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Study on Introductory Situation of Circular Economy in Architectural Design in Japan

Takuya OKUMURA [1]*, Takashi KANETA [2], Sayaka NISHINO [3]

[1-3] *Department of Architecture and Architectural Engineering, Kyoto University, Japan*
E-mail address: nishinosayaka@archi.kyoto-u.ac.jp

Abstract: The concept of the circular economy is gaining popularity due to the growing awareness of sustainability. However, Japan seems to have lower awareness of this concept compared to other countries. The aim of this study is to clarify the current status of the implementation of circular design in Japanese architectural design. The case studies utilizing the 'Circular Design Toolkit' framework and interviews with architectural designers who practice the circular economy is conducted for it.

Key words: circular economy, Circular Design Toolkit-Framework, architectural design, Japan

1. INTRODUCTION

Circular economy is a way of thinking that applies the mechanisms of the natural world to business models, homeland policies, and products to circulate resources without producing waste [1]. Japanese industrial waste was about 420 million t/year in 2018. The construction industry accounts for about 37% of the total waste in the EU and about 18% in Japan [2], so immediate measures are required in the construction industry. Note that Japanese construction waste soil is not considered as waste, so the figure would be higher under the same conditions as in the EU. In addition, Accenture and McKinsey studies have shown that the circular economy not only reduces environmental impact, but also brings new economic benefits and employment opportunities [3], leading to a rapid rise in the current focus on the circular economy. On the other hand, according to the Dentsu report, awareness of the term “circular economy” in Japan is only 29.6%, a low level of penetration compared to China (90.8%) and Germany (73.8%) [4].

Edahiro, however, noted that in Japan, there have been many good practices related to the circular economy for a long time, such as the recycling culture of the Edo period, but the current efforts and technologies are not well known [5]. In other words, in Japan, there may be a variety of things that are actually practicing the concept of circular economy, although the term “circular economy” is not used. Therefore, it is necessary to investigate the possibilities and actual conditions of the architectural field to see if there are any cases that embody the mechanisms and methods of the circular economy. The purpose of this study is to understand the introduction of the circular economy in Japanese architectural design. The following two points will be examined through literature survey and interview survey.

(1) Japanese architectural cases where the circular economy concept has been applied and the methods used

(2) Japanese technology, culture and ideas that can be used as barriers and lubricants for the introduction of the circular economy

The phases of the study will include the project planning, schematic planning, schematic design, and design development phases prior to the start of construction. This is because the concept of the circular economy is to eliminate the possibility of resource waste from the planning and design stages, and to create a system that continues to circulate resources. In addition, since many environmental facilities have already been implemented in Japan and around the world, this study does not include the evaluation

axis of environment and facilities. In this study, the terms circular economy building and sustainable building are defined as follows, respectively.

circular economy building: a building designed using the concept of circular economy

sustainable building: a building that (1) conserves energy, resources, recycling and hazardous substances throughout its life cycle, (2) harmonizes with the local climate, traditions, culture and surroundings, and (3) maintains or improves the quality of human life in the future, within the limits of the carrying capacity of the local ecosystem, through the design, construction and use phases [6]

The difference between the two is that sustainable building assumes that waste will be generated, and there is no mention of economic benefits. In this study, circular economy buildings are treated as a subset of sustainable buildings.

2. CIRCULAR ECONOMY

2.1. Origins and development process

Accenture states that the origins of the circular economy can be traced back to the late 18th century [7], while Malthus, in his "An Essay on the Principle of Population" [8] published in 1798, states that an increase in human population leads to a decline in global self-sufficiency. Hotelling describes that "contemplation of the world's disappearing supplies of minerals, forests, and other exhaustible assets has led to demands for regulation of their exploitation. The feeling that these products are now too cheap for the good of future generations, that they are being selfishly exploited at too rapid a rate, and that in consequence of their excessive cheapness they are being produced and consumed wastefully has given rise to the conservation movement [9]". More recently, the publication of the book "The Limits to Growth [10]" in 1972, which focused on the finite nature of resources and the risk of depletion, has stimulated debate on resource depletion and economic development. After several years, the focus of the debate shifted from problems to solutions. In their 1998 book "Factor Four: Doubling Wealth, Halving Resource Use [11]", Weizsäcker et al. argue that economic growth and global sustainability are compatible and that human societies can coexist without facing resource depletion. They state that to achieve this duality, we need to create at least four times more value from the resources we consume, and conducted a variety of case studies. The fundamental concept of the circular economy, i.e., the combination of resource circulation and economic growth, was born out of these processes.

