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# Suggestion for sustainable development of Korean traditional wooden Structure (Hanok)

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**Abstract:** Recently, the wooden structure has been revived again as an eco-friendly structure technique. It is the counterattack of the wood material, which has become more recognized as a finishing material pushed by the concrete material in the rapid growth after the Industrial Revolution. However, it is difficult to conclude that this is a tendency of the construction market in the whole country. Perhaps this is a tendency to appear more strongly in Korea. It could be seen by comparing the characteristics of the overseas construction market with Korean's and the advanced constructed case of large-scale wooden structures in overseas. National wooden buildings show own characteristics such as construction methods, materials, and member dimensions of wood structures by country, which could be seen as a result of continuously developing their own technology.

However, in Korea, despite its unique wooden structure and technology (Hanok; Korean traditional housing), it has not been developed continuously and treated it only as a living building exhibit. This is evidenced by the fact that only one percent of the building is constructed with traditional wooden building technology. Therefore, there are various efforts to modernize the traditional wooden structure technology, but it still does not reach the level of advanced wooden technology abroad.

The characteristics of the Korean wooden building market were analyzed in order to suggest ways to develop the Korean wood structure technology. The characteristics of Hanok construction were analyzed through quantitative criteria to define the main development tasks for Hanok development to propose the long-term development path.

**Key words:** Hanok, Korean traditional wooden structure, Korean wooden structure market

## 1. Background

Recently, as the value of Hanok has been widely recognized as eco-fridendly green architecture to imprive the quality of life, various efforts have been made to spread and activate Hanok. 'Hanok' is a traditional residential cultural heritage in Korea. Only a few decades age, it was one of the main archicture styles to be easilies found in Korea, but is now giving its place to a large apartment and serves as a living building exhigit. The Korea government also recognized Hanok as a building asset, enacted 'Act on the Promotion of Building properties such as Hanok' enforced it as of 2015, and each local government also supports policy for the spread Hanok. Nevertheless, Hanok has been pointed out as the biggest problems in the high construction cost[1] and maintenance difficulty. Compared with Minisry of Land, Infrastructure and Transport(Apartment appraisal of 5.5 million won per 3.3㎡, based on 2017), it's about three times more expensive as the standard price of 12~14 million won per 3.3㎡, which has been a major disadvantage to the client since most of Hanok is built as a single-family house. In addition, there is a difficulty in activating Modernized Hanok due to the problems of the small size of Hanok and its related companies, heat insulation confidentiality[2] inadequate standardization in design

and construction[3], etc. To improve these problems, 'Hanok Technology Development Research Project'[2] is progressing for the development of future residential models through the modernization of Hanok. As a part of the reseach in this paper analyze the characteristics of Korean wooden market, the construction characteristics of Hanok and to define the main development tasks for Hanok development to propose the long-term development path.

## 2. Characteristics analysis of Korean wooden market

**Table 1.** Building start-up share by domestic structure (2001~2016)[4]

| *Year Structure* | *2001* | *02* | *03* | *04* | *05* | *06* | *07* | *08* | *09* | *10* | *11* | *12* | *13* | *14* | *15* | *2016* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rebar and steel frame | 74.1 | 87.5 | 87.2 | 86.7 | 88.1 | 85.5 | 84.1 | 84.7 | 83.9 | 85.8 | 86.8 | 87.1 | 87.3 | 87.3 | 87.7 | 88 |
| Concrete | 12.7 | 10.8 | 11.5 | 11.6 | 10.1 | 11.1 | 11.1 | 10.5 | 10.4 | 8.7 | 8.07 | 7.5 | 7.2 | 6.8 | 6.2 | 5.4 |
| Wooden Structure | **0.86** | **0.80** | **1.20** | **1.63** | **1.73** | **3.00** | **3.95** | **4.44** | **5.19** | **4.80** | **4.87** | **5.12** | **5.20** | **5.52** | **5.80** | **6.18** |
| Others | 12.3 | 0.83 | 0.05 | 0.00 | 0.01 | 0.29 | 0.76 | 0.33 | 0.43 | 0.57 | 0.20 | 0.25 | 0.31 | 0.35 | 0.33 | 0.43 |

* Building permit and start-up statistics (2017) - Ministry of Land, Infrstructure and Transport Country city office Architecture Policy Officier Department of Green Architecture

Table 1 shows the building start-up share by Korean structure from 2001 to 2016. In the status of start-up by domestic structure, the start-up share of rebar and steel frame is still 88.02%, showing the highest share in 15 years, but also that of wooden structures are steadily increasing from 0.86% to 6.18%.

