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W350 - The Roadmap Of Super High-Rise Timber Building -

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Abstract

This research and technology development project is based on the concept and plan of Sumitomo Forestry Co., Ltd., and designed by Nikken Sekkei Ltd., and is aiming to realize 350 m supertall timber-framed buildings in urban areas by 2041, the 350 year anniversary of Sumitomo Forestry's founding(Fig. 1). By constructing office-based multi-use buildings which have 70 stories above ground with GFA of 455,000 m^2, using a huge amount of timber of 185,000 m^3, this project envisions to connect forests and cities, and to solve the problems in both of forests and cities. At the present stage, the main objective is to identify the issues related to wood, such as building structural systems, construction methods, materials used, and resource development, and to create a roadmap for future technologies to be researched and developed.

Keywords: Timber, Supertall Building, Damper, CO_2 Emissons, Timber Interface

1. Outline of Building Plan

For the purpose of conducting a concrete technical verification, the construction site is set at Marunouchi, Chiyoda-ku, Tokyo, and the scale of the building is set as a supertall building with 70 stories above ground and around 350 meters high. The plan shape is set as 80 m × 80 m, and the column span is set with 10 m grid. The internal frame is made by wood only; meanwhile, a hybrid frame is adopted in the outer frame so as to utilize the characteristics of materials, i.e. the compressive force is resisted by wood and steel, and the tensile force is resisted by steel. In this way, the necessary stiffness and strength can be maintained against the lateral force induced by strong wind or earthquake.

In general, a supertall building has “center core”, however in this project, we provided core stiffness within the “timber interface” areas which are allocated like balconies around the building. From the viewpoint of traveling length of escape route to the outside of building envelope, this layout will provide safer route (Fig. 2). In addition to the escape route, “timber interface” can provide a continuous interior and exterior environment filled with fresh air, abundant nature and sunlight those were difficult to be provided in a general high-rise buildings. And the central void which optimizes the internal space promotes natural ventilation and lighting, and creates comfortable living space.



Figure 1. Bird View CG.

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2. Outline of Structural Concept

2.1. Seismic Performance Optimized for the Seismicity in Japan

We decided the structural framing system for W350 considering the site specific seismicity at the construction

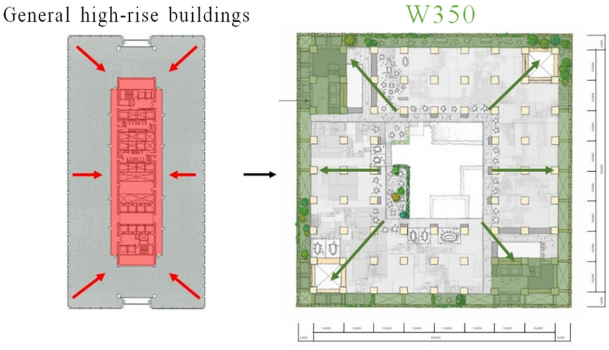


Figure 2. Concept comparison between a general high-rise building and W350.

site, Marunouchi, Chiyoda-ku, Tokyo. In June 2016, MLIT (Ministry of Land, Infrastructure, Transport and Tourism) has announced a countermeasure for high-rise buildings against the Nankai trough long period ground motions. Along with this guideline, the Sagami trough which would have more influence in the Kanto Plane than Nankai trough seems to induce a strong ground motion at the period band of 7 to 9 seconds.

In order to against this long period ground motions, we designed the outer frame as a stiff tube system, and provided the first natural period of 5 seconds which can avoid a resonance under Sagami trough earthquake(Fig.3 and Fig. 4).

2.2. Steel Braced Tube Frame with Dampers

Steel braced tube frame with dampers is adopted for the outer frame. Steel braces (partially with dampers) are provide in the allover outer frames so as to maintain the required stiffness and strength against to strong winds or earthquakes. Dampers in the outer frame are provide for the entire building vibration using the effective energy absorption function of brace with damper.

Columns and beams in the outer frame is hybrid of wood and steel utilizing the properties of both material, i.e. the compression force resisted by the combination of wood and steel, and tension force resisted by the steel (Fig. 5).

The lateral load is resisted by the outer frame only, the internal frame has to resist to the gravity load only. Therefore, there is no lateral resisting elements such as wall and brace in the internal frame, and it is easy to accommodate partial voids in the building. This system can expand various possibilities of architectural planning and facility planning.