The first use of the circular economy term in Japan's environmental policy was in 1999, when the Ministry of Economy, Trade and Industry (METI) formulated the "1999 Circular Economy Vision". However, in the "2008 White Paper on the Environment and the Recycling-Oriented Society [12]," the Ministry of the Environment states that looking back on Japan's history, as in other countries and regions in the past, people formed a society in which the spirit of "*mottainai*" (wastefulness) and the desire to keep things clean were in harmony with nature, or a primitive recycling-oriented society. They says that in the Edo period, there were technologies, experiences, and social structures that Japan should refer to today. Ishikawa says that the Edo culture was also a sustainable culture and that "the use of solar energy until the Edo period was not carried out in a single direction, but the social structure itself was built so that it could be used only with the solar energy that had recently fallen on the Japanese islands. Moreover, a system was established over a long period of time so that the used materials could be almost completely reused when they were no longer needed [13]". Furthermore, Ishikawa points out that the specific method of making this sustainable culture possible is the extensive use of plants, and refers to Japan during the Edo period, which was dependent on plants, as a "plant nation [14]". Thus, the Edo period was the starting point of Japan's process of forming a circular society. The traditional techniques, culture, and background of Japan in the Edo period can be a lubricant for the implementation of the circular economy in Japan.

2.2. Conceptual characteristic

The Ellen Macarthur Foundation has identified in their report [15] that Industrial Ecology, Cradle to Cradle, Performance Economy, and Boom Economy as particularly influential concepts in the development of a theory of the circular economy. The following five elements are common to these concepts and the conceptual characteristics of the circular economy. (1) Use of waste materials, (2) Elimination of waste and pollution from the design stage, (3) Dematerialization of the economy by providing services instead of products, (4) Shift to renewable energy (4) Shift to renewable energy (5) Use and recycle resources and energy locally and within the region.

The conceptual characteristics of the modern circular economy are compared with past economic models. Currently, countries are shifting their economic systems in the order of the linear economy, the recycling economy, and the circular economy.

The linear economy consumes and produces large quantities of finite resources, resulting in significant waste production in exchange for life enrichment. In contrast, the recycling economy has introduced the concept of resource recycling, known as the 3R principle (Reduce, Reuse, Recycle), to protect the sustainability of the earth. Nakanishi defines the recycling economy as "reducing the generation of waste and using useful waste as a recyclable resource, and reducing the burden on the environment as much as possible by conducting proper waste disposal and reducing the consumption of natural resources [16]". On the other hand, The Ellen Macarthur Foundation defines the circular economy as the following. "A systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution. It is based on three principles, driven by design: eliminate waste and pollution, circulate products and materials (at their highest value), and regenerate nature. It is underpinned by a transition to renewable energy and materials. Transitioning to a circular economy entails decoupling economic activity from the consumption of finite resources. This represents a systemic shift that builds long-term resilience, generates business and economic opportunities, and provides environmental and societal benefits [17]". Thus, the recycling economy assumes that waste is generated, while the circular economy eliminates the waste itself, and the idea is to generate economic benefits by circulating resources.

