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Design theory of Haraichi Kindergarten based on Japanese traditional structural detailing

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Abstract

This laminated wood structure for a kindergarten is based on the same housing-design method of "Shinkabe; wooden column-exposed wall construction" which has been used for the Japanese traditional wooden houses for a long time. This kindergarten, in spite of containing relatively wide span rooms like school gymnasium, class rooms and meeting room has no big size members. Not only from the view point of artistic detailing but also in economical and modular co-ordination factors, laminated wood columns and beams are one-side same thickness members (width size 12cm). To obtain the necessary performance as the kindergarten , they are used frequently as the members of part of Three Dimensional Truss or those of Rigid Rahmen frame using reliable glued-in rod connection.
As a result, we could achieve a long-span school gymnasium having high-side light, deep eaves and walls with smooth suface. They were necessary to assure for children to be active,

Keywords: Japanese traditional detailing, reference line, bare wooden frame, integration of rooms with different sizes, same thickness wooden members, mitigating light & wind, deep eaves, three dimensional truss, glued-in rod

Figure 1: Looking up at the three dimensional frame of all-purpose room as a gymnasium and an assembly hall

1.Introduction

This kindergarten has the history more than 45 years in the same place which is a part of the precinct of Ryougonji Temple. The owner of this kindergarten is the priest of this temple,too. Through these years, next to next several buildings were attached according to the increasing children. But upon experiencing the earthquake of 2011.3.11, the owner decided to rebuild the main school building worthy of healthy, strong and aesthetic ones. We responded to his hope by planning one-story school building in which a variety of rooms with different sizes are integrated in a simple plan, using laminated wood construction in which a variety of structural method are adopted to achieve the architectural requirements and detailing various parts carefully to ensure for children to move around in safety.

Figure2: Deep and long eaves sheltered children from the midday sun, yet free from structural obstacles.

2. Integration of a variety of rooms with different sizes

Genarally speaking, a kindergarten facility consists of a variety of rooms with different sizes. Therefore, structural system is apt to be exaggerated by adopting large-size colum and beam system. In this kindergarten, we thought to make use of each partition-wall as bearing wall according to Japanese traditional housing system -Shinkabe- in which walls are set on the reference line and parts of walls are not bulged out of the width of columns. Furthermore the high precision of laminated wood members and embedded metal joints enabled to make the flat surface detailing between walls and columns without discrepancy. In case of the rooms especially requiring long-span such as class rooms and gymnasium, Structural truss were incorporated achieving effective control of ventilation and sun light in the summer seasons..