3. Disaster Prevention Plan

In W 350, more originality and ingenuity are required for disaster prevention plans, including fire prevention zones and fire fighting plans. One of them is the Sky Lobby, which functions as a fire spread prevention for each fixed number of floors and also serves as a refuge floor. As described above, the allocation of evacuation stairs and lifts in the “timber interface” area is effective for the disaster prevention plan too.

Sumitomo Forestry has already commercialized the fire-resistant laminated timber composed of one-hour fire-rated wood. The development of three-hour fire-rated wood is one of the future technical challenge. There is also the possibility of developing tree species with higher intensity and growing faster from the genetic level (Fig. 6).

4. Situation of Forest Resources, Environmental Issues and W350 Project

About 70% of Japan's land is forested, and 40% of the forested area, i.e. about 30% of the land is man-planted forest. The cycle of tree planting, logging, building production, and replanting has fostered Japan's national land, climate, urban and forest environments, maintained forestry and surrounding industries, and created the Japanese tradition of wooden architecture (Fig. 7). However,

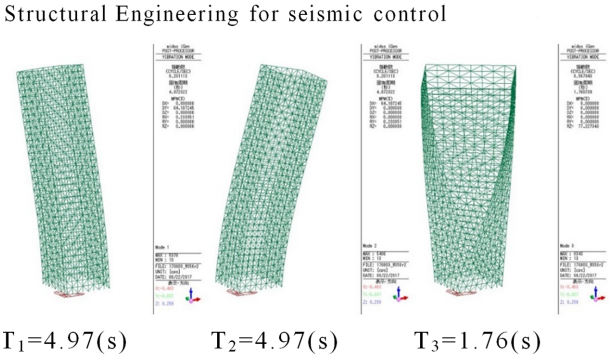


Figure 4. Results of modal analysis (mode shapes).

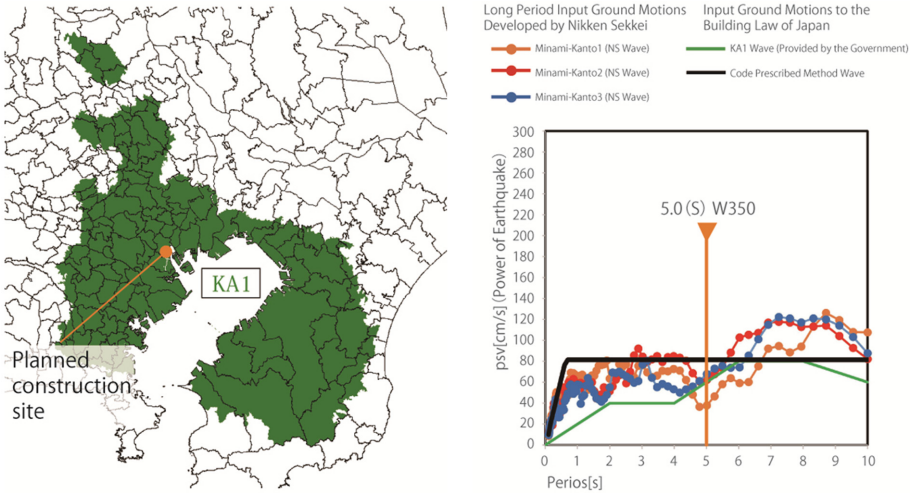


Figure 3. Long period ground motions in Tokyo and the first natural period of Structural Engineering for seismic control.