3. CASE STUDY

3.1. Circular Design Toolkit and case collection

The Ellen Macarthur Foundation and ARUP provides "Circular Buildings Toolkit" (Figure 1). In this chapter, cases that can be called "circular economy buildings" in Japan are selected and analyzed by using the "Circular Design Toolkit" to find out how each building contributes to the improvement of resource recycling and environmental problems. However, "11. Design for nature" is excluded from the framework of the study. Referring to the SHINKENCHIKU DATA [18] and each designer's website as appropriate, the authors researched and narrowed down the list using the keywords "sustainable," "circular economy," "waste," and "resource recycling". Information obtained from experts was also used as a source of information. Next, based on the Circular Design Toolkit, the methods used in each building for circulation of resources and environmental consideration were categorized from the perspective of embodying the circular economy theory. As a result, 36 cases were obtained (Table 1).

3.2. Results and discussion

The results were: Circular Buildings Toolkit framework 1 (Refuse new construction) in 7cases, 2 (Increase building utilization) in 4 cases, 3 (Design for longevity) in 10 cases, 4 (Design for adaptability) in 7 cases, 5 (Design for disassembly) in 11 cases, 6 (Refuse unnecessary components) in 11cases, 7 (Increase material efficiency) in 10 cases, 8 (Reduce the use of virgin materials) in 22 cases, 9 (Reduce the use of carbon intensive). 10 (Design out hazardous/ polluting materials) was not applicable to any of the cases.

The most frequently used method was "8: Reduction in the use of virgin and renewable materials". The most frequently used method was "use of processed wood (or other biobased materials) such as CLT in building structures". This was due to the use of laminated timber such as CLT, new materials made from construction materials, fire ash, and other naturally occurring, biodegradable resources such as soil and grass in the cases. In case 20, domestic wood was used as CLT. In case 12, they developed a completely recyclable concrete that uses pyroclastic flow sediment *Shirasu* instead of sand. This fine and porous silica concrete has excellent humidity control properties.

The second most frequently used method was "6: Refuse unnecessary components." Among them, "prioritizing simple, automatic energy strategies over complex, mechanical energy management" was used in many cases. The environment of the building was regulated by the use of natural energy such as light, wind, and rain. In case 18, rainwater is collected by the roof, which is folded every 1.2m, and distributed to the planting louvers and flower beds. This reduces the surface temperature by the effect of water sprinkling and evapotranspiration.

