Study of Description of Technological Characteristics in Construction Industry

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***Abstract*—Various factors work on an artificial system, and the composition rule and grammar of that system have some tendency. To create certain special system, through understanding its composition rule and grammar, it is necessary to analyze what are the factors (Node) to compose total system and how do they compose, but it is difficult to make clear what Nodes are directly. There are several ways to analyze artificial objects, and one of the ways is "Architecture" concept. Basic view point of this concept is to analyze the interfaces between elements those are the components of artificial system, such as product, organization, or process. In this paper, "Architecture" is defined as follows: the fundamental rule about composition (method of structure) and the fundamental technique (method of construction) of an artificial system, from the point of view of how to divide the system into some elements (modules) and how to design their joints (interfaces). It is for the purpose of indicating one approach regarding effective development method through such discussions for developing products of each area whose development speed increases at present. Eventually, we consider indicating the approach related to the flow of developing products that correspond to the characteristics of each product area and design philosophy unique to the designer.**

***Index Terms*—architecture concept, integration, modularity, technological tendency, hierarchy structure**

I. Introduction

Recently, many managers of manufacturing companies have commented on the difficulties of total management of product development. Several companies have succeeded in creating excellent products that have had a major impact in their particular industrial fields. There is thus a need to understand the fundamental mechanisms of product creation [1].

In case of construction industry, it is difficult to compare one project with the other ones because of complicated conditions. Each site has some special conditions including regulation, geology, neighbor and so on. At same time, there are many kinds of works in each construction project, so management of construction projects is complex and unclear in several aspects.

On the other hand, it is quite important to review the basic engineering characteristics of construction industry. There are several steps to develop products, such as analysis, design, and arrangement. It is reasonable to approach every step with some domestic reasons. However, it is not difficult to find unreasonable industrial project models.

This paper analyzes the characteristics of construction technology, and develops description method to make clear fundamental tendency of technology. This method would demonstrate the importance of understanding Strong points and weak points of each technological tendency.

II. Method Of Thchnology Description

A. Fundamental Architecture Logic

Based on experience in how architects consider the design of the built environment, it is possible to establish a fundamental architectural design logic that is applicable to all types of products and services. In this context the term 'architecture' takes on a broader definition to that of the professional architect, as all products and system incorporate architectural principles in their design and organization. In the creation process of products, it is possible to understand that there are two main parts: 1) creating design-information, and 2) producing the physical product.

By adopting a design-information view of industries, it is proposed that product architecture may be a significant factor in determining the industrial sectors in which firms are more likely to exhibit competitive performance [2]. More specifically, Japanese firms tend to be more competitive in the manufacture of products with an integral "Architecture" [3]. On the other hand, a prevailing view in the literature is that over time the product architecture of a firm shifts from being integral to modular. There appears to be an inevitability regarding the evolution towards modular "Architecture." This raises an interesting question regarding the type of architecture adopted by firms that can succeed in maintaining competitiveness over time.

The design-information view of industries considers a product as being design information that is embodied in a particular medium or material [4]. Products comprise physical components, functional elements and interfaces between interacting physical components [5]. A productive resource is considered to be an information asset and the production process is regarded as a system of productive resources, for example, on the factory floor. Production or commercial manufacture is then considered

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as the repeated transfer of design information from the production process to a material or medium.

Fujimoto also highlights that product architecture can include process architecture [6]. Process architecture concerns the correspondence between the components of a product and their production process. The term ‘product-process architecture’ encompasses production process influences and is used throughout this paper. Existing literature emphasizes two classification methods for types of architecture; modular versus integral.

Ulrich defines modular architecture as “a one-to-one mapping from functional elements in the function structure to the physical components of the product, and specifies de-coupled interfaces between components” [7]. On the other hand, integral architecture is defined as “a complex (non one-to-one) mapping from functional elements to physical components and/or coupled interfaces between components.” It is important to note that most products do not fully satisfy the definition of either modular or integral “Architecture.” In reality, a type of architecture exists to a certain degree and Fujimoto refers to architecture as a spectrum [4].