**Table 2.** Building start-up share by domestic wooden building faciltieis(20011~2016)[4]

| Facilities | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Residential | 69.03 | 73.90 | 74.81 | 78.03 | 80.41 | 80.92 |
| Commercial | 19.24 | 16.70 | 17.80 | 15.57 | 13.86 | 12.97 |
| Education | 0.52 | 0.21 | 0.34 | 0.43 | 0.24 | 0.36 |
| Medical | 0.09 | 0.04 | 0.06 | 0.03 | 0.04 | 0.02 |
| Information | 0.09 | 0.08 | 0.00 | 0.03 | 0.08 | 0.00 |
| Security | 0.02 | 0.01 | 0.00 | 0.05 | 0.02 | 0.01 |
| Culture | 8.08 | 5.27 | 4.73 | 4.10 | 3.83 | 3.54 |
| Public office | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Athletic | 0.09 | 1.70 | 0.09 | 0.13 | 0.04 | 0.81 |
| Others | 2.85 | 2.09 | 2.18 | 1.62 | 1.49 | 1.37 |

* Building permit and start-up statistics (2017) - Ministry of Land, Infrstructure and Transport Country city office Architecture Policy Officier Department of Green Architecture

Table 2 shows the permits share by domestic wooden building facilities from 2011 to 2016. As of 2016, the 'residential' facilities occupied the most overwhelming share with 80.92% of the total, followed by a very large difference in 'commercial(12.97%)' and 'culture, wlefare(3.54%)' facilities. On the other hand, it has been shown that wooden archicture is rarely built up to 10 or less a year in the fields of 'medical', 'information' 'security, disaster prevention'. One interesting fact is that people's demand is increasing in 'sports facilities', which require a large space that is difficult to imagine in connection with wooden buildings. It suggests that the Korean wood structure market is showing sufficient growth potential due to its applicability to various facilities, and it is necessary to develop the technology for application to various facilities.

Since the form of Hanok is also still limited to houses, the technological development of wooden archicture is very slow. In order to develop and spread the unique wood structure technology style of

Korea, it's necessary to expand the functions of Hanok limited to 'Residence' and to increase the possibility of being used for various facilities. Especially, in order to diversify the facilities, large span construction technology and multi-layer construction technology must be based. Moreover, In order to spread the hanok, it needs to develop to meet the requirements as the building of the city center.

## 3. Characteristic analysis of Hanok

It's difficult to give an academic definition in short of Hanok. It's very difficult that even a person who has studied Korean traditional architecture for long time defines Hanok in a word since time, morphology, color, material factors exist in multiple ways. Therefore, if we simply apply the modern wood structure technology to Hanok, there is a problem of the lack of identity of Hanok. Therefore, a Hanok construction classification system is needed to quantitatively analyze the remaining construction characteristics except the design of Hanok. To do this, the anxieties about the identity of the hanok must be concurrently.