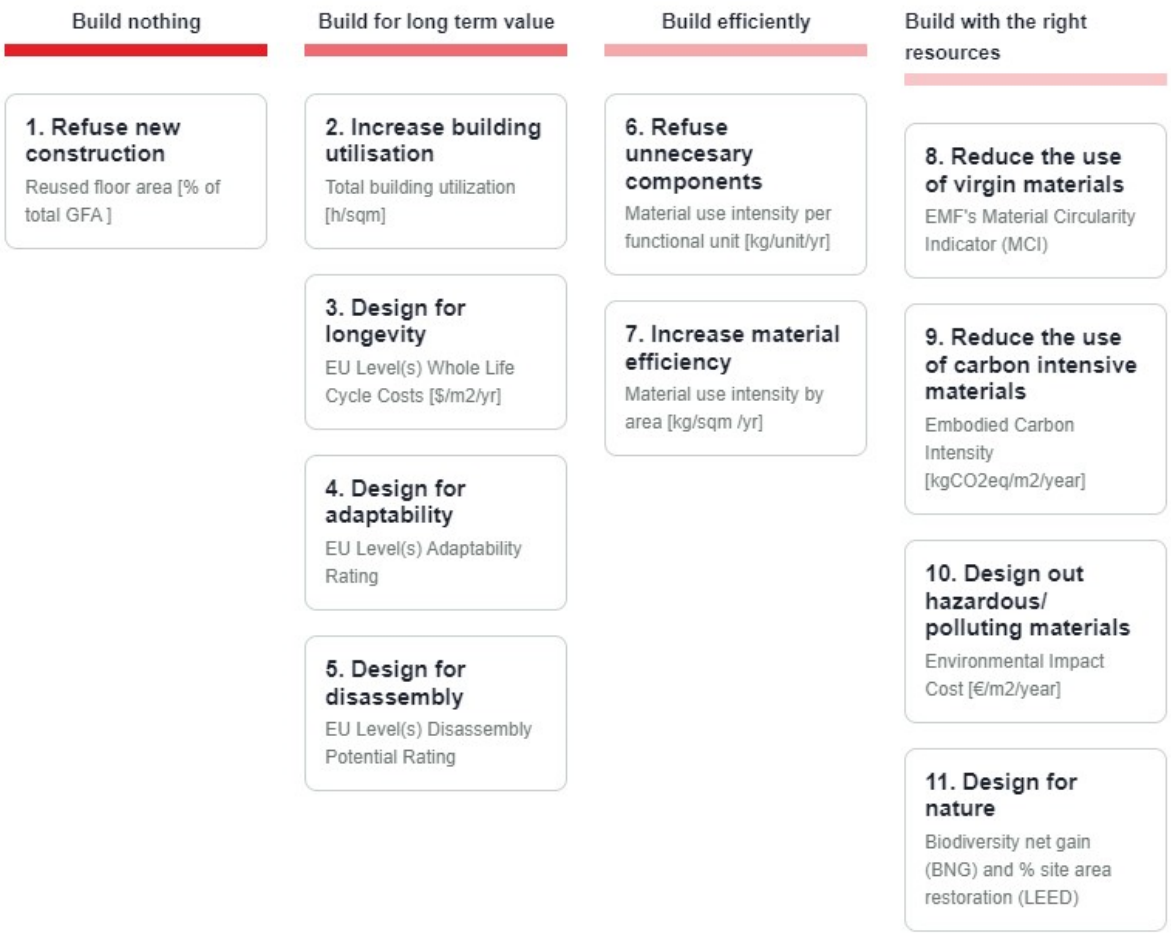

Figure 1. Circular Buildings Toolkit framework [19]

The third most frequently used method was "5: design for disassembly". The most common method was to "develop a way to bond or connect removable parts of the building".
In addition, in the survey process, the use of "local production for local consumption" and "forest circulation" were frequently mentioned. "Local production for local consumption" was mentioned by 14 cases. As the name suggests, local production for local consumption means building with locally available materials and resources, which not only stimulates the local economic cycle, but also reduces transportation costs and environmental pollutants by shortening the distance over which building materials are transported. This is also a way of thinking that leads to "forest circulation". There were several examples of local revitalization efforts that are not limited to local production for local consumption, but also take into consideration a circulation that extends to the local community and the lives of the people who use the products.

4. IMPLEMENTATION IN ARCHITECTURAL DESIGN

4.1. Methodology

Interviews with designers will be conducted to understand how the concept of circular economy is interpreted and practiced in Japanese architectural design, and what are the success factors and challenges. The survey covered the following two firms. One is NORI ARCHITECTS, the architectural design firm that designed the case 27 "GOOD CYCLE BUILDING 001 ASANUMA CORPORATION NAGOYA BRANCH OFFICE RENOVATION" in the chapter 3. This firm implemented the largest number of methods in the case study. The other is Atelier DEF, who has a partnership agreement with CIRCULAR ECONOMY JAPAN and is the only firm in Japan, according to the authors' research, that has adopted circular economy as its corporate philosophy and is working to put it into practice. The following 11 questions were asked, and were informed in advance and conducted by means of structured interviews: the interview for NORI ARCHITECTS was conducted on January 19, 2023, and for Atelier DEF was on January 20, 2023.