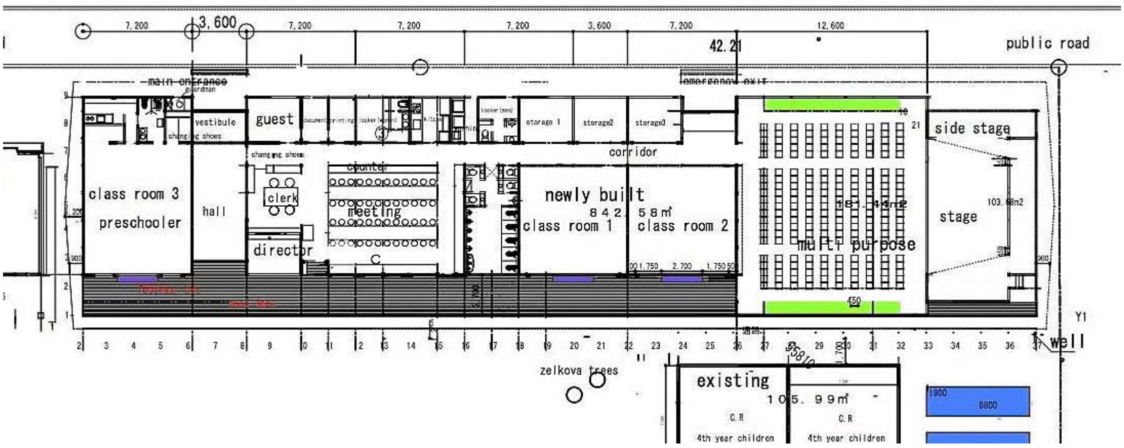


Figure3:Simply integrated plan

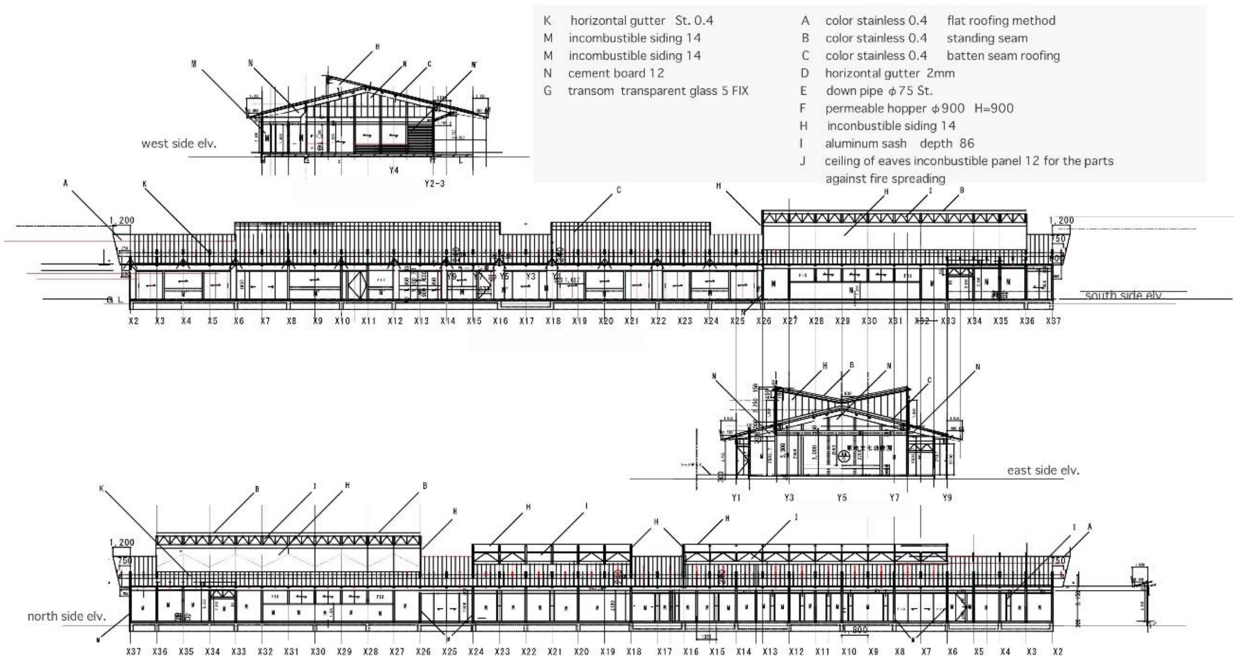


Figure5: Elevations and .exterior finishing

Japan is a humid country, then since the old age our ancestors have used structural wooden members in bare condition letting them breathe in the natural air for preventing damage from the decay. Fundamentally columns and beams were not wrapped except for fireproof buildings like storehouses or castles with thick mortal. In the house buildings each partition was simply modular coordinated using the dimension of nearly 910mm length or multiple length. Therefor in the market like commercial home centers in Japan a lot of flat building materials are sold on 910 mm size or its multiple dimension. For eliminating waste of materials, for shortening the thinking time for planning and for achieving rational construction including extension and structural alteration, this 910 mm modular coordination system still remains as a deep-rooted social system. Even in the roof, this system is an extension of this idea despite roof tiles or metal sheets. In this case, roof is covered by standing seam construction of color stainless steel and galvanized steel in which the interval of standing seam is 455mm of a half of 910mm. . And for setting the snow slide stopping bars or the outside-air-conditioner-machine stands, effective fasteners are used. In this kindergarten these methods are totally combined. This kindergarten has a plan to set solar power panels on the roof using these fasteners for further functional addition in the future.,