Table 3: Components of Standard Classification and Numbering System (SCNS) [5]

| Level I | Level II | Level III | Remarks |
|---|---|---|---|
| Standard Classification and Numbering System (SCNS) | Standard Classifications (CLN)* | (CLF) Facility Facet | e.g. Building, Airport |
| | | (CLS) Space Facet | e.g. Office, Bed room |
| | | (CLE) Element Facet | e.g. Column, Beam |
| | | (CLW) Work Section Facet | e.g. Steel structure, Piping |
| | | (CLM) Construction Material & Assembly Facet | e.g. Vessel, Re-bar, Concrete |
| | | (CLA) Construction Aid Facet | e.g. Wood form, Crane |
| | | (CLG) Management Facet | e.g. Scheduling, Contracting |
| | | (CLP) Attribute and Property Facet | e.g. Heat transmission |
| | Project Numbering Systems (PNS) | (GBS) Geometry Breakdown Structure | Multi-facet for 3D design |
| | | (WBS) Work Breakdown Structure | Multi-facet for scheduling |
| | | (CBS) Cost Breakdown Structure | Multi-facet for cost control |
| | | (EBS) Equipment Breakdown Structure | Multi-facet for procurement |
| | | (OBS) Organization Breakdown Structure | Multi-facet for participants |
| | | (RBS) Risk Breakdown Structure | Multi-facet for risk |
| | | (MBS) Measurement Method Breakdown Structure | Multi-facet for estimating |
| | | (SBS) Specifications Breakdown Structure | Multi-facet for specs |
| | | (DBS) Drawing Breakdown Structure | Multi-facet for drawings |
| | | (PBS) Physical Breakdown Structure | Single facet for numbering |
| | | (FBS) Functional Breakdown Structure | Single facet for numbering |

*Eight facets defined by ISO (1994) [6]

### 3.1. Hanok/Wooden Structure construction information classification system(HanClass)

Developing and formulating project numbering systems (PNS) is one of the major tasks in the early stage of construction projects[7]. Well-organized PNS not only facilitates effective construction project management but also accumulates projects in an automated manner. "HanClass" was developed based on Standard Classification and Numbering System, SCNS for the construction industry like Table 3 that Jung et al. (2013) [5] defined to utilize the concept of PNS.

"HanClass" has been developed and updated through Hanok technology development project that has been going on since 2013 to make construction costs and schedual management scientific and systematic by covering planning, design, construction and maintenance stages to modernize Modernized Hanok. "HanClass" fully reflected Korean or International Standard Classification and was

developed so that it can be applied as a basis when writing documents such as design books, specifications, standard quantities, costs statements, milestones, etc occurred during building Modernized Hanok, covering the whole life cycle of the construction project.

"HanClass" reflected Korean standards and International standards such as UniFormat[8], MasterFormat[9]. In this way, traditional Hanok with complicated terminology could be simplied so that it could be understood by modern construction site. And this structure could be automatically associated with international standards. In the developed "HanClass", CLF, CLE , CLW, CLG was defined in CLN as Table 4 shows, and GBS, WBS, CBS, and MBS were developed, moreover SBS and DBS are under development.

Table 4: Component and Example of HanClass: 2017

| SCNS | Components | Number of items* | Example of list / PNS sequence | Remarks |
|---|---|---|---|---|
| HanClass CLN | HanClass_CLF01 | 9 | **H:** House | |
| | HanClass_CLF02 | 39 | **H1:** Detached house | |
| | HanClass_CLF03 | 120 | **H1411:** General detached house | Application criteria of information classification in the construction industry |
| | HanClass_CLE01 | 6 | **B:** Structure | UniFormat if available (1st digit) |
| | HanClass_CLE02 | 35 | **B1010.1:** Wood structure | UniFormat if available (5 digit) |
| | HanClass_CLE03 | 49 | **B1010255:** Column | UniFormat if available (8 digit) |
| | HanClass_CLW01 | 15 | **C06:** Wood works | |
| | HanClass_CLW02 | 46 | **C0610:** Wood framing | |
| | HanClass_CLW03 | 266 | **C06061113.11:** Glulam column < 180mm | MasterFormat if available (6 digit) |
| | HanClass_CLG_LifeCycle | 6 | **PRE:** Planning | |
| | HanClass_CLG_Locater | 7 | **L101:** First floor | |
| | HanClass_CLG_Crew | 38 | **CR061:** Carpenter | |
| HanClass PNS | HanClass_GBS | - | *CLF02 – CLG_Locater – CLE03 – CLW03* | No. of geometric objects |
| | HanClass_WBS | - | *CLF02 – CLG_Locater – CLW02* | No. of CPM activities |
| | HanClass_CBS | - | *CLF02 – CLG_Locater – CLW03* | No. of cost items |
| | HanClass_MBS | - | *CLW03* | No. of SMM |
| | HanClass_SBS | - | *Under development* | No. of spec chapters |
| | HanClass_DBS | - | *Under development* | No. of drawings |

*Number of items for CLN is the line number of standard lists, and the number of items for PNS is the case of first mock-up project.