Table 1. Japanese circular economy buildings and their methods

Case	Building Name	Location	Designer	Main use	Year	Total floor amount	Circular Buildings Toolkit framework									
							1	2	3	4	5	6	7	8	9	10
1	MITSUBISHI PAVILION @earth	Aichi, Nagoya	MITSUBISHI JISHO SEKKEI	Theater (Pavilion)	2004	1,965					Y	Y		Y		
2	PLANTSPACE SEMINAR ROOM IN FOREST	Kanagawa, Yokohama	KISHIMOTO + KUMA + SEJIMA STUDIO COE ADVANCED DESIOGN SCHOOL KEIO UNIVERSITY	Seminar House (temporary)	2005	20								Y		
3	JAPAN PAVILION NAGAKUTE	Aichi, Nagoya	NIHON SEKKEI	Exhibition Hall (Pavilion)	2005	5,914					Y			Y		
4	INUJIMA ART PROJECT	Okayama	SAMBUICHI ARCHITECTS	Art Museum	2008	789	Y					Y		Y		
5	LOHAS DESIGN OF A TEMPORARY ASSEMBLY HALL	Fukushima, Hongu	URABE LABORATORY, COLLEGE OF ENGINEERING, NIHON UNIVERSITY, +HARYU WOOD STUDIO	Housing (temporary)	2011	106					Y	Y				
6	Satoyama-Nagaya	Kanagawa, Sagamihara	Bioform Architectual Design Studio	Tenement Houses	2011	378						Y				
7	YANMAR MUSEUM	Shiga, Nagahama	NIHON SEKKEI	Museum	2013	2,910			Y			Y		Y		
8	JST Building	Osaka	Atelier kishishita + Man*go design and Architect	Office	2013	8,245			Y							
9	SUMITA TOWN OFFICE	Iwate, Sumida	MAEDA CORPORATION・HASEGAWA CORPORATION・NAKAI ARCHITECTS, ＋MODERN ARCHITECTURE INSTITUTE	Town hall	2014	2,883				Y			Y	Y		
10	HOUSE IN SHINMEICHOU	Kanagawa, Kawasaki	MOKU-CHIN KIKAKU	Tenement house (rental)	2014	93	Y	Y	Y	Y		Y				
11	Duplex House Connected by Doma	Gunma	Takashi Fujino／Ikimono Architects	Housing	2014	152	Y							Y		
12	R・torso・C	Tokyo, Shibuya	Yasuhiro Yamashita×Atelier Tekuto	Housing	2015	103								Y		
13	House in Aichi	Aichi, Nagoya	MIKAN	Housing	2015	186						Y	Y		Y	
14	The House Revived in Hida Takayama	Gifu, Takayama	Eiji Ueno／Oak Village	Housing	2015	135	Y									
15	one year project	Fukushima, Yama	ADX	Housing	2016	52						Y	Y			
16	SHIN-TOYOSU BRILLIA RUNNING	Tokyo, Koto	ENVIRONMENTAL PROTECTION ARCHITECTURAL INSTITUTE	Sports facility	2016	1,713					Y		Y			
17	MEIJI JINGU CAFÉ MORI NO TERRACE	Tokyo, Shibuya	OAK VILLAGE WOODEN ARCHITECTURE LABORATORY	Rest house	2016	167			Y					Y		
18	HOUSING IN GOHONGI	Tokyo, Meguro	NAKA ARCHITECTS STUDIO	Housing	2017	219		Y				Y		Y		
19	MEGOTAMA – EARLY CHILDHOOD EDUCATION AND CARE CENTER	Yamagata, Kanayama	ATELIER ZO	Nursery school	2017	1,334				Y	Y					
20	TAKENAKA TRAINING CENTER TAKUMI EXPANTION	Hyogo, Kawanishi	TAKENAKA CORPORATION	Training center	2018	1,631								Y		
21	CLT PARK HARUMI	Tokyo, Chuo	MITSUBISHI JISHO SEKKEI, LANDSCAPE PLUS	Exhibition Hall (Pavilion)	2019	1,631					Y		Y	Y		
22	SHIRASU／Sakurajima	Kagoshima	Asei Suzuki／ASEI ARCHITECTS	Housing	2019	202					Y			Y		
23	soil house	Fukushima, Minamisoma	ADX	Housing	2019	137								Y		
24	HYOGO FORESTRY HALL	Hyogo, Kobe	TAKENAKA CORPORATION	Office	2019	1,567				Y				Y		
25	KAMIKATSU ZERO WASTE CENTER	Tokushima, Kamikatsu	HIROSHI NAKAMURA & NAP	Refuse disposal facility, hotel	2020	1,176				Y	Y			Y	Y	
26	HONMACHI BASE	Gifu, Seki	MET ARCHITECTS NAWAKENJI-M	Office, restaurant etc.	2020	149		Y		Y	Y					
27	GOOD CYCLE BUILDING 001 ASANUMA CORPORATION NAGOYA BRANCH OFFICE	Aichi, Nagoya	NORI ARCHITECTS + ASANUMA CORPORATION	Office	2021	2,779	Y		Y		Y	Y		Y	Y	
28	MK10 MOBILITY	Kyoto/ Okayama, Maniwa	KYOTO UNIVERSITY KOMIYAMAKEN(YOSUKE KOMIYAMA, HIROSHI TAKEYAMA) MEIKEN LAMWOOD	Rest house	2021, 2022	33			Y	Y	Y	Y	Y	Y		
29	SANU 2nd Home Yatsugatake1st	Yamanashi, Kitamori	ADX	Subscription-based 2nd house	2021	61			Y		Y		Y			
30	House of Earth	Kanagawa, Yokohama	Junya Inagaki + Satoshi Sano + Takuo Nagai + Eisuke Hori ／ Eureka	Housing	2021	150								Y		
31	BYAKU Narai	Nagano, Shiojiri	TAKENAKA CORPORATION, TSUBAME ARCHITECTS	Accomodations, factory etc.	2021	1,487	Y	Y	Y			Y				
32	MISATO ATELIER	Akita, Misato	MOLX ARCHITECTS	Office	2021	118						Y	Y			
33	Wind and Fire with Farmer's House	Ehime, Matsuyama	Takeshi Ikeuchi／studio colife3	Housing	2021	132						Y				
34	LOAM	Tokyo, Setagaya	Asei Suzuki／ASEI ARCHITECTS	Housing	2022	193						Y		Y		
35	OKI HONJO FACTORY H1	Saitama, Honjo	TAISEI DESIGN PLANNERS ARCHITECTS & ENGINEERS	Factory	2022	18,837			Y					Y	Y	
36	SHINKENCHIKUSHA SHODOSHIMA	Kagawa, Shodoshima	SUNAKI	Housing, gallery etc.	2022	259	Y		Y				Y	Y		
TOTAL							7	4	10	7	11	16	10	22	4	0

