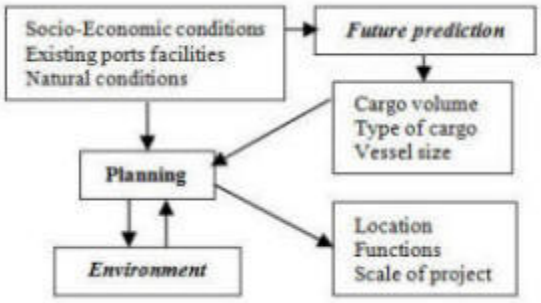
Based on the results of the above surveys and analyses, we have a summarization of the planning system, and human resource are some important factors that are surveyed and analyzed.

The advantages and disadvantages in the operation of existing port facilities are considered to give a plan that is correspondent with the requirements in being time.

and design conditions. High accuracy of the results is required.

2.1.2 Planning

Natural and socio-economic conditions concern with planning. Natural conditions are the results of survey process. They include soil conditions, wind, tide, currents, waves, erosion, and salinity. Planning is a process to convert all of above conditions into objectives and functions of structures. Besides, prediction in future is important also. It affects the scale and kind of structure. Any planning process changes environment conditions. The good planning process not only satisfies the requirements of socio-economic conditions but also minimize adverse environment effects. It reduces environmental costs.



The purpose of planning process can be shown hereinafter chart:

In this phase, designers have to collect and analyze all of conditions and requirements about natural and socio-economic conditions in being time and future, existing port facilities system and then give some reasonable solutions for planning.

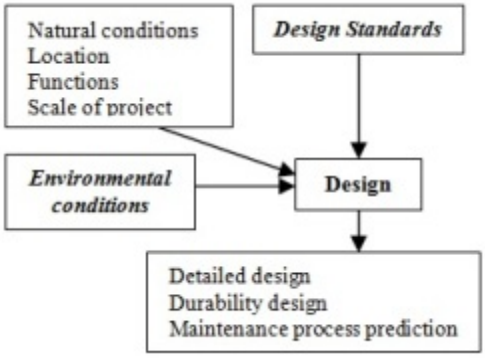
In the most cases, functions and scale of project have to be reflected by all conditions and requirements of social-economy. Therein, population and its growth, economic growth estimation, social policies, transportation

In the end of planning phase, we have general plan chart of project with location of port facilities and their scale also.

2.1.3 Design

The results of the functional analysis and planning are converted into structural requirements in design process. The role of design phase is to ensure that the targets and requirements in the previous phases can be realized in structure and throughout its life cycle. This means that the structures must be serviceable and durable, that they can be maintained and repaired, and finally that they can be demolished if needed.

Design process converts result of survey and planning to the real structures; it can be shown as follows:



In designing port facilities, the following matters should be taken into consideration.

- Functions of the facilities: Since facilities often have multiple functions, care should be exercised so that all functions of the facilities will be exploited fully.

Importance of the facilities: The degree of importance of the facilities should be examined in order to design the facilities by taking appropriate account of safety and broad economic implications. The design criteria influenced by importance of facilities are those of environment conditions, design seismic coefficient, lifetime, loads, safety factor, etc.

The detailed design includes generally the following phases:

- ordinary mechanical design
- durability design (lifetime)
- final design

It is necessary to consider the physical external forces, deterioration, lifetime, structural type, construction works, cost, and influence on the

All of elements, which are considered in this process, such as construction method, equipment, technology … are to ensure the quality of structures. Like as survey phase, human reliability has an important role, beside the other elements. Almost all the structure failures are caused by low construction quality. Therefore, execution of good construction management is important for high quality of

environment and landscape when selecting the materials. It is most important to ensure the required quality. In recent year, in addition to more traditional materials, new material such as stainless steels, titanium and new rubbers, and recycled materials such as slag, coal and dredged sediment have been begun to be used.

2.1.4 The relationship of survey, planning and design

Survey, planning and design are the first steps of structures. They are correlated rigorously, and the results of one step become the initial data for the next step.