In CLF, the facility(F) of "Application criteria of information classification in the construction industry" of the Ministry of Land, Infrastructure and Transport[10] was referred. The Ministry of Land, Infrastructure and Transport has divided the facility into three parts: architecture, civil engineering and plant. This was classified into 10 categories, 74 sub categories and 381 sub-sub categories. Among them, 3 categories, 26 sub categories and 120 sub-sub categories correspond to architecture. In this study, we reconstructed 120 sub-sub categories of architecture depending on the use and size of the facility and as a result, there are 9 categories, 39 sub categories and 120 sub-sub categories.

"CLG_Locater", CLG_LifeCycle and CLG_Crew were configured in CLG so emphasized the applicability in temrs of management. In addition, it was developed so that 3D drawings and history, process information can be linked automatically through PNS ans GBS as main feactures.

### 3.1.1. Features of wooden structural parts

The most important and difficult part of the Hanok classification system development is to express the name of the traditional building element which is used in various complexity in the name of the absence of modern architecture. The use of the traditional name is too complicated for modern architects, and if the name of the modern architecture is applied as it is, there is a fear of losing the characteristic of the

hanok construction. For example, in the construction of a hanok, Beam members are expressed differently by the location and the purpose as like ‘Dae Ryang’, ‘Chang Bang’, ‘Pyeong Bang’, ‘In Bang’. The name of each member includes various meanings such as shape, thickness, and position, as in the Western molding detailing style. So that, it is difficult to express it simply as a beam. Therefore, this study focused more on the definition of standard names to express the characteristics of Hanok. Nevertheless, there was still difficulty in communicating with the field worker who stuck to the traditional architectural style in the accumulation of construction information of the actual construction cases to be described in Section 3.2. In this way, the definition of the name should be revised through the continuation of the research project. Figure 1. shows a simple example of iteam. As shown in the figure, for the analysis of the characteristics of the hanok construction, the hanok wood structure was divided into roof, roof structure system, column, beam and Floor. Particularly, in the case of standardized production, the sizes of the columns and the beam members are expressed together. And The names of special members such as 'Dori' and ' Jangyeo ' are to be represented as much as possible. Our team has a high interest in this aspect in terms of the standardized production of members for spreading hanok in the future.