Q1. How long has your firm been committed to implementing the circular economy in its architectural design work? What was the impetus for your efforts?
Q2. How has your architectural design practice changed before and after introducing the circular economy Theory?
Q3 What projects do you think have been the most successful in implementing the circular economy?
Q4. What factors contributed to the success of Q3?
Q5. Which projects do you think were the most difficult to implement in the circular economy?
Q6. Regarding Q5, what were the factors that made it difficult?
Q7. In implementing the circular economy, did you encounter any significant discrepancies between your expectations at the planning and design stage and the reality during the construction or after the completion of the project? If so, what were the points at which discrepancies occurred?
Q8. Based on your experience, what do you think are the biggest barriers to the implementation of the circular economy in architectural design?
Q9. Based on your experience, are there any traditional Japanese techniques or cultures that can be used as a lubricant for the implementation of the circular economy in architectural design?
Q10. Based on your experience, what do you think are the new modern technologies and ideas that are necessary or effective for the implementation of the circular economy in architectural design?
Q11. What do you think is the role of the designer/architect in implementing the circular economy?

4.2. Results and discussion

About Q1, in both firms, the practice of the circular economy did not begin as its implemntation, but rather as a way of approaching architecture and design philosophy, which the two firms had each taken on, and which the experts referred to as the “circular economy”. About Q2, Both firms did not feel that the number of steps or the time required to complete a project had changed significantly. However, there was a significant change in the design process. At NORI ARCHITECTS, the design was reordered and restricted due to differences in the timing of ordering materials. Atelier DEF was referring to the need to consider a design method that “does not produce waste materials” and that “standardizes” the design. In addition, NORI ARCHITECTS stated that the cost of materials had not changed much, but the cost of demolition to make use of the existing materials had increased.