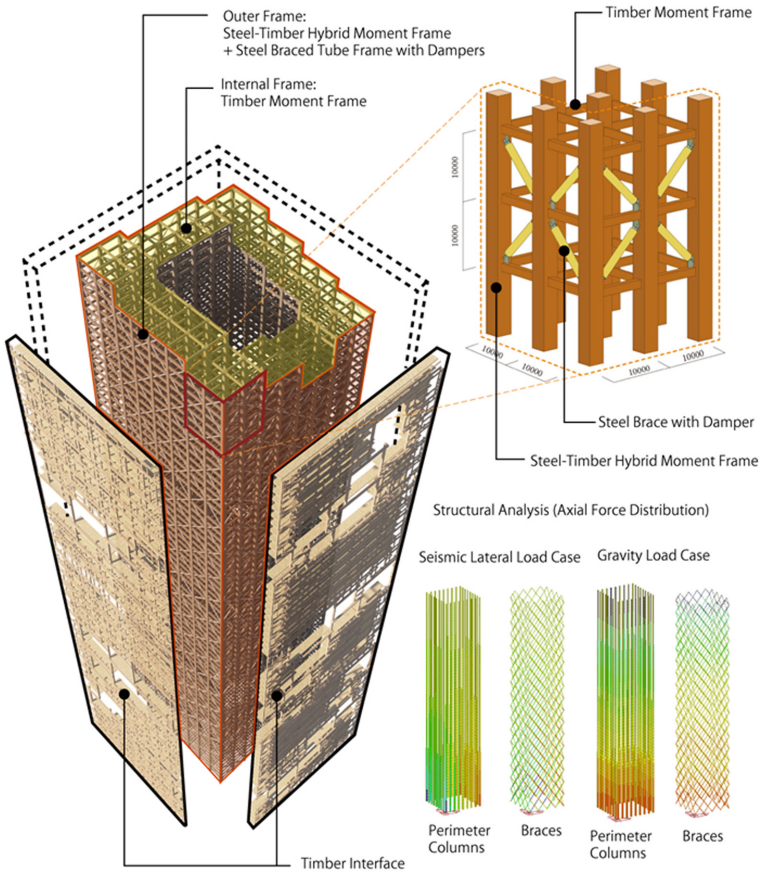


Figure 5. Structural Framing System.

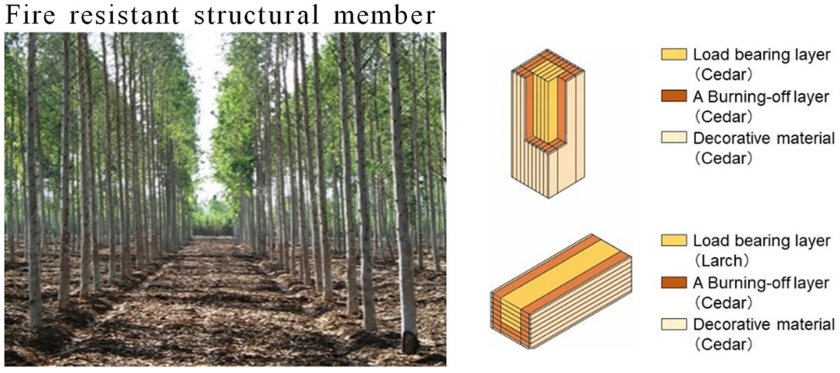


Figure 6. Fire-Rated Timber(by courtesy of Sumitomo Forestry).

due to the modernization, Japan's forests have been devastated and forestry industry has been in decline, and this cycle is beginning to break down. Japan's urban environment and wooden building traditions are in crisis. This situation is becoming a problem not only in Japan but in the forests of the world.

In the past 100 years, the temperature of the earth has increased by about 0.7 degrees Celsius, and the temperature of Tokyo has increased by 3.0 degrees Celsius (Fig. 8). It is said that this is mainly due to the heat island effect.

Only about 35% of forest growth is used as domestic wood. It is important to increase wood demand in non-residential buildings where the ratio of wood structure is low. The wood volume of 185,000 m^3 used by W350 is equivalent to the annual supply of housing products of Sumitomo Forestry of about 8,000 households (Fig. 9). The use of a large amount of wood to stimulate demand for wood in non-residential buildings is great significance of W350.

In comparison with steel buildings of the same scale, it is expected that CO_2 emissions during the construction

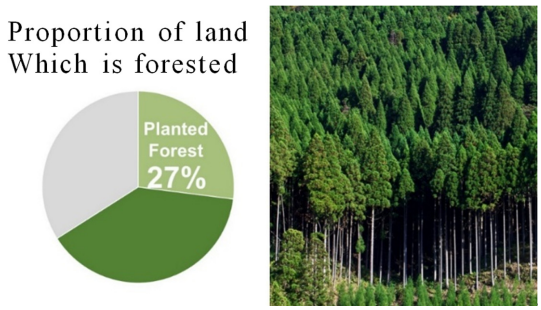


Figure 7. Ratio of Planted Forest in Japan.