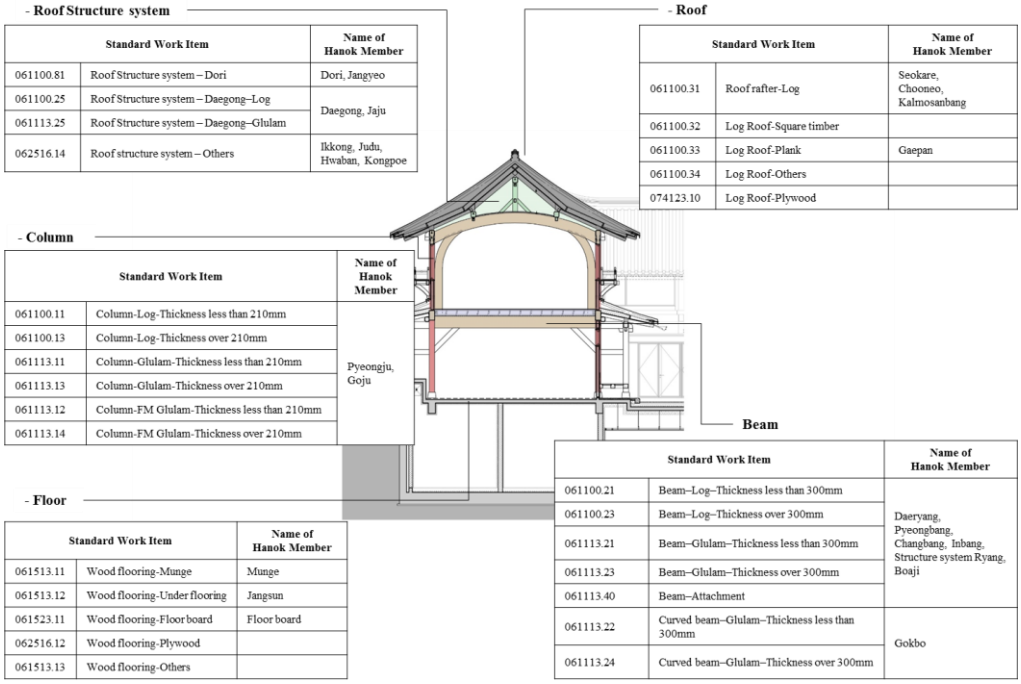

Fig 1. Sample of Standard Work Item (HanClass_CLW03)

### 3.2. Characteristic analysis of Hanok construction information through ‘HanClass’

In the meantime, through the study of the first and second stages of Hanok technology development (2009~2016), the residential performance of Modernized Hanok by developing construction methods and design technology, element technology was improved to reduce construction costs innovatively and contributed to the expansion and dissemination of technology by applying the technology developed focusing on housing. For this, seven examples of modern hanok architecture were actually constructed. In this study, six cases were used as the analysis data of the characteristics of the Hanok construction, except for the case where the villages were actually built. The actual construction examples used in the analysis are shown in Table 4. For the quantitative analysis of the demonstration project, the work classification system of Modernized Hanok’s standard classification[11] and the characteristics classification[12] of carpenter were based. Through this, we compared and analyzed the characteristics of construction costs and changes in amount of money by work type and wooden structure(columns, beams, roof, roof structure system, floor, others).

Table 4: Analysis of Modernized Hanok construction period

Unit: Million KRW

| Category | Case 1 | | Case 2 | | Case 3 | | Case 4 | | Case 5 | | Case 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site view |  | |  | |  | |  | |  | |  | |
| Facility | Housing | | Housing | | Housing | | Exhibition hall | | Education | | Exhibition hall | |
| Location | Yong-in | | Yong-in | | Seoul | | Suwon | | Sunchang | | Naju | |
| Floor area($m^2$) | 69.3 | | 126.1 | | 142.2 | | 950.4 | | 445.5 | | 264 | |
| Total cost | 254 | 100% | 275 | 100% | 282 | 100% | 1936 | 100% | 815 | 100% | 578 | 100.0% |
| Temporary work | 3 | 1.2% | 9 | 3.3% | 9 | 3.2% | 114 | 5.9% | 24 | 3.0% | 20 | 3.5% |
| Earth work | 12 | 4.7% | 10 | 3.6% | 3 | 1.1% | 60 | 3.1% | 7 | 0.9% | 4 | 0.7% |
| Concrete work | - | - | 13 | 4.7% | 15 | 5.3% | 238 | 12.3% | 86 | 10.8% | 80 | 13.8% |
| Masonry work | 26 | 10.2% | 31 | 11.3% | 11 | 3.9% | 84 | 4.3% | 40 | 5.0% | 36 | 6.2% |
| Metal work | - | - | - | - | 1 | 0.4% | 16 | 0.8% | 3 | 0.4% | 9 | 1.6% |
| Wood work | 84 | 33.1% | 59 | 21.5% | 96 | 34.0% | 540 | 27.9% | 170 | 21.3% | 149 | 25.8% |
| Insulation/ Waterproof work | 2 | 0.8% | 9 | 3.3% | 6 | 2.1% | 67 | 3.5% | 40 | 5.0% | 23 | 4.0% |
| Window work | 23 | 9.1% | 22 | 8.0% | 46 | 16.3% | 145 | 7.5% | 72 | 9.0% | 61 | 10.6% |
| Finish work | 60 | 23.6% | 43 | 15.6% | 37 | 13.1% | 188 | 9.7% | 96 | 12.0% | 66 | 11.4% |
| Roof work | 41 | 16.1% | 62 | 22.5% | 19 | 6.7% | 246 | 12.7% | 95 | 11.9% | 61 | 10.6% |
| Electrical/ Equipment work | 3 | 1.2% | 17 | 6.2% | 39 | 13.8% | 238 | 12.3% | 167 | 20.9% | 69 | 11.9% |

