ON THE DAMAGE AND CAUTION TO WOODEN HOUSES
BY RECENT EARTHQUAKES IN JAPAN

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SUMMARY

Recent big earthquakes took place in the central vicinity of Japan urged us to reconsider safety of buildings and people under seismic action. Common defects of wooden houses deduced from the investigation of the damaged houses were described in this paper. The author proposes and argues how to harmonize architectural requirements with structural safety in relation with the conventional and contemporary houses in this country.

GENERAL ASPECTS

Wooden houses are regarded as fairly strong against earthquake because of their character of lightweight and lowrise. However, some 7,000 wooden houses collapsed or were seriously damaged by the Off Miyagi-ken Earthquake (M 7.4) in June 1978.While 390 houses were destroyed by the Off Izu-peninsula Earthquake(M 6.8) in May 1974.

Nearly one million houses have been built every recent year in this country. Such an enormous number of buildings can not always be checked completely in spite of the established regulations for building. The author intends to point out the weakness of this construction according to his investigations of the above mentioned damages of the earthquakes.

NECESSITY OF CONTINUOUS FOUNDATION AND ANCHORAGE OF THE BUILDING

Foundation An adequate construction of the foundation of a building can be effective to reduce damage of the upper structure in the case of earthquakes. From this point of view, foundations made of stone or concrete-block are not desirable even for wooden houses, because they loosen during an earthquake as shown in Photo.1. Continuous concrete foundations are apparently useful, among which the reinforced concrete foundation beam is the most preferable.

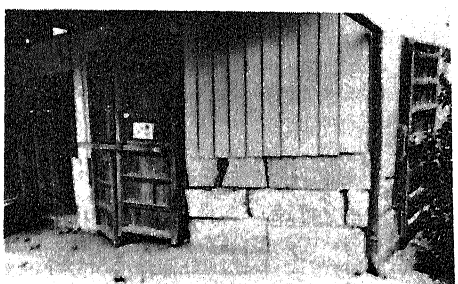

Photo.1 Tree layers of tuffaceous stone was apparently disadvantageous against earthquake.

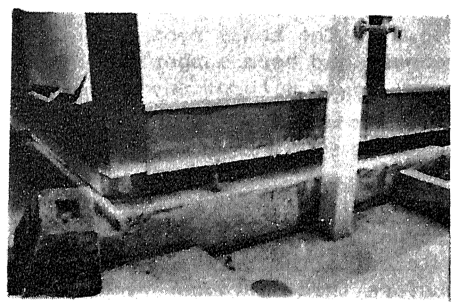

Photo.2 An anchorbolt was not nutted up to the sill due to lack of its projection. The sill lifted up.

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Anchorage It is said that a building having no connection to the foundation resulted good during earthquake because the building only displaced laterally without injury. It does not seem to be practical because its displacement is as large as one meter depending on the intensity of the earthquake.

It should also be noticed that, an anchorbolt has to resist not only against base shear but also turn over of the building caused by the earthquake(Photo.2).

HEAVY ROOF TILES---STATUS SYMBOL VS STRUCTURAL SAFETY

Roof tile is the most preferable material not only for archtectural design but for other performances as well as the status symbol of a conventional Japanese residence. However, the only disadvantage of this material is to make a building at the top, and instable in the case of earthquake as shown in Photo.3. It weighs 2 to 4 times more than other foofing materials, and the center of gravity in a house of tiled roof is estimated 20-25 % higher than that of metal roof.[1] One of the solutions for this conflict is, for instance, to use lighter material such as metal sheet shaped like clay tile.

Stability of the roof tiles during earthquake is closely concerned with the rigidity of the roof trusses, purlins, as well as rafters(Photo.4). To avoid severe vibration of the roof during the event, bracings in vertical and horizontal plane among roof trusses are necessary.

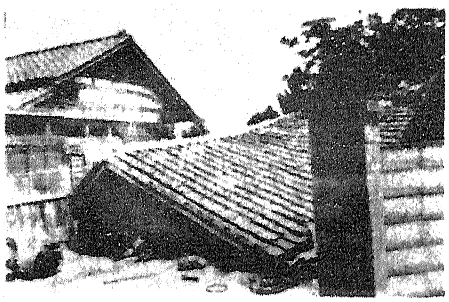

Photo.3 The heavy roof of this warehouse had been supported by several posts without any wall.

Photo.4 Remarkable difference of the damage of roof tiles is caused by the rigidity of the roof structure.

