



Laboratory of Engineered Timber Joints
Wood Technology Division, Timber Engineering Section
Forestry and Forest Products Research Institute

Introduction of Researches in the Laboratory of Engineered Timber Joints

接合研究室における最近の研究の紹介

BY

Kohei Komatsu*1

小松幸平

Norio Kawamoto*1

川本紀雄

Noriyuki Kanaya*2

金谷紀行

Laboratory of Engineered Timber Joints(ETJ) is very new laboratory whose born was October in 1988. It has only one year passed now. During the past year, we have been doing a lot of experiments relating to the engineered timber joints.

Followings are brief introductions of recent researches done mainly by the members of the Laboratory of ETJ. Some of which, however, were done with members of Timber Structures in which Komatsu was belonged while the experiments were done.

接合研究室は1988年10月に誕生したばかりの非常に新しい研究室で、現在まだ1年しか経過していないが、我々はその間、構造設計を要する木材の接合に関する数々の実験を行ってきた。

以下は、主に接合研究室のメンバーによって行った最近の研究を簡単に紹介したものであるが、中には小松が構造性能研究室在室中に行ったものも含まれている。

- *1.Laboratory of Engineered Timber Joints 接合研究室
- *2.Former in the Laboratory of ETJ, at present Research Information Section 前接合研究室。現在研究情報科

1. Full-Size Loading Test on The Two-Story Glulam Portal Frames

【Aim of the Research】

- ① to make sure the possibility of rigid-jointed timber frame structures using straight glued laminated timber.
- ② development of moment-resisting joints which enable the rigid-jointed timber frame structures.
- ③ development of non-linear Finite Element Method which can consider the nonlinearity of each fasteners composed of moment-resisting joints.
- ④ verification of nonlinear FEM by the full-size experiments.

【Summary of Result】

- ① Three types of moment-resisting joints were developed using the nailed joint with steel side plates, bolted joint with steel side plates, and drift-pin joint with insert-type steel plates.
- ② Three full-size (Span 8m) two-story portal frames were made using three different joint methods. Comparisons between nonlinear FEM analysis and full-size loading test showed that the behaviour of the portal frame composed of nailed joint was most precisely predicted, while drift-pin joint was affected by the initial clearance between pin-hole and pin.

1. 2層集成材門型ラーメンの実大加力試験

【研究の目的】

- ① 通直集成材を用いた剛節骨組み架構の可能性の確認。
- ② 木質剛節骨組み架構を可能とするモーメント抵抗接合法の開発。
- ③ モーメント抵抗接合を構成する個々の接合具の非線形性を考慮した非線形有限要素法の開発。
- ④ 実大実験による非線形FEMの検証。

【結果の要約】

- ① 鋼板添え板釘打ち接合、鋼板添え板ボルト締め接合、鋼板挿入ドリフトピン打ち接合による3種類のモーメント抵抗接合法を開発した。
- ② 3種類の異なった接合法を用いて、3体の実大（スパン8m）の2層門型ラーメンを製作した。実大加力試験と非線形有限要素法による解析を比較すると、釘接合ラーメンの挙動が最も精度良く推定できた。一方、ドリフトピン接合によるラーメンは初期ガタの影響が見られた。

