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Holzarchitektur als konstante Lösung in einem Kulturumbruch

Wooden architecture as a constant at a time of cultural change

Architettura in legno quale soluzione costante in un periodo di rivolgimento culturale

Document in English

Wooden architecture as a constant at a time of cultural change

Japanese traditional wooden buildings are characterized with the apparition of columns and beams that shows a simplicity and vigorousness of the structures. Such beautiful structures are realized by the processing of joint with high accuracy. Many of traditional wooden buildings are composed of columns and beams constituting a kind of rigid frames. Such frames are usually very sensitive to dimensioning of components and joints, since the section loss of columns at joints can be excessive. Underestimation of the dimensions can cause the fracture of the columns and lead the whole buildings into collapse. On the other hand, when the joints are appropriately designed, it is possible to realize earthquake-proof buildings by applying the partial embedding behavior of the grain at the joints to the tenacity of the frames. In general, the timber frame structure shows large displacement at the joints. The collapse of buildings is provoked usually by the joint fracture. The behavior of the timber frame structure can be correctly forecast by modeling load-deformation of its joint as an elastic-plasticity spring. This behavior of wood-to-wood joints is dominated mainly by the compressive strain inclined to the grain of wood. From the experimental study, I derived a practicable design formula that enables the estimation of the rigidity and the compressive yield strength of wood-to-wood contact in both cases of parallel displacement and inclined displacement. This design formula is now authorized and widely used for the structure design of traditional joints in Japan. In this lecture, I present some of timber buildings realized with the proposed wood-to-wood joint design method.

The first example that I designed using the joint method is the structure of "Forestry Mechanization Center" in Gunma Prefecture by architects, ALSED CO, LTD. This building has the rigid frame structure made of glued laminated timber of Japanese cedar. At its joint “Crosspiece + wood dowel”, a continuous beam runs through the cut-out applied to a pair of confronting columns. Many wooden dowels are then driven into the panel zone instead of drift-pins. This joint method allowing the addition of two different strengths – partial compressive strength resulting from high ductile behavior of crosspieces and sharp rising shear strength of wood dowels – demonstrates the moment resisting performance equal to the steel sheet insertion fixed with drift-pins.

Illustration 1: Seisui-ji in Sado island (808)

Illustration 2: “Crosspiece + wood dowel” joint of Forestry mechanization center

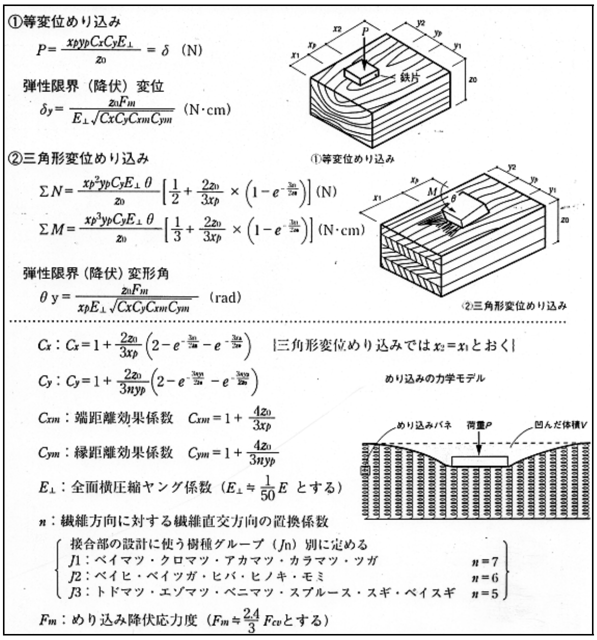

Illustration 3: Design formula of compressive rigidity and yield strength inclined to the grain of wood

Illustration 4 is a recreation facility in Asuka Day Nursery (Nara Prefecture Sakurai City) that I designed with ALSED CO, LTD. As for the realization, a master builder specialized in temples in Nara, city with many world heritages, took charge of the processing and assembly. The structure of this building is bi-directional rigid frame without steel fasteners. The roof is spanned with rafters penetrating columns. These are assembled with wood dowels. The ridge direction system consists of rigid frames made up of upper and lower flanges sandwiching a web plate with the help of wood dowels. The fulcrum girder method was adapted to the roof frames spanning 14m. This is a type of frame that can resist the bending moment by vertical load with scissors of the fulcrum girder without using steel plates.