WALL FRAMINGS

Inadequate construction and arrangement of bearing walls The adequate construction and necessary total length of sear bearing walls in a house is regulated in the building code of Japan.[2] Including old buildings, constructed before this contemporary building code was enacted, many inadequate structures can be found even in newly built houses. The main defects of wall framings in terms of struotural design are itemized as follows:

(1) Lack of the necessary shear bearing walls or of the 'in-plane'rigidity of a frame. Especially, the absence of effective structural partitions in a house is apparently disadvantageous for lateral forces.(Photo 5.)

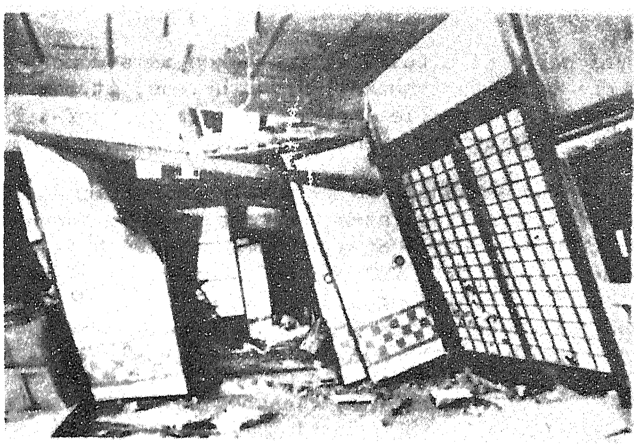

Photo.5. Scarcely any useful wall can be seen inside of this house. Lintels and hangwalls were helpless to avoid large inclination.

Photo.6. Zig-zag crack at the notch of the colmn

(2) An eccentric arrangement of the bearing walls in a building can sometimes twist the building to collapse due to the seismic force. Conventional Japanese houses usually have wider openings on the south side than on the north side.

(3) It seems that the length of a bearing wall as longer it is as better becomes the structure. 91 cm length walls are less reliable than longer walls even if their total lengths are equal.

(4) Insufficient strength of the connection of timber bracings to adjacent members. Often, bracings are pulled out or warped to break by the action of lateral forces.

(5) Even a bracing normally working under compressive forces, should be fastened to its ends so as to endure tensile forces caused by alternative shock to the bracing during an earthquake[(3)]

(6) Knee-braces have the effect of reducing the deformation of frames against lateral forces when they are fastened to the columns and beams. Careful attention should be paid to secure the effect. Columns should have sufficient cross-section against the thrusts from knee-braces.

<u>Traditional construction and contemporary improvements</u> In the case of a Japanese traditional (or conventional) houses, bearing walls are scarce by its nature. Intergration of outdoor and indoor life is a character of the nation. Resisting mechanism of such an instable building is that, posts and deep beams are consisting an imperfect rahmen frames. Adding to this reason, the role of the lower tie among columns (Ashigatame) should be emphasized. To ensure this mechanism, columns should be large enough in cross-section, which can not always be expected in contemporary wooden houses.(Photo. 6.)

BEHAVIOR OF THE NON-STRUCTURAL PARTS

Injuries of non-structural parts of a building are taken as a minor problem for the total damage due to an earthquake. Nevertheless, it may be serious when we consider the danger for people striken by falling roof-tiles as well as hardships in daily life after the event.

As the seismic force applied to an object is generally proportional to its weight, each part of a building receives lateral forces in accordance with its weight. Consequently, heavier parts of a building should be constructed stronger than lighter elements. Injuries of unexpected parts of a building sometimes are caused by behinding the above mentioned principle. Examples which could be seen in the recent earthquakes are the rain-shutter box, the steel balcony(Photo.7), as well as the thick tiled wall introduced in Photo.8.

Since wooden construction is soft compared with other structures, seathings or covering materials such as plywood, fibreboard, gypsumboard, cement sheet, as well as steel sheet may contribute to increase in-plane stiffness of building elements. Non-structural members could consist the sub-structure of the body which assist the main structure when it is firmly connected to the body. This is a benefit for wooden construction, and there is a way to harmonize architectural design with earthquake engineering.

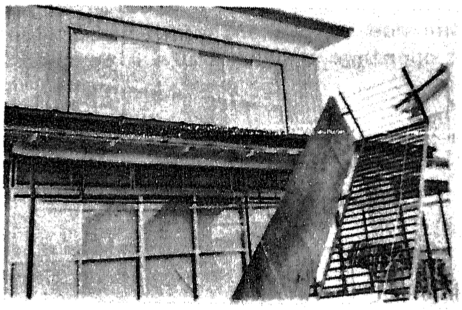

Photo.7. A steel balcony tumbled off the upstairs. It had been screwed only to the wall upstairs.

Photo.8. A tiled wall slipped out due to the poor connection to the sheathing.......

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