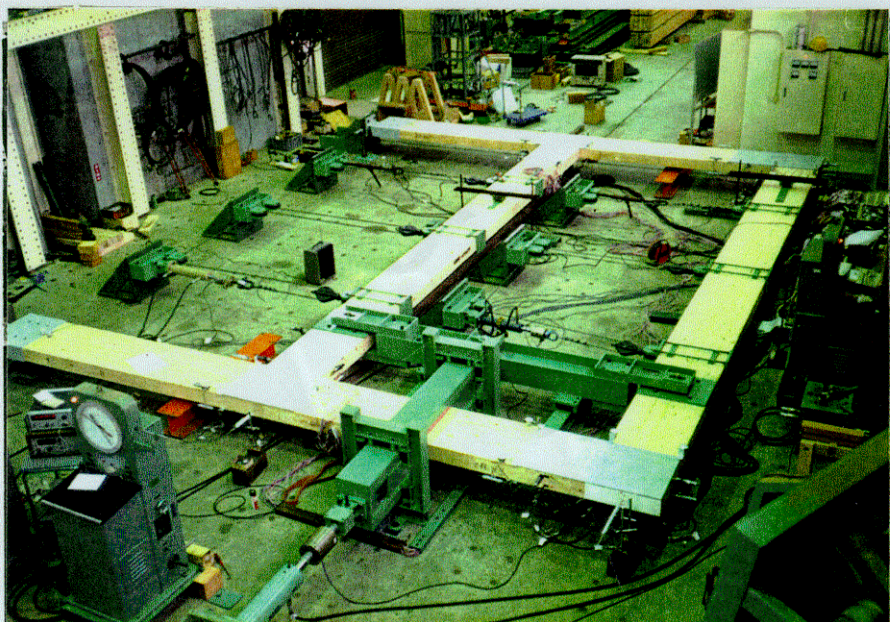


Photo. 1 Full-size two-story glulam portal frame loading test(CN3472-24)

写真 1 集成材による実大2層門型ラーメンの加力試験

2. Depth Effects on the Modulus of Rupture of Glued Laminated Beam

【Aim of the Research】

- ① derivation of an equation for predicting modulus of rupture of glued laminated beam composed of arbitrary laminae without using size effect modification factor.
- ② verification of derived equation by a series of destructive tests on the full-size glued laminated beams having various beam depth (from 30cm to 91cm) and span (5.7m to 12m).

【Summary of Result】

- ① an equation which can predict modulus of rupture of any glulam beam composed of laminae with arbitrary grade, size, and arrangement at the most critical section in the beam was derived by applying the multi-layer composite beam concept.
- ② size effect on the MOR could be expressed by only the equation derived in this study without using so-called modification factor.
- ③ experimental result obtained on the full-size Douglas fir glulam beams was compared with predicted one based on the Monte Carlo method. In consequent, derived equation was considered to be roughly held good.

Photo. 2 Four-points bending strength test on Douglas Fir glulam beam with largest depth of 91 cm (CN2575-14).

写真2 最大梁せい91cmの
ダグラスファー集成梁について
の4点曲げ強度実験

2. 集成材の曲げ破壊係数に及ぼす 梁せいの影響

【研究の目的】

- ① 寸法調整係数を用いることなく、任意のラミナ構成から成る集成材の曲げ破壊係数を予測する計算式の誘導。
- ② 様々な梁せい（30cm～91cm）、スパン（5.7m～12m）を有する集成梁における一連の実大破壊実験を通じて、誘導した計算式を検証する。

【結果の要約】

- ① 任意のラミナ等級、ラミナ寸法、断面内ラミナ配置を危険断面のみについて考慮した集成梁の曲げ破壊係数（MOR）を予測し得る計算式を、多層積層複合梁の概念を応用して、誘導した。
- ② MORに及ぼす梁せいの影響を、いわゆる「寸法調整係数」を用いずに、今回誘導した計算式で説明できた。
- ③ ダグラスファー集成材を用いた実大曲げ破壊実験の結果とモンテカルロ法を用いた計算予測値を比較した結果、誘導した式は概ね妥当であると判断された。



3. Strength Properties of Dowel-type Fasteners in Glued Laminated Timber Made of Domestic Softwood Timber

【Aim of the Research】

- ① to make sure the effects of joint configuration(end or edge distance and fastener space) on the strength properties of dowel-type fasteners in glued laminated timber made of domestic grown softwood timber represented by SUGI(*Cryptomeria*).
- ② to clarify the difference between joint strength loaded perpendicular to the grain and parallel to the grain, as well as the difference between drift pin joint and bolt joint.
- ③ evaluation of current design equation for dowel-type fasteners like drift pin, bolt and so on.

【Summary of Result】

- ① In the case of parallel to the grain loading, effects of end distance and fastener's space were more evident as the diameter become larger. Yielding strength of drift pin joint with insert steel plate could be well predicted by the equation derived by Larsen.
- ② In the case of perpendicular to the grain loading, edge distance and aspect ratio of dowel were greatly affected on the joint strength.
- ③ For ultimate strength, bolt joint was stronger than drift pin joint owing to the effect of washer. For stiffness, no clear distinction was observed.