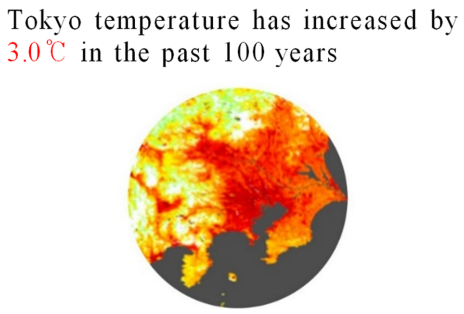


Figure 8. Global Heating.

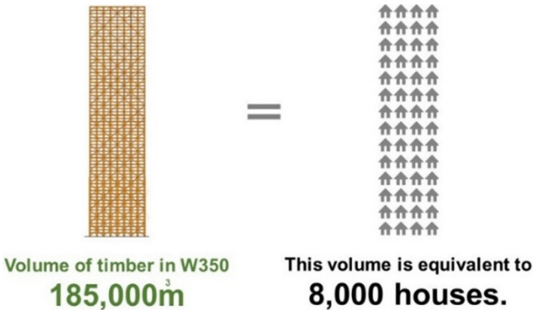


Figure 9. Volume of Timber in W350.

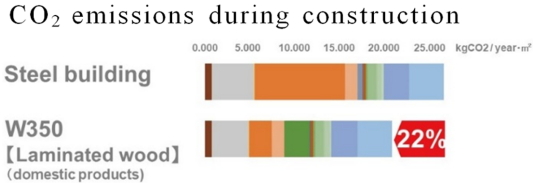


Figure 10. Estimation of CO_2 Emissions in W350.

can be reduced by about 22% when the main structure is glued laminated timber, and reduced by about 26% when the main structure is lumber (Fig.10).

5. Timber Interface

5.1 Timber Interface and External Environment

"Timber Interface" consists of wood with a small cross section, thus it can be used for facility renewal with short design life, daily cleaning of windows, and general maintenance of buildings.



Figure 11. Interior of Timber interface.



Figure 12. Interior of W350.

About 70% of Japan's land is forested, and 40% of the forested area, i.e. about 30% of the land is man-planted forest. The cycle of tree planting, logging, building production, and replanting has fostered Japan's national land, climate, urban and forest environments, maintained forestry and surrounding

Until now, the facade of modern buildings has been made thin and transparent, but the interior and exterior environments were separated by glass. In W350, balconies are provide along the perimeter, and by utilizing a slightly thicker façade, it can provide the continuous interior and exterior environment filled with fresh air, abundant nature and sunlight those were difficult to be provided in a general high-rise buildings. This "timber interface" has the function of structural element protection from the severe exterior environment (Fig. 11 and Fig. 12).

5.2 The Possibilities of Timber Interface

Because the Timber Interface consists of wood with a smaller cross section than the main structure, it can be updated at regular intervals, resulting in better wood cycle. The replaced wood can be reused in smaller houses, and the final waste is reused as fuel for biomass power generation, producing a thermal cycle that holds the wood together with carbon for a long time. Replaceable wooden exterior and interior materials can be constructed by carpenters who have built houses up to now, and contribute to the succession of interrupted



Figure 13. Transmission of Japanese wooden technology.

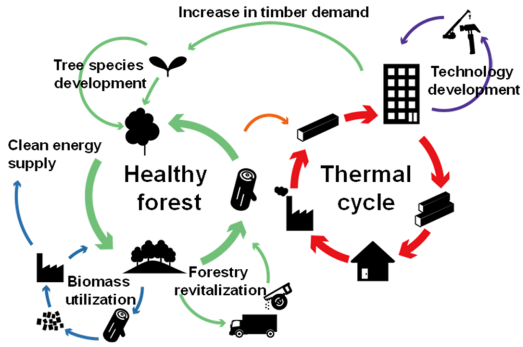


Figure 14. Various cycles.