Survey is the first stage of design process. The results of survey are initial data of planning and design. As the role of data, their accuracy is the most important factors of survey. With proposal of planning and design, the designers give the kinds of data be surveyed and their accuracy. Accuracy of data depends on survey methods, experiment methods, equipment and especially human skills. Planning and design with the high accuracy data will avoid some mistakes, such as uneven settlement, slide of structures … Besides, accuracy of data also effect to safety factors be used in design standards. If the accuracy is higher, safety factors can be smaller. Designers can save material volume and costs. Depending on the results of planning, designers have the suitable decisions for kind of structures.

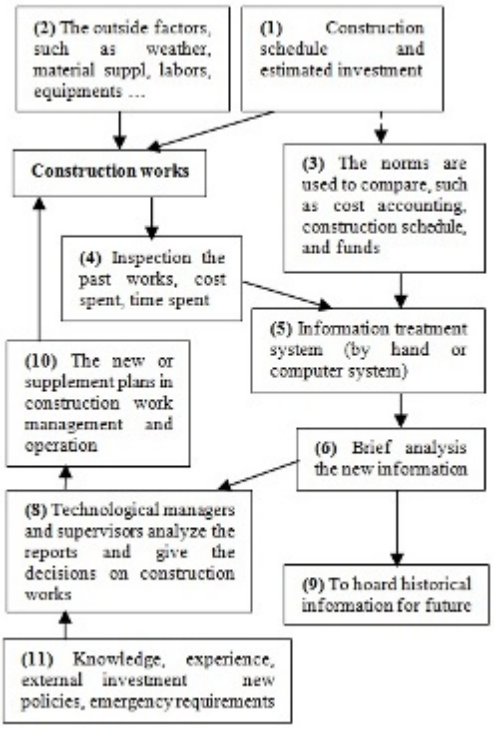
These three stages have the close relationship together, the result of the prior stage affects the decision of the next one. Finally, the results of design process play the important role in the initial cost account, and affect the maintenance cost also.

2.2 Construction stage

Construction process converts result of design into real structure. In this phase, the quality of structure is the primary aim.

structures. This affects also the needs for maintenance costs.

In order to carry out design rationally, it is necessary to give sufficient consideration to the construction method. In the case that the construction period is stipulated, it is necessary to give consideration both to the design and the construction method, in order that it will be possible to complete construction work within stipulated period. The construction period is general determined by things like availability of the materials, the construction equipment, the degree of difficulty of construction, the opening date and the natural conditions. The construction management cycle is shown following flow chat:



Based on construction schedule and estimated investment, box (1), the activities of construction work are carried out. Due to the outside factors, box (2), actual activities of construction work that can be accompanied with given schedule or not are recorded in box (4). The contents in box (1) that are become the norms in box (3) are used to compare with results of actual activities, box (4). And then, the information of (3) and (4) will be sent to information treatment centre. There, the information is analyzed briefly and sent the results to (6). These results will be held like

Maintenance refers to a system consisting of a series of linked activities involving the efficient detection of changes in the state of serviceability of the facilities and the execution of effective measures such as rational evaluation, repair, and reinforcement.

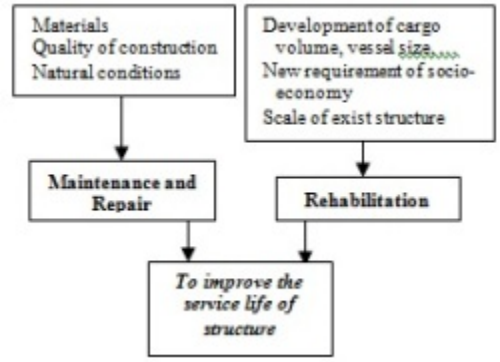
Main constitutive structures in port facilities are generally made of steel and/or concrete. Those construction materials will exhibit superior performances in marine environments, but are difficult to be well maintained in good conditions;

as history information in box (9) for future, and sent to technological managers and supervisors in box (8). They will analyze these reports with their knowledge and experiment. And then, they consider with some other outside factors, such as more or less investment, new policies … to give the reasonable decisions for remain construction works.