Photo. 3 Strength test on drift-pin joint with insert steel plate in SUGI glued laminated timber loaded perpendicular to the grain (CN1952KAWA-26)

写真3 スギ集成材における鋼板挿入式ドリフトピン接合の繊維直行方向加力による強度試験

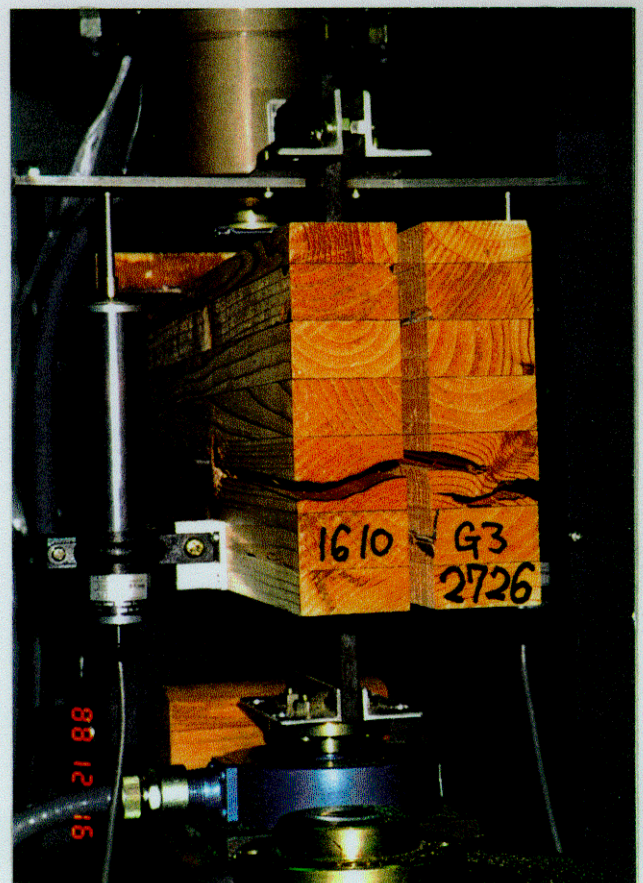
3. 国産針葉樹集成材におけるダボ型接合具の強度性能

【研究の目的】

- ①端明き、縁明き、接合具間隔等の接合部形状がスギに代表される国産針葉樹集成材におけるダボ型接合具の強度性能に及ぼす影響を明らかにする
- ②繊維直交方向加力と繊維平行方向加力並びに、ボルトとドリフトピンの接合強度の違い等を明らかにする。
- ③ドリフトピンやボルトといったダボ型接合具に関する現行設計式の評価

【結果の要約】

- ①繊維平行方向加力の場合、端距離と接合具間隔の影響は接合具の直径の増加に伴ってより明白となる。鋼板挿入型ドリフトピン接合の降伏耐力は Larsen の誘導式によって正確に予測可能であった。
- ②繊維直交方向加力の場合、縁明きとダボの有効長さ直径比 (l/d) が接合耐力に大きな影響を及ぼす。
- ③終局耐力に関しては、ワッシャーの影響でボルト接合のほうがドリフトピン接合より強いが、剛性に関しては違いは明瞭ではない。



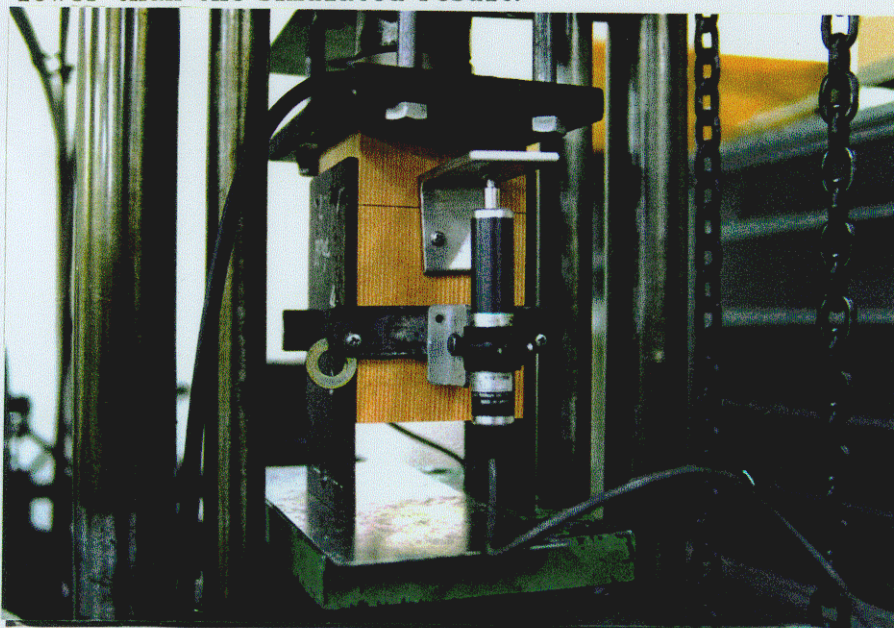
4. Shear Performance of Nailed Timber Joints with Steel Side Plates