Returning to the reference to firms’ competiveness in the manufacture of products with an integral architecture, examples of this type of products includes cars, motorbikes, games software and compact consumer electronics. By competitiveness, Fujimoto is referring to both productive and market performance. Productive and market performance in turn influence profit, and competitiveness results from having leading performance in any of these areas [8].

Shifting to viewing architecture types from a dynamic perspective, an established view is the tendency of products to ultimately become modular over time. Architecture shifts in a cyclical pattern; newer products with changing design elements tend to be integral products and products with stable design elements tend to be modular products. Time facilitates standardization, a characteristic of modular architecture in which the interfaces between components are standardized [9].

B. The Definition of “Architecture”

Generally, “Architecture” is defined as follows: “how we split the artificial system into modules, how to allocate functions to each module, and how to design and coordinate interfaces among different parts, or modules.”

It is possible to understand that this concept came from Architecture (Building). There are many complicated parts in building components, and original concept of “Architecture” is the situation of a mass with many complicated elements. Thus, computer processors were designed with this concept at first, and after that, many computer components were studied with this logic. Finally, several industrial fields, such as automobile, motorcycle, and computer software, were analyzed with “Architecture.”

“Architecture” concept is based on the design information of productive activities (Fig. 1). Basically,

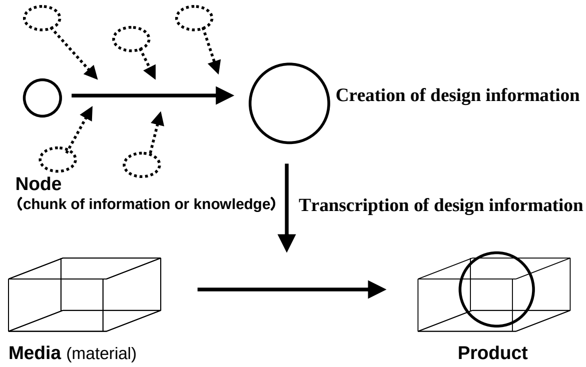

Figure 1. Components of Construction Project.
(Design Information and physical materia[4]l).

“Architecture” is defined on a given artificial system, such as product, production process, organization, and so on. Architecture means a basic design approach to understand connections between functions and structures of system, and to interconnect elements of system [3].

C. Types of “Architecture”

There are two typical indexes in the concept of “Architecture”; “Modular–Integral” and “Open–Close.” An index of “Modular–Integral” is based on the situation of interfaces between elements [3].

If a system is “Integral Architecture,” the rules of design of interfaces must be adjusted to each other, and optimum coordination must be sought for that particular system to fully elicit its potential performance. In contrast, “Modular Architecture” provides standardized interfaces linking different parts and modules. Therefore, it is possible to produce various products by putting together independent parts as long as they are compatible with these interfaces. With “Modular Architecture,” the independence of each module is maintained, and evolution of a system is accelerated. Standardization of interfaces between modules causes a restriction of the range of total system performance.

Open “Architecture” is one kind of modular “Architecture” with an industry standardized interfaces, under which parts and modules can be gathered across corporate and product borders. Open is based upon the concept concerning the common use coverage of interfaces, and it is possible to make information of interface simple in modular “Architecture.” This is the point of the relationship of modular and open. Open-Closed axis is very important view point, but this paper focuses on the index of Modular–Integral axis to make clear the confusion of functions of products.

As next stage of our study, we tried to analyze the merit and demerit of the systems of “Architecture” type.

Generally, with modular “Architecture,” the independence of each module is accelerated to be developed and maintained of a total system. On the other hand, standardization of interfaces between modules causes a restriction of the range of total system performance. With integral “Architecture,” it is possible total high-performance to meet any requirement.

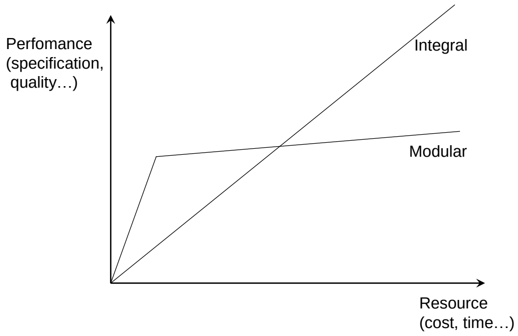

Figure 2. Performance of Integral “Architecture” and Modular “Architecture” ; revision of [10].