Illustration 5 is Iwamura Kazuo Ehon-no-Oka Art Museum built in Tochigi Prefecture Bato-cho (architect Masamitsu Nozawa, structure engineer Masahiro Inayama). The structure of span direction is knee brace truss system. The ridge direction consists of the rigid frames with the above mentioned I-beam made of wooden flange and web plate. Japan cedar of 80 years old from the region is used for the structural material. These joints are also realized with the details enabling the rigidity and strength by engaging wood mutually without play. At the first meeting, our master builder read the drawings, grimaced, and then left mutely. However, he succeeded in having realized all the joints with surprising accuracy. Even a business card can not slide into his joints.

Gifu Academy of Forest Science and Culture (Illustration 6), a collaboration with architect Atsushi Kitagawara, is an ensemble of buildings stabilized mainly with wooden lattice walls. In addition to its load bearing performance in both vertical and horizontal ways, the wooden lattice wall is an attractive translucent ventilative component with beautiful wooden texture. The intersection of the vertical and horizontal member is designed to be a halving joint. A large number of halving joints with high ductility increase the anti-seismic performance of the wall. In order to lower the building cost, we used only a type of standardized lumbers (10.5/10.5/400) very common for housing construction, and applied computer controlled automatic processing “Pre-cut” to the joints. For further rationalization, all these pre-cut components were pre-assembled in an atelier and transported to the building site.

Illustration 4: Recreation facility in Asuka Day Nursery

Illustration 5: IWAMURA KAZUO Ehon-no-Oka Art Museum

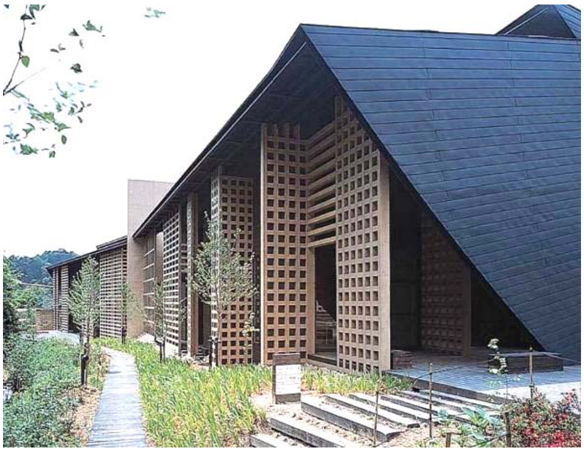

Illustration 6: Gifu Academy of Forest Science and Culture

Illustration 7 is Hida Beef Cattle Information Center built in Gifu Prefecture (architect Atsushi Kitagawara, structure engineer Masahiro Inayama). A defect of the wooden lattice wall is the low initial rigidity, while the maximal strength is high and tenacious. In the case of a former example, Gifu Academy of Forest Science and Culture, not only the wooden lattice walls but also plywood bearing walls were partially used to compensate the low rigidity. As for Hida Beef Cattle Information Center, the initial rigidity has been improved by inserting petaloid diaphragms into the lattice. Owing to this good combination between the wooden lattice and white painted diaphragms, the beautiful façades have appeared.

Illustration 8 is Kaisho Forest View Tube in Aichi Prefecture Seto-City that I designed with Kitagawara Studio, Tokyo Univ. of Fine Arts. This is a tower of 14m high built in Seto nature preserve in Aichi Expo site. The wooden lattice walls of this tower were made of only local cypress from thinning. The base structure was built without concrete for environmental protection and supports the whole building only with the steel pipe screw piles driven every 2.7m. In this tower, "Glass stiffening wooden lattice wall" is used to increase the rigidity and strength by combining the glass sheets with the wooden lattice walls. The result of full scale shear wall tests demonstrated the increase of maximal strength while maintaining the plastic deformation until the stroke limit of our hydraulic cylinder (drift angle 1/11). The glass sheet edges left a depression on the surrounding wood, but the glass itself remained intact.