2.3 Maintenance and repair

This is the last component in life cycle management. Most structures after being used for a time must be maintained, rehabilitated or repaired to continue lifetime in used. When we design, we have to predict problems that may occur in future based on analysis the past process. This prediction, quality of structure and materials to be used decide maintenance process, such as maintenance or not, when to maintain or rehabilitate or repair … In this phase, some elements as method, technology, materials to be used are considered.

The following flowchart is shown the factors to concern with maintenance, repair, and rehabilitation.



nevertheless they are subjected to extremely severe atmosphere from the viewpoint of materials deterioration. Therefore, it is important to build a rational maintenance strategy during the service life for satisfying required performances. Consequently, some port structures suffer from heavy deterioration, which may result in lack of their structural capacities against requirements. The typical structural deterioration is caused by chloride ions seawater that induce corrosion of steel as well as steel-bars embedded in concrete.

Periodic maintenance is the only way to be taken in port structures after commencement in service for avoiding heavy deterioration and consequent loss of structural capacities. In addition, effective and rational maintenance can be achieved with understanding both the process and progress of deterioration and the relationship between materials deterioration and decrement in structural capacities. For this purpose, it is important to establish a comprehensive maintenance management system that provides engineers with quantitative information on deterioration as well as several alternatives of maintenance work.

The system enables to predict the process of future deterioration, to implement rehabilitation plans for minor repair, major repair, strengthening …, and to estimate arising cost due to maintenance work. In particular to support engineers in making decisions of measures or remedial work taken against predicted future deterioration, some alternatives should be offered based on a combination of maintenance cost minimization and quality maximization approach.

When designing a structure, it is necessary to give due consideration to the system of future maintenance and to select the types of structures and the materials used so that future

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maintenance will be easy executed, while reflecting this aspect in the detailed design.

2.4 Relationship of design, construction and management

Design, construction, and maintenance are three main components of Life Cycle Management. The goal of design is a detailed design that is suitable with actual conditions and environment requirements. In the construction, quality management of structure is the most important because it effect to maintenance strongly. Actually, maintenance process depends on design and construction quality very much. To explain this matter more clearly, we can see diagram below:

or repair. Thus, the total cost is not so much, and maybe it is lower than the total cost in the first case, C_{t2}.

This is a part of the application of LCM for structure. And this is also very simple example to explain the relationship between the initial cost and maintenance cost. Actually, the maintenance cost depends on not only initial cost, but also construction quality, and how to maintain or repair. Thus, the estimation the total cost is a complex subject, and designers need to consider carefully when they select and analysis the factors.

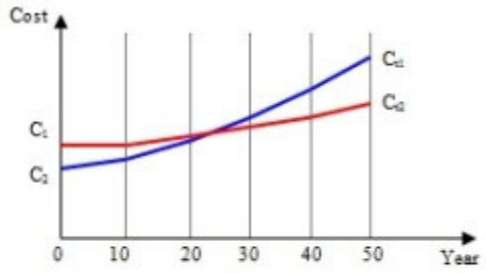
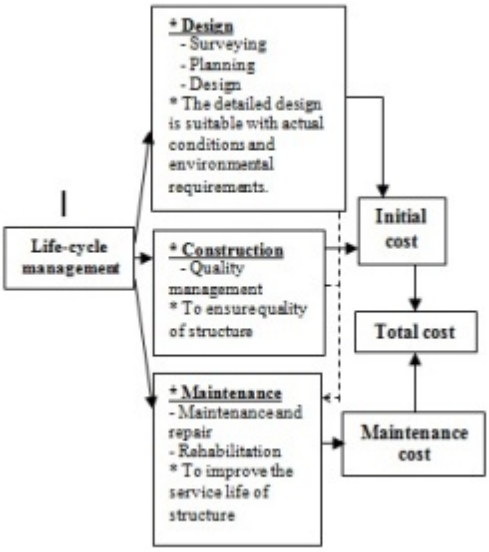


Fig.1 Total cost for two solutions

For example, design life span of structure is 50 years. The structure is built in seawater that has corrosive characteristic, so material used is reinforced concrete. Assuming that design and construction conditions are good, i.e. the structure gets at good condition after built. We have two options to choose.