Figure4:Structure for high side lights Figure6: Outside machine Figure8: Fastener

3. Structural details making multi-purpose room

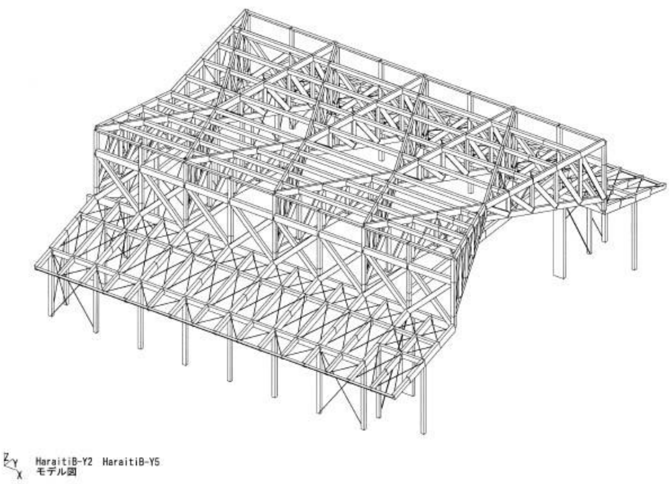


Figure9: Structural isometric of multi-purpose room. Figure10: Detail of long span

This multi-purpose space are used for a gymnasium, a meeting room and an assembly hall with more than 300 people when the entrance ceremony or the school play are held. So the sufficient ventilation and light are needed to keep comfort for people. To achieve them, the high side lights being set between symbolic large beams like bird wings are designed and those spatial beams mitigate the rapid flow of winds in the typhoon season and the strong sunshine in the summer season. The longitudinal long-span girders are extended into the upper parts of the stage which has 9 meter-wide house-curtain of folding up system. For opening it, the winch machine and wiring devices are set by making use of vacancy of truss holes on the stage. 5 units of stair boxes are put away in beneath the stage floor usually. According to the kind of event, they are drawn out from this storage space. Especially when the commemorative picture is needed, this device demonstrates its ability as tiered stand.



Figure8: Hight side light Figure9: Stair boxes under the stage Figure:10 Winch above the stage

4. Structural details making class rooms and deep eaves

To increase the continuity between class rooms and ground was the most important item offered by the client. We answered this demand by making 3.6 m cantilever canopy without any posts at edge using spatial truss as knee joints and string beam. In the backward of of this spatial truss, horizontal beem are set compounding T mode beam to take responding stress from spatial truss This fundamental method was inherited since more than one thousant years ago in Japanese carpenters. In the country like Japan having relatively long rainy season, various devices for making cantilever have been developped through the histry. One of the most impressive example is the tower of five story pagoda you can see every place in Japan through the north to the south. And also we intended that this large roof could be looked afloat by separating roof from walls visually inserting transoms with sashless glass fixed by structural sealing. To emphasize the sharp edge-line of the eaves, horizontal gutters were setbacked inwards about 1.2m.