But it is difficult to get the fundamental grade performance with small amount of resource, and not so easy to stop the development of performance of system in many cases (Fig. 2). These two types have their own merits and demerits. It is almost impossible to say which is better in general, and they are just different type of system. But we must understand the characteristics of these types and make strategies to fit to these “Architecture” types [11].

III. Description With “Architecture” Concept

Description of characteristics of construction technology is essential, because it is almost impossible to understand strong points and weak points of particular technics without any objective indicators [12, 13]. If we need to take part in international competition to get construction projects, understanding of these points could be the most important.

Standard details of construction work in Japan and UK are studied with “Architecture”, and tried to describe hierarchy diagrams (Fig. 3 is the legend of this description). Especially, complicated technical parts are picked up such as opening of external wall.

A. Standard Detail of Rise on Baseplate

Rise on baseplate is one of the most complicated parts in architecture, but it is possible to find clear difference between Japanese standard detail and UK detail (Fig. 4, Fig. 5) [14, 15].

There are three main elements that are foundation, rise and external wall. All elements including small parts are integral type especially for waterproofing in Japanese standard detail (Fig. 6). On the other hand, there are few integral elements in UK standard detail (Fig. 7). For example, there is a special detail like a tray around blocks in Japanese system, but UK system has only flat surface baseplate under bricks and blocks.

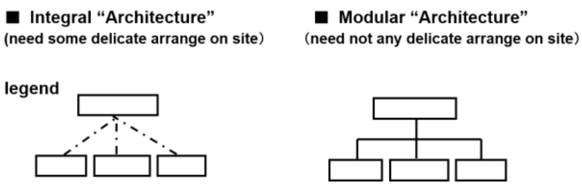

Figure 3. Architecture types with legend.

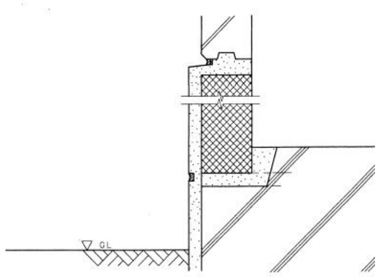

Figure 4. Standard Detail of Rise on Baseplate (Japan) [14].

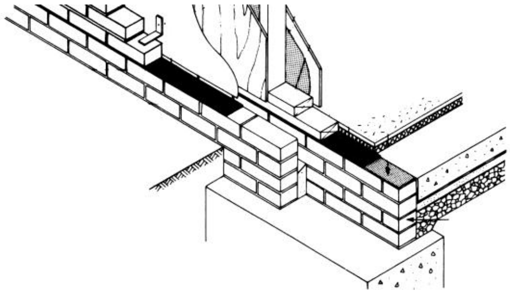

Figure 5. Standard Detail of Rise on Baseplate (UK) [15].

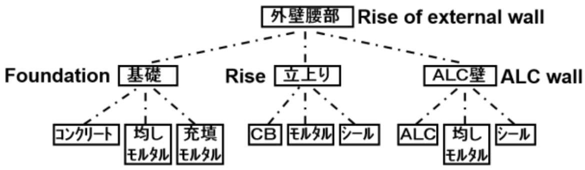

Figure 6. Hierarchy Description of Rise on Baseplate with “Architecture” Concept. (Japan).

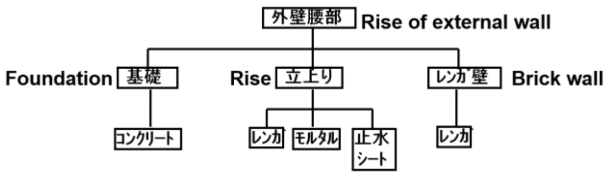

Figure 7. Hierarchy Description of Rise on Baseplate with “Architecture” Concept. (UK).