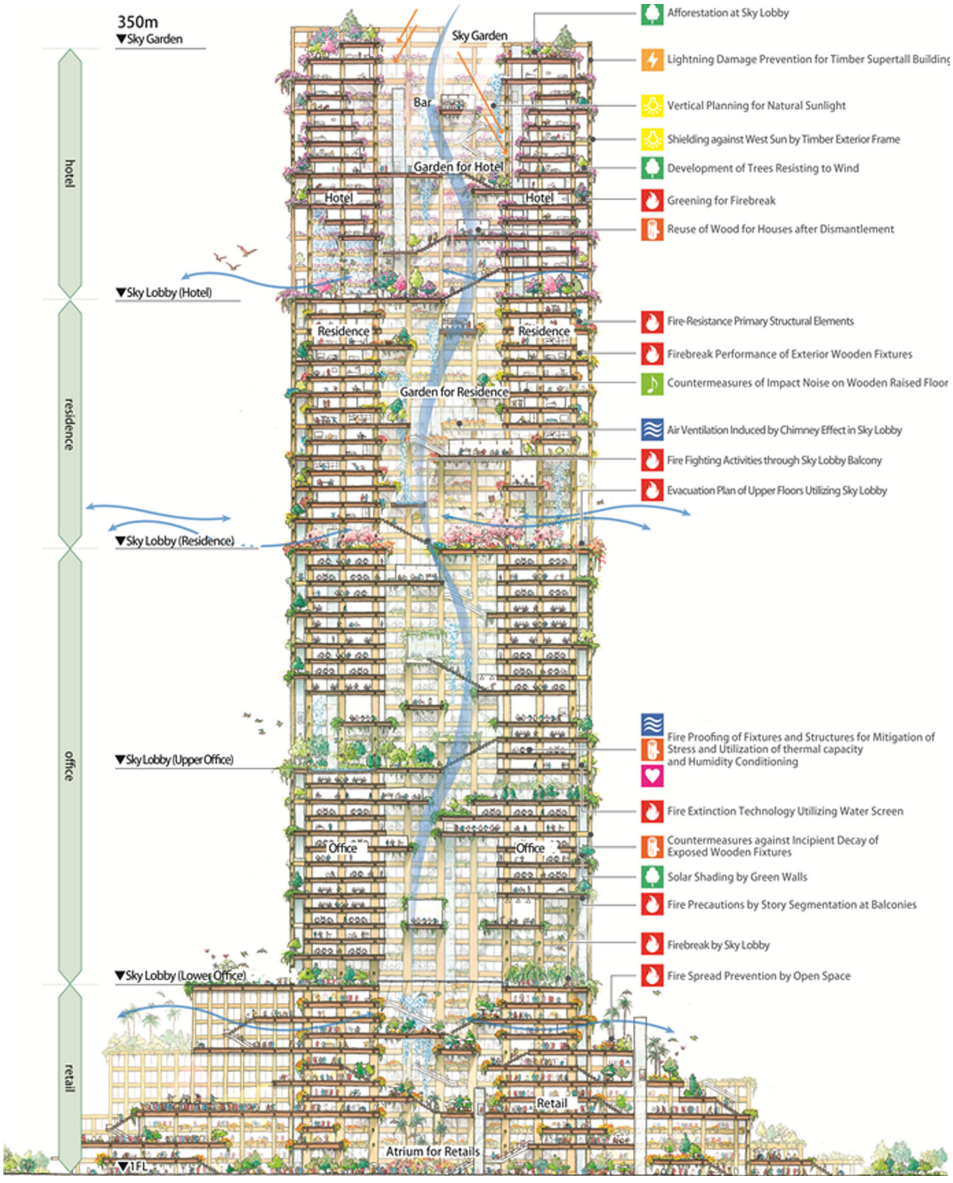


Figure 15. Section of W350.

traditional Japanese woodwork techniques and the cultivation of younger technicians (Fig. 13). Increased demand for wood has the potential to revive forestry and rural areas by bringing together the latest technologies, such as robotics, with the wood industry of logging, distribution, wood processing and construction (Fig. 14).



Figure 16. Panoramic View of Eco-Wooden City.

6. Conclusion (Future Vision of Eco-Wooden City by W350)

This research and development project was started in order to study whether the realization of a 350 meter-high wooden supertall building in an urban area in Japan could be an effective means to restore the circulation of crumbling forests, to restore forests, and to revitalize the urban environment in Japan and the world (Fig. 15 and Fig. 16). We believe that each of the technical verification and discussions aimed at realization of W350 will reveal the modern meaning of wood, timber and forests, and the social significance of constructing supertall building by wood.

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References

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