【Aim of the Research】

- ① to make sure the effects of timber density, nail diameter, thickness of steel plate, and load angle to the grain on the performance of nailed timber joints with steel side plates.
- ② to predict the nonlinear behaviour of nailed timber joints with steel side plates using nonlinear finite element method specially developed.
- ③ to evaluate the current permissible nail load determined based on the wood-to-wood nailed joint strength.

【Summary of Result】

- ① Effects of steel plate thickness, load angle to the grain on the ultimate strength of nailed timber joints with steel side plates were rare. While timber density acted as a dominant role to the shear performance of nailed timber joints.
- ② Nonlinear behaviour of nailed timber joints could be predicted reasonably by the FEM up to the slip deformation of the order of nail diameter. In the more large deformation region, effect of nail head resistance was observed.
- ③ According to the Monte Carlo Method using experimental data obtained in this research, the current permissible load of nail with steel side plates were estimated about 30% lower than the simulated result.



4. 鋼板添え板釘打ち接合のせん断性能

【研究の目的】

- ① 木材の密度、釘径、鋼板厚さ、加力角度等が鋼板添え板釘打ち接合の一面せん断性能に及ぼす影響を明らかにする。
- ② 鋼板添え板釘打ち接合の非線形挙動を開発した非線形有限要素法で推定する。
- ③ 木材と木材の釘接合強度に基づいて決められている現行の釘に関する許容耐力の評価。

【結果の要約】

- ① 鋼板厚さ、加力角度は鋼板添え板釘打ち接合のせん断性能に殆ど影響しない。一方、木材の密度は釘接合のせん断性能に支配的な役割を演じている。
- ② 釘接合の非線形挙動はすべり変形が釘径のオーダー程度であれば非線形FEMで推定可能であるが、それ以上の領域では釘頭の抵抗効果が認められた。
- ③ 本研究の実験結果を用いたモンテカルロ法によれば、鋼板を添え板とする釘の許容耐力は推定値より約30%低く見積もられている。

Photo. 4 Single shear test on nailed timber joint with steel side plates (loaded parallel to the grain)
(CN7958-13)

写真4 鋼板添え板釘打ち接合の一面せん断試験（繊維平行方向加力）

5. Performance of Glulam Moment Resisting Joints

【Aim of the Research】

- ① to clarify the structural performance of glulam moment resisting joints composed of two different joint methods, i.e. nailed joint with steel side plate and drift pin joint with insert steel plate(s).
- ② to develop the working stress design method for glulam portal frames built on-site using the straight glulam members by employing the moment-resisting joint technique.
- ③ to obtain basic data for considering the ultimate strength design method in near future.

【Summary of Result】

- ① According to static cyclic loading tests, moment resisting joints using nails with steel side plates showed higher initial stiffness, ductility, and suitable damping capacity compared with those joints using drift pins with insert steel plate(s).
- ② Drift pin joints should be designed in WSD method by taking account adequate load factor because of its brittle characteristics, while nailed joint might be able to be designed on the basis of ductility, because suitable ductility can be obtained as the the number of nail decreases if more higher permissible nail load than the current ones should be assigned.

5. 集成材モーメント抵抗接合の構造性能

【研究の目的】

- ① 2種類の接合法、すなわち鋼板添え板釘打ち接合と鋼板挿入ドリフトピン接合、によって構成された集成材モーメント抵抗接合の構造性能を明かにする。
- ② 剛接合技術を駆使し、現場で通直集成材の部材を組み上げていく集成材ラーメン架構の許容応力度設計法を開発する。
- ③ 近い将来の終局耐力設計法を考えるうえでの基礎的なデーターを得る。

【結果の要約】

- ① 静的正負繰り返し加力試験の結果によると、鋼板添え板釘打ち接合は、鋼板挿入ドリフトピン接合と比較して、高い初期剛性、大きな靱性、そして望ましい減衰特性を示した。
- ② ドリフトピン接合はその脆性的特性のため、十分な荷重係数を見込んだ許容応力度設計で設計されるべきである。一方、釘接合の場合は、もし現行より高い許容耐力が与えられるならば、釘本数を減少でき、接合部に適度な靱性が得られるので、靱性に期待した設計も可能かもしれない。