Figure11: The place where activity occurs Figure13:: Sharp-edged eaves

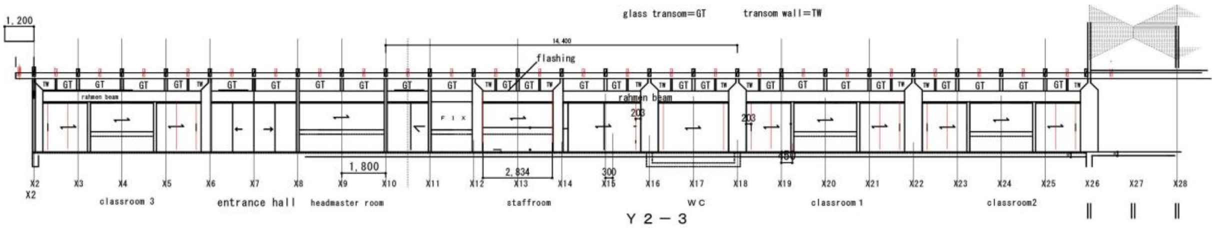


Figure12: Structure plane Y2-3

Figure13: Looking outside through the window

Figure14: Spatial Knee Joint

5. Structural Calculation

The characteristic of this structure is based on traditional wooden post and beam structure meaning exposed frame which is adequate to Japanese climate. Main members have the same width, 120mm. Depending on the position, another depth dimension is changed according to occurred stress like 90, 120,150,180,210,240,300 and 450mm. Structural glued laminated lumber made by larch tree E105-F300 was used for stablility of strength and flexibility of length. We confirmed the horizontal rigidity by partially located 24mm structural plywood ceiling zone.being put up on the toilets and other small chambers.

Vertical structural walls of X direction are composed of wooden braces flanked with double plaster-boards of 12mm thickness. In the calculation they are evaluated from the view point of allowable shear strength and deformation. Vertical structural elements of Y direction are mainly composed of wooden rigid rahmen frame which resists the horizontal loads from the earthquake. At the joint of column and beam, glued-in rod construction was adopted with epoxy resin injected deformed bar. In this case, regarding strength and rotational stiffnes we used the confirmed experimental data for structural calculation.

For the stress analyzation, replacing both rigidity of posts and beams and rigidity of joint deformation of braces into rigidity of steel brace, adding rotational stiffness of glued-in rod joint, the main structural calculation was done by using the three -dimensional stress analization software, STAN/30 of KOZO KEIKAKU ENGINEERING Inc.

Under the rule of Japanese Architectural Regulations, Rout 1 (Allowable Stress Calculation 1) was used. At the general joint points, the ready-made metal joint- Tec.One- was selected. for the reason of little sectional loss. At the glued-in rod joint points, we evaluated the occurred stress considering ultimate bending strength M_u together with ductility factor μ (${}_{S}M_a=0.2\times M_u\times(2\mu-1)^{1/2}$, μ = 1.30)

Figure15: T mode beam Joint

Figure16: R-H construction

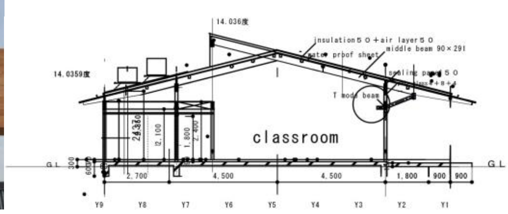
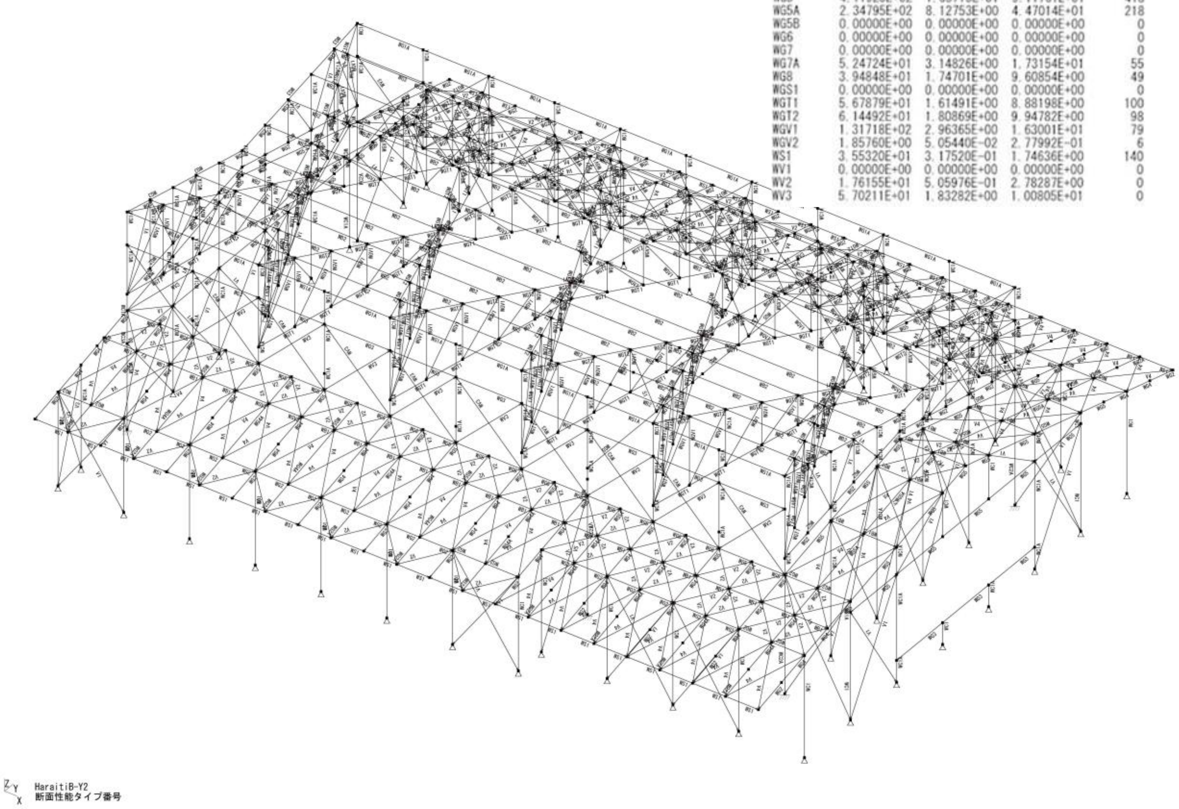