The first, the structure has no covered to protect from corrosion. The initial in this case is not so much, called C_1. But after 10 years, seawater goes through inside the concrete and to deteriorate of structure, we have to repair it to continue its service life. Depends on the deterioration level, we give the suitable repairing method. Then, after every used period, we have to check and repair if needed. Finally, the total cost maybe is so high like above figure, C_{t1}. The second, when the structure is constructed, we cover whole parts that might be deteriorated easily. In this case, the initial cost is higher than of above case, called C_2. However, we can use structure longer without maintenance



3. APPLICATION OF LIFE-CYCLE MANAGEMENT ON NEW PORT

The model of Life Cycle Management can be shown following flow chat:

The results of surveying have to satisfy the requirement of input data. If yes, they are used in planning and detailed design, if no, we have to survey again until these results are good.

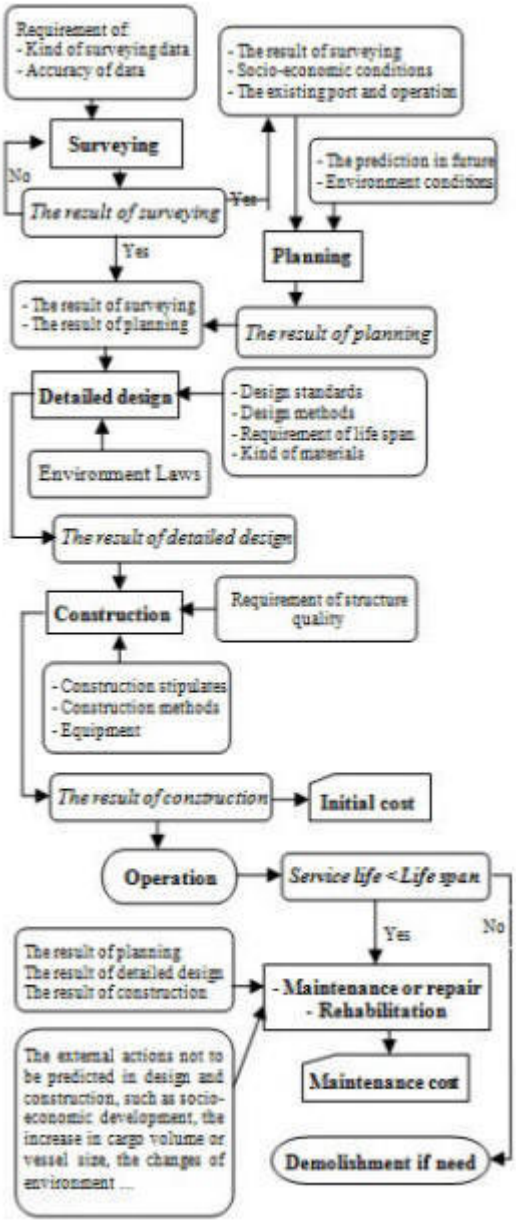
The process is continued step until the project finish and can be operated.

After used for a time, structure will be maintained, repaired or rehabilitated. If the actual service life is less than design life span, maintenance process is carried out. If not, the structure is demolished if need.

Following flow-chat is used for the new project, with the existing projects, we start from operation box.

superior performances in marine environments, but they are difficult to be well maintained in good conditions; nevertheless, they are subjected to extremely severe environment from the viewpoint of materials deterioration. Consequently, some reinforced concrete marine and coastal structures suffer from heavy deterioration, which may result in lack of their structural capacities against requirements. The typical structural deterioration is caused by chloride ions in seawater that induce corrosion of rebars embedded in concrete. Many studies have been conducted to date about the mechanism of chloride-induced deterioration and useful results are available to tackle the problems.