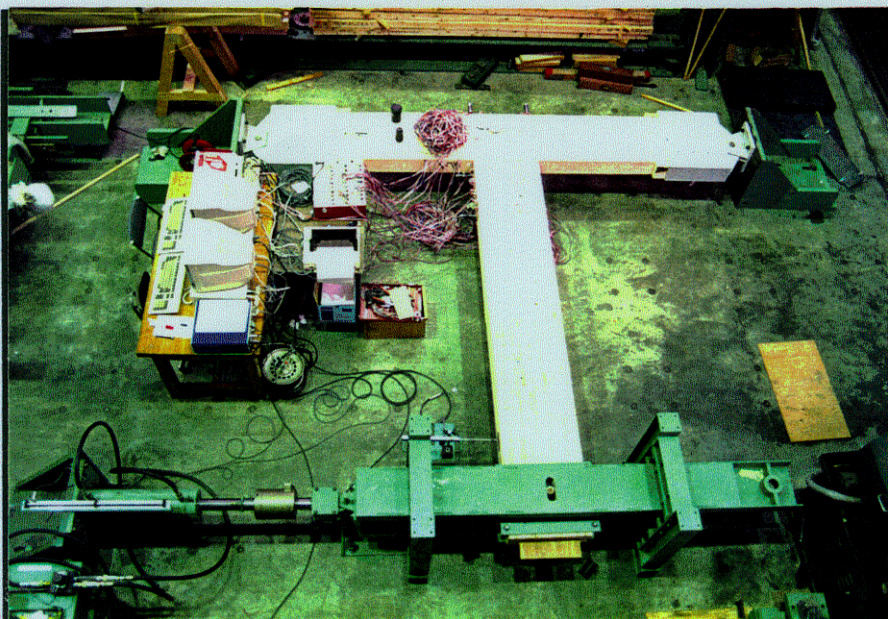


Photo.5 Static cyclic loading test on the glulam moment resisting T-shape joint. This photo shows drift pin joint with insert steel plate (CN3484-20)

写真5 集成材T字型モーメント抵抗接合における静的正負繰り返し加力試験。写真は鋼板挿入ドリフトピン接合を示す。

6. Ongoing Researches 6. 現在進行中の研究

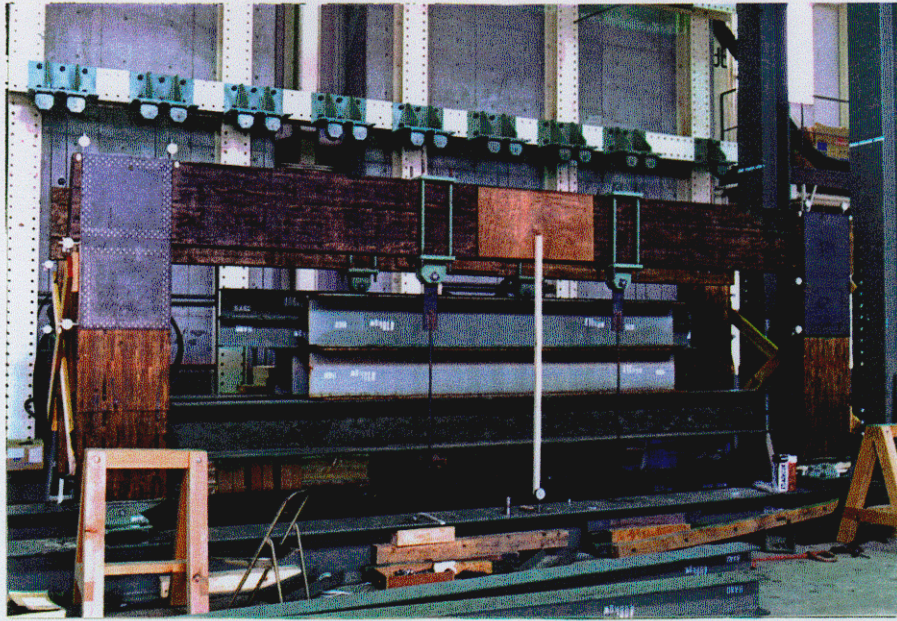


Photo. 6 Duration-of-Load test on glulam portal frames. In this portal frame, every joint has different fastener's arrangement. Dead load was assigned to satisfy the condition that the most critical fastener meets to the permissible long term load(CN1421-13).