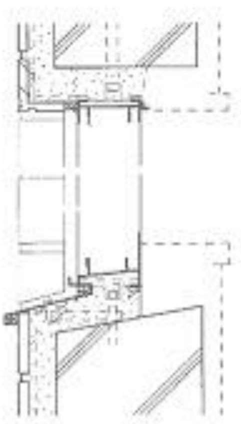

Figure 8. Standard Detail of Opening on External Wall (Japan) [14].

Figure 9. Standard Detail of Opening on External Wall (UK).[15]

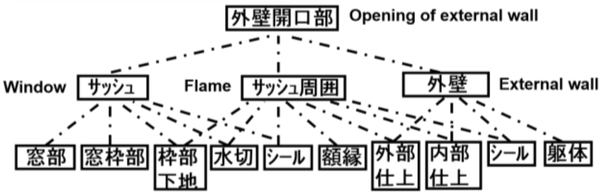

Figure 10. Hierarchy Description of Opening on External Wall with "Architecture" Concept. (Japan) .

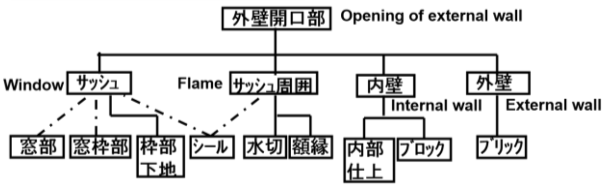

Figure 11. Hierarchy Description of Opening on External Wall with "Architecture" Concept. (UK).

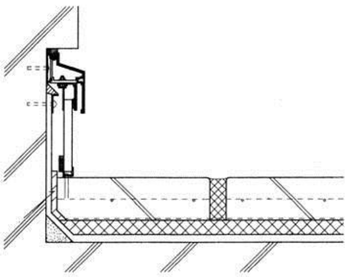

Figure 12. Standerd Detail around Asphalt Roofing. (Japan)[14]

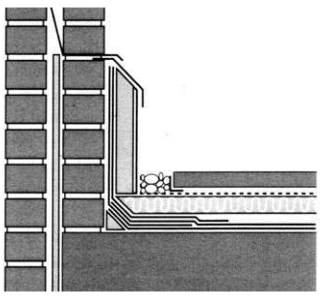

Figure 13. Standerd Detail around Asphalt Roofing. (UK)[15]

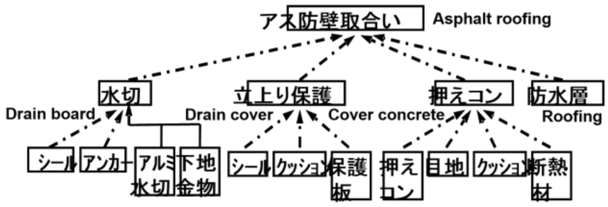

Figure 14. Hierarchy Description around Asphalt Roofing with "Architecture" Concept. (Japan).

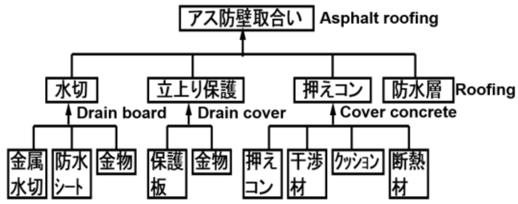

Figure 15. Hierarchy Description of around Asphalt Roofing with "Architecture" Concept. (UK).

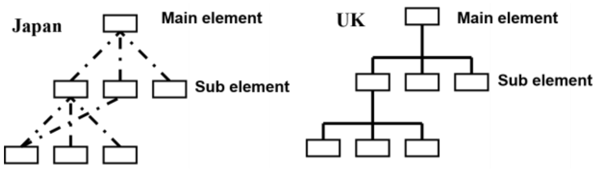

Figure 16. Hierarchy description with "architecture# concept.

B. Standard Detail of Opening on External Wall

There are many construction technological elements around opening on external wall. Especially, window system has several elements and parts such as window, casing, sill and apron (Fig. 8, Fig. 9).

It is possible to find integral type anywhere in Japanese standard detail, and this detail makes high leveled waterproofing system (Fig. 10). Alternatively, there are not so many integral parts and elements in UK standard detail (Fig. 11).