### 3.2.1 Characteristic analysis of construction costs by process of Modernized Hanok

The average construction costs per 3.3m² of Modernized Hanok empirically constructed up to now have been 7 million won. This is about 60% of the construction costs of traditional Hanok.

In addition, as a result of the comparison of the average amount of each work type per 3.3m² of 6 Hanok construction, 25% of carpentry, 14% of finishing work, 12% of rook/tgutter construction, 11% of window construction, which account for 62% of the construction costs. In particular, in the case of carpentry, roof/gutter construction, which occupy a high percentage of the total construction costs, the construction costs were reduced by 60%, 68%, 58%, respectively per 3.3m² compared to traditional Hanok due to the development of Modernized Hanok construction such as dry construction method, roof truss structure, improved Korean food tile, etc. through timber factory and wood joint hardware, ligjtweight steel(C-Stud) structure. In other words, the average construction costs per 3.3m² was estimated to be 1,600,000 won for carpentry 900,000 won for finishing, and 800,000 won for roof/gutter construction. As a result of detailed analysis of the amount of construction by separating occupying a high proportion in Hanok construction carpentry into wooden structure, there were 50% of roof(from rafters to roof tile), 19% of Roof structure system member(Dori. Jongdori, Daegong), 16% of beam(Changbang, Inbang, Jangyeo, Jusimdori, Daeryang, Gokbo), 9% of column, respectively, which occupied for 85% of all carpentry. The average construction costs per 3.3m² by each part of wooden structure were estimated at 740,000 won of roof, 260,000 won of Roof structure system, 250,000 of

beam, 140,000 won of column. The amount of roof carpentry accounted for 10% of the total construction costs, so the average construction costs were high. In particular, it should be noted that when the floor area is increased, the cost of wood work per floor area is increased due to the increase of the sectional area of the member and the roof structure is complicated. In other words, it need to find a way to reduce the amount of cost through the development of new methods of rafters with lots of quantity and a long working time among roof carpentry, and the application of construction methods such as a truss method. In addition, it's necessary to reduce the construction costs of wooden structure through the development of Hybrid that is a composite construction method and to search the technology development plan of large- span Hanok.

### 4. Conclusion

The continuous development and interest of the wooden archicture industry provides a great opportunity for the development of Korean traditional wooden architecture. The continuous development of Korean traditional archicture style has great significance in terms of diversification of architecture style and preservation of Korea's identity. However, since domestic wooden archicture industry is focused on houses, which limits the development of Korean traditional architecture. Therefore, various efforts are needed to apply Hanok to a variety of buildings without confining it to houses. For this, Korean wooden structure technology of creating large spaces and high-rise buildings should be developed. Though wooden structure archicture with span 30m or more and 10 stories or more is being built since wooden structure technology has already advanced to a certain level abroad, if this is applied to Hanok, it's necessary to study carefully designs because it can lose the traditionality of Hanok. In addition, there is no accurate data or standards to refer to wooden archicture in Korea, so the construction characteristics of Hanok were quantitatively analyzed through proposing to develop Hanok standard classification to build this. As a result, the construction costs of roof and roof structure system representing the characteristics of Hanok are still very high and the construction period is also long. If Hanok has a long span and high-rise building, the technology development for this should be systematically proceeded as an element to be applied more and more. On the basis of this research, further studies are being carried out on the cost reduction and characterization methods considering the quantitative aspect, productivity and productivity of the modernized hanok construction, and the analysis will be continued to provide the basic data for the modernization of the hanok .

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