写真6 集成材ラーメン架構における長期載荷実験。このラーメン架構のすべての接合部は異なる接合具の配置で構成されている。死荷重は最も力を受ける接合具がその長期許容耐力となるような条件から決定されている。



Photo. 7 Four-points bending strength test on glulam beam joint specimen. This joint is basically composed of drift pin joint with insert steel plate, but steel plate itself is also connected on-site by the "high-tension bolts" to make the on-site labor easier than the conventional method (CN9790-14).

写真7 集成梁継手試験体における4点曲げ強度試験。この継手は基本的には鋼板挿入ドリフトピン接合から構成されているが、鋼板が「高力ボルト」によって現場接合されるので、施工がこれまでの方法より容易となる。

6. Ongoing Researches (Continued) 6. 現在進行中の研究 (つづき)

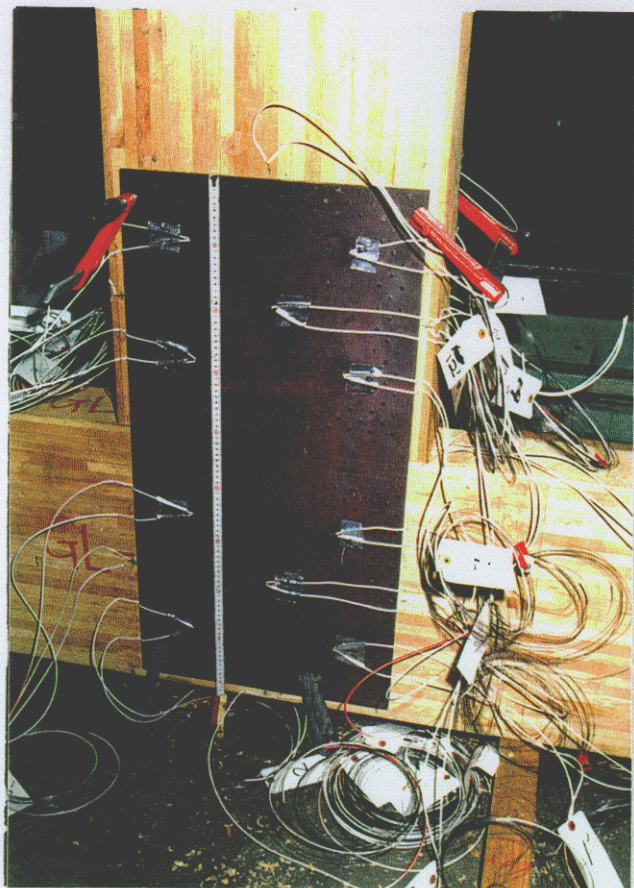


Photo. 8 Glulam moment resisting T-shape joint specimen composed of nails with steel side plates. Photo. shows a lot of thermo couples attached on the steel plates to measure heat distribution under fire endurance test. This experiment is being done with co-operation with Fire Protection Research Laboratory (CN43-38KAWA-14).

写真8 鋼板添え板釘打ち接合で構成された集成材T字型モーメント抵抗接合試験体。写真では載荷燃焼実験下での鋼板の温度分布測定用の多数の熱電対が見える。この実験は難燃研究室との共同で行われている。

