Abstract—In this research, structural planning of long-span Hanok considering lateral loads has been studied. Hanok is a Korean traditional timber house, the structural members of which are mainly comprised of timber. The long-spanning of Hanok can be considered by two types, that is, beam direction and dori direction. Beam direction is related to depth, and dori direction is related to width of Hanok. In general, beam is subjected to concentrated load, on the other hand, dori is subjected to distributed load. Therefore, beam direction is more sensitive to long-spanning than dori direction. Hanok has various appearance types in elevation, that is, single storied, two-storied, partly two-storied, double storied, two-storied castle gate, two-storied palace gate, multi-storied pagoda, and so on. And Hanok has various appearance types in plan, that is, linear type, L type, C type, closed type, and so on. If Hanok is subjected to lateral loads, such as wind load or seismic load, both the elevation and plan irregularities can cause irregular lateral movement, that is, torsional movement. To prevent torsional movement and secure the safety of Hanok, three design methods can be applied, that is, seismic resistant design, vibration control design and seismic isolation design. In this research, the schematic structural planning approaches for long-span Hanok against lateral loads have been studied and presented.

Index Terms—Hanok, lateral loads, structural planning, long-span

I. INTRODUCTION

Hanok is a Korean traditional timber house, the structural members of which are mainly of timber. The traditional Hanok, which is shown in Fig. 1(a) has histories of more than 2,000 years, and the structure type of Hanok can be classified as post and beam structure as shown in Fig. 1(b). Nowadays, the new-styled Hanok, which is shown in Fig. 1(c) has been developed and get people’s attention. The new-styled Hanok has modernized bathroom, kitchen, insulation system, heating and air-conditioning system, and so on, to accommodate the contemporary life style of people. The joints of main structural members of traditional Hanok are mostly mortise and tenon joints, whereas, those of the new-styled Hanok are steel joints. The wood which is used in the traditional Hanok is mainly raw wood, that is, lumber, whereas, that of the new-styled Hanok is engineered wood, that is, glue-laminated wood.

Various researches on the timber structure and Hanok have been carried out around the world. Seo et al. [1] studied the static and cyclic characteristics of wooden frames with traditional mortise and tenon joints under lateral load, Han et
al. [2] evaluated the mechanical performance of tenon joints
to modernize the traditional Hanok, Kang et al. [3] studied
the static performance of mortise and tenon joint, Lee et al.
[4], [5] performed analytical modeling and evaluated lateral
capacity of dori-direction Hanok frame with mortise and
tenon joint, and Kim et al. [6] evaluated effective lateral
stiffness of steel joints used in new-styled Hanok.

As for the dynamic analysis of timber structure or Hanok,
Fang et al. [7], [8] studied static and dynamic characteristics
of ancient Chinese timber structure, Hwang et al. [9]
analyzed the natural frequency of Hanok according to
vibration amplitude, and Kim [10] and Lee et al. [11]
performed dynamic experiments on a new-styled Hanok and
extracted its dynamic characteristics according to excitation
amplitude.

For the longevity of Hanok, researches on the maintenance
and management are now on the rise. Park et al. [12]
studied on the distribution of moisture contents on traditional Hanok,
and Kim [13] evaluated moisture contents of column
members of traditional Hanok more than three years and
extracted patterns of moisture contents according to
orientation to the sun and wood type.

To help the structural design of Hanok in early design
stage, Kim et al. [14] and Kim [15] developed section list
tables for both lateral and vertical members, respectively.
And Kim [16], [17] developed automated structural design
software for both horizontal and vertical members of Hanok.

In this study, the schematic structural planning of
long-span Hanok considering lateral loads has been studied.
The concept of long-spanning of Hanok, the appearance
types both in elevation and in plan, and the conceptual
seismic design method peculiar to Hanok has been presented.

II. THE LONG-SPANNING OF HANOK

The long-spanning of Hanok can be considered by two
types, that is, beam direction and dori direction. Beam
direction which is shown in Fig. 2(a) is related to depth, and
dori direction shown in Fig. 2(b) is related to width of Hanok.