Periodic maintenance is the only measure to be taken in reinforced concrete marine structures after commencement in service for avoiding heavy deterioration and consequent loss of structural capacities. In addition, effective and rational



4. APPLICATION OF LIFE-CYCLE MANAGEMENT ON EXISTING PORT

4.1 How to apply Life Cycle Management for existing ports

Main constitutive structures in port facilities are generally made of steel and/or concrete. Those construction materials will exhibit maintenance can be achieved with understanding both the process and progress of deterioration and the relationship between materials deterioration and change in structural capacities. For this purpose, it is important to establish a comprehensive maintenance management system that provides engineers with quantitative information on deterioration as well as several alternatives of maintenance work.

This system consists of the following five stages:

Inspection and quantification of current deterioration: basic data are supplied to the system regarding information on materials and structures as well as the results of inspection on current conditions of structural members.

Evaluation of current deterioration: The estimated results of materials deterioration by the system are adjusted to those of inspection followed by modification of the calculation parameters.

Prediction of future deterioration: The future deterioration process of structural members is predicted by using material degradation models with the modified parameters.

Proposal of measures: Several methods of measures for repair and rehabilitation including their execution timing and frequencies are proposed from the viewpoints of estimated life-cycle cost and design lives.

Decision of the most probable method: The most appropriate measure is selected by engineers among subsidiary work to the other methods. The life expectation of the method varies, but is fixed to 15

alternatives of proposals on the basis of benefit versus cost judgment.

4.2 Estimation and prediction on progress of deterioration of reinforced concrete structures

To find out an appropriate solution for maintenance or repair of existing structure, estimation and prediction on progress of deterioration is necessary. Three fundamental parameters have been proposed for the prediction by Dr. Yokota and Dr. Hamada1: chloride content on the surface of concrete, an apparent diffusion coefficient, and the depth of concrete cover to a rebar embedded. Using these three parameters, it is possible to calculate the chloride content in concrete at a certain position and time. The progress of deterioration can be estimated and predicted in two ways, i.e. calculating the chloride content and having visual inspection. Alternative measures for rehabilitation can be proposed based on the results of these two measures.

4.3 Proposal some rehabilitation methods

Measures generally taken for rehabilitation to port structures were classified based on the past records of rehabilitation. Methods and their characteristics are summarized in Table 1.

Table 4-4 General method of repair and rehabilitation

Name	Abbreviation	Lifetime (in year)	Note
Crack injection	CI	Not applicable	
Surface coating	SC	15	
Sectional reform	RS	Long	SC if required
Cathodic protection	CP	20	
Desalination	DS	Long	SC if required
FRP covering	FC	30	RS if required

Crack injection has been widely used but can be applicable only in the early stage of deterioration. Surface coating has been also used in the early stage of deterioration as well as years in this system. Cross-sectional reform includes patching and removal of concrete cover part followed by casting of new concrete. This method is the most popular one for rehabilitation to degraded port structures. Its cost varies depending on the extent of removal parts. Surface coating was executed a few times with RS method. Cathodic protection and desalination have been executed with surface coating. When cathodic protection is applied, annual maintenance cost will increase.

4. CONCLUSION

Life Cycle Management for construction project is a new concept. Actually, it is an optimizing process of life cycle cost that covers the whole project cycle from surveying to maintenance. This is a difficult subject because there are many aspects, and many parameters concerned. The main issue is how far such aspects and parameters can be pursued because we cannot get 100% accuracy for all portions that we take into account.

The fundamental matter to choose the best solution is to maximize lifetime and to minimize the total cost of project. Normally, comparison is made among alternatives in terms of life cycle cost within a given lifetime, and then the chosen solution has the minimum total cost. Life Cycle Management is not only to apply for the new structures, but also for the existing structures. With this application, the existing structures will be maintained, repaired or rehabilitated more efficiently. Although it is difficult to consider and analyze many aspects in this theory, Life Cycle Management is being applied more and more widely in the world because of its benefit.

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