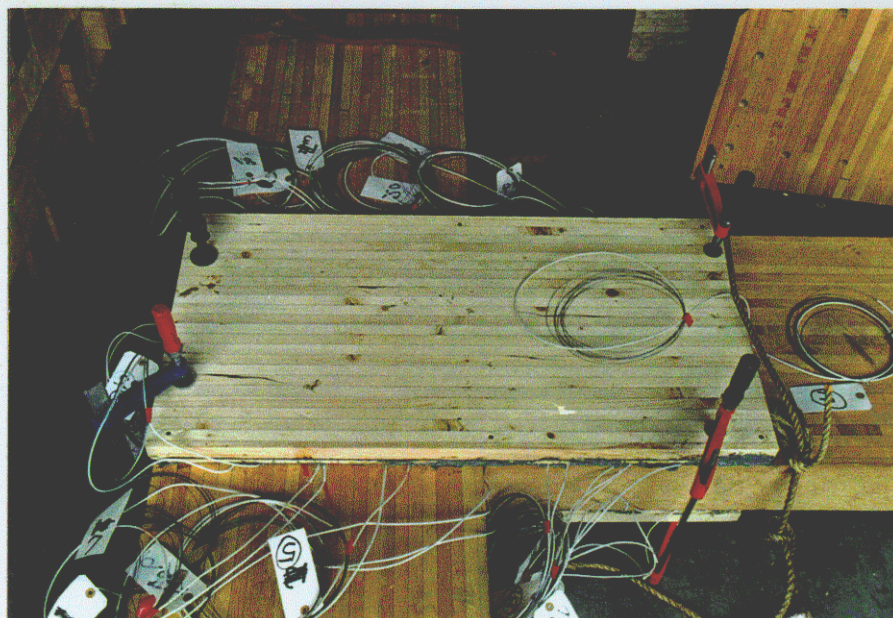


Photo. 9 Glulam moment resisting T-shape joint specimen composed of nails with steel side plates. A glulam plate of 30 mm thickness was glued on the steel side plate to protect it from direct fire attack in the fire endurance test. This experiment is being done with co-operation with Fire Protection Research Laboratory (CN43-38KAWA-17).

写真9 鋼板添え板釘打ち接合で構成された集成材T字型モーメント抵抗接合試験体。載荷燃焼実験下で鋼板が炎に直撃されるのを防ぐために厚さ30mmの集成材の板を鋼板の上に接着した。この実験は難燃研究室との共同で行われている。

7. Miscellaneous Experiments

7. その他の実験



Photo. 10 Static cyclic loading test on a glulam cross lapped knee joint specimen. This moment resisting joint was composed of two column members and a single beam member jointed with 12 mm through bolts with "Appel Rings" inserted at interfaces between beam and column leaves. On-site use elastomer glue was also added for the other specimen (CN5359-15).

写真10 集成材交差重ね合わせ軒肩接合部の静的正負繰り返し加力試験。このモーメント抵抗接合は柱-梁部材の接合界面に「アペルリング」を挿入し12mmボルトを通して接合したものである。別の試験体には更に現場用弾性接着剤を塗布した。



Photo. 11 Static cyclic loading test on glulam knee joint specimen. This joint is basically composed of drift pin joint with insert steel plate, but steel plate itself is also connected on-site by the "high-tension bolts" to make the on-site labor easier than the conventional method (CN1090-19).

写真11 集成材軒肩接合部試験体における静的正負繰り返し加力試験。この接合部は基本的には鋼板挿入ドリフトピン接合から構成されているが、鋼板が「高力ボルト」によって現場接合されるので、施工がこれまでの方法より容易となる。

7. Miscellaneous Experiments (continued)

7. その他の実験 (つづき)

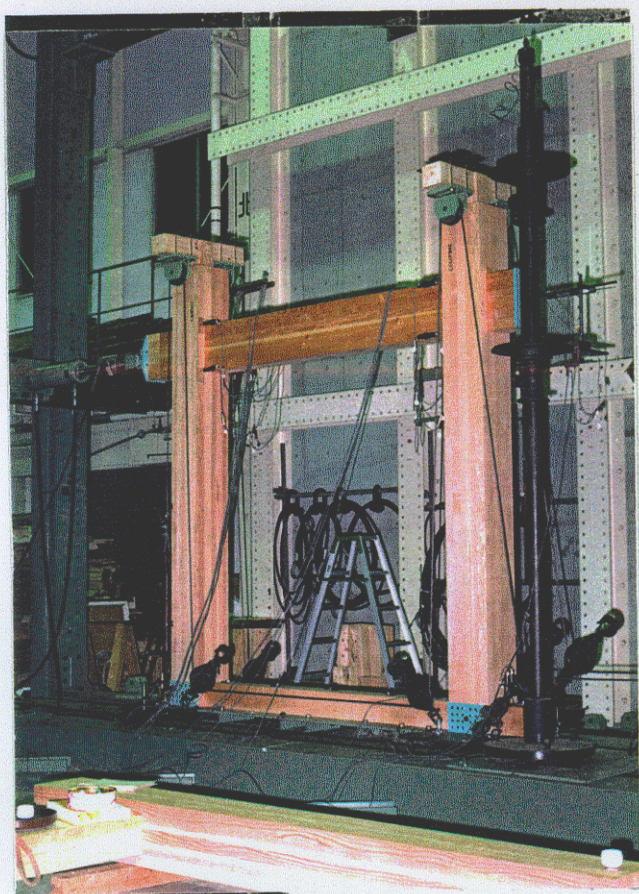


Photo. 12 Static cyclic loading test on a traditional post and beam "Nuki" frame structure. Post and "Nuki"-beam joint was composed of traditional "Nuki" joint whose load carrying capacity depends on embedment strength of timber (CN3928-35).