Illustration 9 is Nagaike Nature Center built in Tama City, Tokyo (architect Masamitsu Nozawa, structure engineer Masahiro Inayama). The building is one-storied house construction covered with green roofs varying the height at random. This is an architectural consideration for environmental symbiosis with nature. The structure consists of the portal rigid frames with the truss girder and column. Two kinds of truss-girder, flat or inclined types, were located along the 4m x 4m grid plan. Different combinations of these girders enabled various green roofs like shed and HP shell. At the joint, the axis of girders does not intersect with the axis of columns. Four girders surround one column like a swastika.   The axial and shear force from the truss girders are transmitted to the columns by simple cogged joints.

Illustration 7: Hida Beef Cattle Information Center

Illustration 8: Kaisho Forest View Tube

Illustration 9: Nagaike Nature Center

Illustration 10 is "Forest Clearing House" in Gifu Academy of Forest Science and Culture introduced above. In this case, tree-form frameworks span 14 m wide interior space and 7 m eaves. When many bars gather at one node, the wooden space frameworks need a complex joint piece like metallic ball joint, and such joint cost becomes more expensive than the timbers. Then, we proposed a type of space truss with eccentric nodes. One node receives two bars at most. As a result, it was possible to apply a traditional joint of knee braces "Beveled housing (dado joint) with bolt". We succeeded in realizing a sober and beautiful structural hierarchy like natural tree at a reasonable cost.

Illustration 11 is Moriyama-cho Health Center in Nagasaki Prefecture that I designed with architect Ben Nakamura. The theme of structure engineering was spanning 12 m with heavy tiled roofs made of low quality small timbers from thinning of the local forests. The maximal dimensions of available timbers were limited to 12/12/400. As a solution, we proposed a type of truss consisting of 10.5/10.5 lumbers. The clearances of 35 mm between arranged even lumbers receive odd lumbers. At their intersections, 17.5 mm notches were applied to both sides of lumbers, in order to realize a variation of halved joint that is not recessed as deeply.
Illustration 12 is Utoko Limited Muroto Factory that I designed with architect Norihiko Dan. This factory, located on the cape coast of Muroto in Kochi Prefecture that is renowned for frequent typhoons, refines offshore deep-ocean water to produce salt and fresh water. The measure against the damage from salt demanded wood building. We conceived a single-bay structure consisting of self-standing GLT walls and roof. The cross section of each wall component measures 12 cm thick and 150 cm high. The walls were alternately arranged obliquely, and these lock together by notched joint. Such crossing raking walls perform trestle in the span direction and bearing walls in the ridge direction. Large-scale Typhoon No.10 hit directly the Muroto cape on the day of inauguration. An anemometer recorded the instantaneous wind velocity 69.2m/s at night. The next morning, I rushed to the site and found the building intact and beautifully under the blue sky after the typhoon.

Illustration 10: "Forest Clearing House" in Gifu Academy of Forest Science and Culture

Illustration 11: Moriyama-cho Health Center

Illustration 12: Utoko Limited Muroto Factory

Following the former example, I designed one another refinery with the same architect (Illustration 13). A vault roof spanning 17m was made of spruce GLT shorter than 6m.This is a low price material widely used for housing construction. The structure consists of scissors trusses composed of these GLT engaged mutually.

Since Kobe Earthquake, a strong concern for the earthquake proof of timber frames is rising in Japan. Regarding this situation, we organize annually “Wooden Bearing Wall Japan Cup”, a competition of strength and feasibility of different walls proposed and built by competitors. In order to judge the strength, a pair of walls is connected to a hydraulic cylinder placed between these walls. Then, these pull each other like tug-of-war until the fall of weaker one. The winner merits the championship cup. Besides, a grand-prix is given to a best wall satisfying the following criteria: (Earthquake proof + Design) / Total cost (materials + processing + workability + environmental impact). Wooden Bearing Wall Japan Cup is opened to students, architects, researchers and builders who are interested in this subject. Anyone can visit the competition, and can see the assembly and tests. Not only the competitors but also many passionate spectators come to discuss how to improve the walls. Wooden Bearing Wall Japan Cup allows us to understand the technical point of wall concept and encourage the realization of walls more reliable, more feasible and more beautiful.

Illustration 13: Sado Deep-ocean Water Bottling Factory

Illustration 14: Wooden Bearing Wall Japan Cup