Figure17: T mode beam backing truss

Table 1: Sum total of surface area, volume, weight of all members

*** Sum total of surface area, volume, weight of all members

Symbol	Surface Area (m2)	Volume (m3)	Weight (kN)	Amount of Members	Amount of Truss
S1	6. 76430E-01	1. 45054E-03	1. 11692E-01	0	4
V0	7. 08670E-01	7. 93711E-04	6. 11157E-02	0	25
V1	5. 60551E+00	6. 61450E-03	5. 09316E-01	0	152
V2	1. 76610E+01	2. 73745E-02	2. 10783E+00	0	656
V3	1. 36616E+00	1. 78626E-03	1. 37542E-01	0	34
V4	5. 41209E+01	1. 33949E-01	1. 03141E+01	0	874
V5	3. 97066E-01	1. 68852E-03	1. 30016E-01	0	2
V6	4. 02874E-01	4. 89491E-04	3. 76908E-02	0	10
WB0	4. 27680E+01	9. 62280E-01	5. 29254E+00	88	0
WB1	1. 47794E+02	4. 43381E+00	2. 43859E+01	343	0
WB2	8. 74800E+01	2. 91600E+00	1. 60380E+01	102	0
WB3	7. 86600E+01	2. 83176E+00	1. 55747E+01	112	0
WB4	0. 00000E+00	0. 00000E+00	0. 00000E+00	0	0
WB6	0. 00000E+00	0. 00000E+00	0. 00000E+00	0	0
WC1	1. 78752E+02	5. 36256E+00	2. 94941E+01	229	0
WC1A	1. 11384E+02	3. 34152E+00	1. 83784E+01	197	0
WC2	6. 12900E+00	2. 86020E-01	1. 57311E+00	3	0
WC2A	4. 03920E+01	1. 88496E+00	1. 03673E+01	15	0
WC3	0. 00000E+00	0. 00000E+00	0. 00000E+00	0	0
WC3A	3. 70440E+01	1. 90512E+00	1. 04782E+01	10	0
WG1	4. 32000E+00	1. 29600E-01	7. 12800E-01	12	0
WG1A	1. 29600E+01	2. 59200E-01	1. 42560E+00	20	0
WG2	1. 22980E+02	4. 42727E+00	2. 43500E+01	230	0
WG2A	9. 88877E+01	2. 96663E+00	1. 63165E+01	181	0
WG3	1. 56698E+02	6. 26792E+00	3. 44736E+01	205	0
WG3A	0. 00000E+00	0. 00000E+00	0. 00000E+00	0	0
WG4	1. 00475E+02	4. 17358E+00	2. 29547E+01	106	0
WG4A	8. 60667E+01	2. 90475E+00	1. 59761E+01	78	0
WG5	4. 11925E+02	1. 65775E+01	9. 11761E+01	418	0
WG5A	2. 34795E+02	8. 12753E+00	4. 47014E+01	218	0
WG5B	0. 00000E+00	0. 00000E+00	0. 00000E+00	0	0
WG6	0. 00000E+00	0. 00000E+00	0. 00000E+00	0	0
WG7	0. 00000E+00	0. 00000E+00	0. 00000E+00	0	0
WG7A	5. 24724E+01	3. 14826E+00	1. 73154E+01	55	0
WG8	3. 94848E+01	1. 74701E+00	9. 60854E+00	49	0
WGS1	0. 00000E+00	0. 00000E+00	0. 00000E+00	0	0
WGT1	5. 67879E+01	1. 61491E+00	8. 88198E+00	100	0
WGT2	6. 14492E+01	1. 80869E+00	9. 94782E+00	98	0
WGV1	1. 31718E+02	2. 96365E+00	1. 63001E+01	79	99
WGV2	1. 85760E+00	5. 05440E-02	2. 77992E-01	6	0
WS1	3. 55320E+01	3. 17520E-01	1. 74636E+00	140	0
WV1	0. 00000E+00	0. 00000E+00	0. 00000E+00	0	0
WV2	1. 76155E+01	5. 05976E-01	2. 78287E+00	0	26
WV3	5. 70211E+01	1. 83282E+00	1. 00805E+01	0	40