写真12 伝統的な「貫構造」架構の静的正負繰り返し加力試験。柱-貫の接合部は木材の面圧耐力に依存した「貫」接合で構成されている。



Photo. 13 Static cyclic horizontal loading test on a full-size two story post and beam frame structure. Post and beam joint was basically composed of traditional splint tenon with hardwood dowels joint (CN9156-32).

写真13 実大2層軸組架構の静的正負繰り返し水平加力試験。柱-梁の接合部は基本的には伝統的な雇いほぞと硬木のダボで構成されている。

References 発表文献

1. Full-Size Loading Test on The Two-Story Glulam Portal Frames

- a.Kohei Komatsu, Fumio Kamiya and Yoshihiko Hirashima : "Full-size Test and Analysis on Glulam Two-Storeyed Portal Frames Subjected to Horizontal Load", Proceedings of the 31st Congress on Material Research, Vol.31, pp.185-191, 1988.
- b.Kohei Komatsu, Fumio Kamiya and Yoshihiko Hirashima : "Full-size Test and Analysis on Glulam Two-Storeyed Portal Frames", Proceedings of the 1988 International Conference on Timber Engineering, Vol.2, pp.205-220, Seattle, 1988.
- c.Kohei Komatsu : "Analysis of Glulam Frame Structures Considering Nonlinear Characteristics of Fasteners I - Derivation of analytical method ", Journal of Japan Wood Research Society, Vol.34, No.7, pp.581-589, 1988. (Japanese)
- d.Kohei Komatsu, Noriaki Maeda and Kazumi Horie : "Analysis of Glulam Frame Structures Considering Nonlinear Characteristics of Fasteners II - Verification by experiments ", Journal of Japan Wood Research Society, Vol.35, No.3, pp.201~211, 1989. (Japanese)

2. Depth Effects on the Modulus of Rupture of Glued Laminated Beam

- a.Kohei Komatsu and Norio Kawamoto : "Modulus of Rupture (MOR) of Large Glulam Beam Composed of Arbitrary Laminae", Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan, pp.77-78, 1988. (Japanese)
- b.Kohei Komatsu and Norio Kawamoto : "Modulus of Rupture of Glulam Beam Composed of Arbitrary Laminae", International Council for Building Research Studies and Documentation, Working Commission W18A - Timber Structures, CIB-W18/21-12-1, Vancouver, September, 1988.

3. Strength Properties of Dowel-type Fasteners in Glued Laminated Timber

- a.Norio Kawamoto and Noriyuki Kanaya : "Strength of drift pin joints in glued laminated timber of sugi - Parallel to the Grain Loading -", Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan, pp.99-100, 1988. (Japanese)
- b.Norio Kawamoto, Noriyuki Kanaya and Kohei Komatsu : "Strength of drift pin joints in glued laminated timber of sugi - Perpendicular to the Grain Loading -", Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan, pp.101-102, 1989. (Japanese)
- c.Noriyuki Kanaya, Norio Kawamoto, and Kohei Komatsu : "Strength of bolted joints in glued laminated timber of sugi", Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan, pp.103-104, 1989. (Japanese)

4. Shear Performance of Nailed Timber Joints with Steel Side Plates

- a.Kohei Komatsu : "Behaviour of Nailed Timber Joints with Steel Side Plates", Proceedings 2nd Pacific Timber Engineering Conference, Vol.2, pp.89-94, University of Auckland, Auckland, 1989.

5. Performance of Glulam Moment Resisting Joints

- a.Kohei Komatsu : "Performance of Timber Moment-Resisting Joints", Proceedings 2nd Pacific Timber Engineering Conference, Vol.2, pp.25-30, University of Auckland, Auckland, 1989.
- b.Kohei Komatsu, Norio Kawamoto and Noriyuki Kanaya : "Performance of Glulam Moment Resisting Joints - Drift Pin Joint vs Nail Joint -", Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan, pp.99-100, 1989. (Japanese)