About Q3, NORI ARCHITECTS cited Case 27 in Chapter 3. Atelier DEF, as a firm, is committed to the practice of the circular economy, resulting in the successful implementation of the circular economy in almost all of the cases. About Q4, NORI ARCHITECTS stated that the success factor in practicing circular economy was “collaboration with the general contractor” and that it requires stakeholders who are responsible for various elements to realize a circular economy building. Atelier DEF has continued to make efforts to reduce waste outside of architectural design by building houses based on the three principles of the circular economy, developing products, and changing the awareness of residents. By using only domestic timber, the firm protects and nurtures the forests, and has complete understanding of the production and distribution process of the materials. Furthermore, by strongly conveying its own corporate philosophy to the client and not wavering in its beliefs.

About Q5, at NORI ARCHITECTS, there has been no other case in which the firm has so consciously addressed the circular economy as in the case 27. Atelier DEF had difficulty in building in Tokyo and other locations that required fireproof performance. About Q6, both mentioned laws and regulations as one of the factors that made it difficult. NORI ARCHITECTS also cited the difference in priorities of the designer and the client during design. Atelier DEF cites the low choice of environmentally friendly building materials available in Japan as a factor.

About Q7, in both firms, there was not much deviation from the original design. NORI ARCHITECTS designed the building at the same time as the material process was being developed, which meant that the design was considered right up to the time of construction. Atelier DEF was concerned about the possibility of a gap between design and construction due to a decrease in the number of craftsmen. About Q8, as a major barrier, NORI ARCHITECTS mentioned the lack of information on building materials and reusable resources and the difficulty of forecasting, making advanced planning difficult. They also pointed out that the larger the scale of the building, the more it does not match the cycle of resource emergence. Atelier DEF also felt that this was a barrier, and stated that with the current method, it was difficult to implement a circular economy practice for complex buildings, and that they had to decline clients’ offers.

About Q9, NORI ARCHITECTS mentioned traditional Japanese architectural methods and cultures such as wood construction and walls as a lubricant. Atelier DEF considered these techniques to have

been cultivated through daily life, and stated that reevaluating daily life itself would be a lubricant in designing a circular economy building. About Q10, NORI ARCHITECTS, stated that building users' participation in construction and facility management is what is needed for true circulation. Atelier DEF answered that it was necessary to design a more contemporary design and planning. In other words, they must not only realize circulation in terms of environmental friendliness, but also fulfill the fundamental objective of enriching people's lives.

Regarding the role of designers and architects in the implementation of the circular economy (Q11), both stated that it is important to play the role of a "cohesive" role, first of all, in integrating the building as a whole.

5. CONCLUSION

In this study, case studies based on literature review and interview surveys were conducted in order to grasp the actual situation of the introduction of the circular economy in Japanese architectural design. The results showed that 36 buildings could be called circular economy buildings in Japan. However, from the interview survey, it was found that even though the concept of "circular economy" had been implemented and was already being practiced, in some cases the approaches were later referred to as the circular economy by experts due to the low visibility of the circular economy in Japan. In other words, it is not that the circular economy is not widespread in Japan, but it is possible that the communication of such activities and initiatives is not active.

The following elements of Japanese technology and culture are barriers and lubricants for the introduction of circular economy in Japanese architectural design.

Barriers

- Building laws and regulations
- Lack of control of reusable and waste materials (lack of information on where and when to find them).
- The clients' awareness of the "circular economy" is low.
- Decrease in the number of craftsmen

Lubricants

- Use of soil
- Use of domestic wood and forests
- Use of burnt cedar
- Circulation in the community and daily life

The following are some of the new methods that can be applied.

- The development of new materials using unused resources such as construction waste soil and fire ash.
- User involvement in construction and maintenance
- Collaboration with various stakeholders
- Data management of materials, clarification of material flow, resource storage
- Communicate and disseminate information

Future tasks will involve enhancing the interview survey and conducting similar surveys of overseas examples. This will enable comparisons and clarify the characteristics of Japanese circular economy buildings and their commonalities with their overseas counterparts.

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