6. Conclusion

The features of Japanese traditional wooden structure consists of clear plan, backed up by modular coordination systems which has been rooted in the social system, and large roof which wraps up the rooms and human activities under itself.

One of the weakest point of this structure was in the large sectional lack of wooden members around at the joint of beams and columns. But recent progressive metal joints and glued-in rod construction are now overcoming its condition and new designs for this construction appear with new esthetics added.

Not only housings but communal buildings, carefully detailed structure can offer human size spaces with marketable parts and members.

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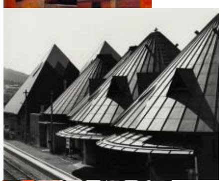
References



[1] Kuniaki ITO. New Developments in Three Dimensional Truss. *IASS PACIFIC SYMPOSIUM* 1971-part2 on tension structures and space frames; 997-1010.

[2] Kuniaki ITO. Forest Pavilion of Ehime Pref. *THE JAPAN ARCHITECT* 1990.12;259-266.

[3] Kuniaki ITO+MAIS. JR Iwaki Hanawa Station. *THE JAPAN ARCHITECT* 1995.4;211-216.

[4] Martha THORNE, HANAWA STATION AND CIVIC CENTER : , *Modern Trains and Splendid Stations,* The Art Institute of Chicago 2001 :94-97. Brunel Awards Commendation 1996 copenhagen

[5] Kuniaki ITO+MAIS. Japanese umbrellas. Hanawa Library+Station. *THE ARCHITECTURAL REVIEW*, MAY1997; 69-71.

[6] Jo Coenen, Bert Natter, HANAWA STATION, *WERELDSTATIONS,* Utrecht Central Museum 2001: 49-53 Invitation from Utrecht Central Museum

[7] Louis I. KAHN and The Kimbell Art Museum, *LIGHT IS THE THEME*: Kimbell Art Foundation 1975

[8] Tetsuro YOSHIDA, *JAPANISCHE ARCHITEKTUR*, 1952, Ernst Wasmuth G.m.b.H.

[9] Toshio AIHARA, Marin KATOV, Naoyuki ITAGAKI, Masato MITSUI and Kuniaki ITO. Design of a Hybrid Structure consisting of a Steel Beam Strings Structure and a wooden HP Shell reinforced by Aramid Fiber Sheets. *Jornal of IASS* 2004.8; 45,n2. 81-91 TSUBOI PRIZE 2004