In Hanok, beam is subjected to concentrated load and the
deflection is proportional to the third times of its length and
flexural stress is proportional to just its length. On the other
hand, dori is subjected to distributed load and the deflection is
proportional to the fourth times of its length and flexural
stress is proportional to the second times of its length. Due to
the structural characteristics of Hanok the actual deflection
and flexural stress is more in beam direction than dori
direction, so that, beam direction is more sensitive to
long-spanning than dori direction. If the span of beam or dori
is more than about 10m, the section size needed becomes so
large that lumber is no longer feasible to be used but
 glued-laminated wood is more feasible and the use of hybrid
system must be considered to accommodate the long span.

III. TYPES OF HANOK IN STRUCTURAL VIEWPOINT

Hanok has various appearance types, and these types can
be analyzed both in elevation and in plan.

Fig. 2. Two-types of long-spanning of Hanok

Fig. 3. Various appearance types of Hanok in elevation
In elevation, Hanok has appearances of single storied, two-storied, partly two-storied, double storied, two-storied castle gate, two-storied palace gate, multi-storied pagoda, and so on, as shown in Fig. 3. And in plan, Hanok has appearances of linear type, L type, C type, closed type, and so on, as shown in Fig. 4. The irregular appearances of Hanok both in elevation and in plan can cause vertical irregularities and plan irregularities, respectively. These irregularities can make the movement of Hanok under later loads so complex that Hanok may undergo severe damage during earthquakes.

IV. STRUCTURAL CHARACTERISTICS OF HANOK UNDER LATERAL LOADS

If Hanok is subjected to lateral loads, such as wind load or seismic load, both the elevation and plan irregularities can cause irregular lateral movement, that is, torsional movement. The torsional movement is mainly caused by the difference between the center of mass and the center of stiffness as shown in Fig. 5. The center of mass is where the seismic force is applied and the center of stiffness is where the structure resists the applied force. To prevent torsional movement it is necessary to make the center of mass and the center of stiffness as close as possible. Various structural techniques can be applied to these processes, that is, structural separation both in plan and elevation, installing braces or walls and installing seismic resistant devices.

V. STRUCTURAL PLANNING OF HANOK CONSIDERING LATERAL LOADS

As the span of Hanok becomes more long it becomes more difficult to control torsional movement. To prevent torsional movement and secure safety of long-span Hanok, it is necessary to take more active methods. In this research, the schematic structural planning methods for long-span Hanok against lateral loads have been studied thoroughly and three schematic design methods have been presented. The presented design methods are seismic resistant design, vibration control design and seismic isolation design. The concept of these three design methods are discussed briefly as follows.

A. Seismic Resistant Design

Seismic resistant design is to make the structure of Hanok strong enough to resist the seismic load, and this design method includes to make the member size big enough or to make joint have enough stiffness. Installing seismic resistant device, which can be said seismic bracket as shown in Fig. 6(a) is one of the seismic resistant design method.

B. Vibration Control Design

The main characteristic of Hanok is that it has heavy roof weight compared to its under-roof structure. The heavy roof weight can make Hanok overturn when it undergoes earthquake and can cause severe damage. This phenomenon
can be mitigated by installing vibration control device, such as, tuned mass damper (TMD) or tuned liquid damper (TLD) on the upper part of the Hanok as shown in Fig. 6(b). It is estimated that, a small mass, approximately 1/100 of roof weight will be sufficient to control the vibration induced by earthquake.

C. Seismic Isolation Design

Seismic isolation design is realized by installing seismic isolation device between superstructure of Hanok and its foundation as shown in Fig. 6(c), so that the vibration period of Hanok becomes large enough to avoid the resonance caused by earth movement of relatively short vibration period.

Under lateral loads, both the elevation and plan irregularities of Hanok can cause irregular lateral movement, that is, torsional movement. To prevent torsional movement and secure safety of Hanok, three design methods, such as, seismic resistant design, vibration control design and seismic isolation design can be applied.

Seismic resistant design is to make the structure of Hanok strong enough to resist the seismic load, and this includes to make the member size big enough or to make joint have enough stiffness. As for the vibration control design, tuned mass damper (TMD) or tuned liquid damper (TLD) can be installed on the upper part of the Hanok. As for the seismic isolation design, seismic isolation device can be installed between superstructure of Hanok and its foundation.

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REFERENCES