C. Standard Detail around Asphalt Roofing

The most complicated part of asphalt roofing is the edge of asphalt sheet, so there are a lot of elements around the edge of that (Fig. 12, Fig. 13).

All upper level elements are combined with the integration of lower level elements in Japanese standard detail (Fig. 14). All elements are made with standard combination with lower level elements in UK standard detail (Fig. 15).

IV. Analysis with "Architecture" Type

The tendency of "Architecture" of Japanese construction details is recognized as integral type (Fig. 16). Main elements tend to have several integrated sub modules, and sub modules have some integrated small parts in Japanese systems. On the other hand, UK construction system has a tendency of modularity. There are many modular elements on each hierarchy in every standard details of UK.

Each Type, Integral and modular, has strong points and weak points, and it is almost meaningless to make clear which is better type. Important point is to understand the peculiarity and ability of each types.

Following is the essence of merits and demerits of modularity and integration;

A. Merits of Modularity

- Resources, such as costs, taken for adjustments and alignments among architectural elements can be significantly reduced in some cases.
- Each module's independence can be maintained and any changes to the entire system can be kept to local leve.
- Reuse at module level is feasible.
- Development and innovation can focus on a module.

B. Demerits of Modularity

- Setting rules for interfaces requires deep knowledge of the system. (Rough rule setting compromises the system value.)
- Useless modules will be generated in separated parts.
- Established rules are hard to reconsider.

C. Merits of Integration

- Setting rules for interfaces requires deep knowledge of the system.
- Performance can be gained in accordance with input resources.
- High performance can be pursued.
- Measures, such as improvement, can be taken among all the elements.

D. Demerits of Integration

- Resources, such as costs, taken for adjustments and alignments among architectural elements are hard to be reduced.
- Even small changes always require reconsidering related systems. (reconsider the entire system in some cases)
- Development and innovation cannot focus on a modular unit.

Modular type promotes classification, integration of interface, and rules of interface to components to control complexity reasonably.

Moreover, if we use the design philosophy of this modular type, it seems to have a tendency to arrange function and structure into one-to-one correspondence as a result.

On the other hand, the integral type tends to repeat arrangement to all components to increase overall performance (quality, performance, etc.) of objects (such as products.) Advantages and disadvantages of these two approaches are in the condition of being back to back and it has been said that products or services are created based on either design philosophy.

However, we focus on the fact that there is a case example that successfully increases levels of these two aspects and develop discussions to change some of our previous thinking. At least, we can find some possibility to study these two "Architecture" types, integral and modular, at once.

It is also considered that Japan, that is a area with a high endowment of integrative organizational capability stemming from its long term employment and long term transaction practices, tends to have a competitive advantage in integral "Architecture." Thus, Japanese contractors would be able to study merits of modular system, and reduce economic resources. This approach to industrial competitiveness could demonstrate additional explanatory power for the reality of Japanese construction industrial competitiveness with this framework of the relationship between capability and "Architecture."

It is also possible to discuss UK construction technology and organization ability with the concept of "Architecture." Domestic technology in the field of construction is difficult to discuss in some case, but industrial competitiveness is necessary to recognize for international competition.

Construction projects are domestic, so it is necessary to analyze not only one area but also several areas together for total understanding. In this paper we studied Japan and UK construction technology with standard detail, and this could be indicated main tendency of these industrial areas as phenomena.

V. Conclusion

This paper develops description method with "Architecture" concept to represent characteristics of construction technology, and examined situation of construction technological characteristics in Japan and UK with "Architecture." From this, we derived a simple analytical framework for assessing each technical tendency by examining strong points and weak points of integration and modularity.

The important point here is to develop the method of description of the technical tendency in construction field. There are few description methods for that, and it is almost impossible to discuss some of the technological issues in construction industrial field.

This proposal is rudimentary trial with "Architecture," and it is necessary to continue to develop description method for not only physical details of construction technology but also several targets. For example, relationship between parts and functions, arrangement of construction process, and structure of elements could be important aspects.

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