EARTHQUAKES AND
TRADITIONAL ASIAN BUILDINGS

John Beynon has had substantial experience in developing disaster resistant buildings, encouraging local architects to provide ideas and skills. Here, he suggests the simple measures that can be taken to improve the earthquake resistance of traditional architecture in Asia — particularly school buildings.

For earthquake resistant design it is traditional Japanese architecture that is often cited as a perfect response, with its light-weight, inter-connected yet flexible wooden structures. For thermal comfort in arid zones, the thick-walled and thick-roofed masonry structures of central Asia are given high marks by the specialists in tropical design. What is less written about is the inherent danger of fire in buildings of wood and paper and of structural collapse in unbonded traditional masonry buildings.

School buildings have a special role in any community as the place where the next generation is shaped. When tragedy strikes it is only natural that communities want to be sure that their children’s lives are safe. This leads to giving a special priority to building school structures that can resist earthquakes. A natural spin-off is that these buildings, with their large rooms, sanitary installations and running water, are easily converted into refuges or field hospitals.

When disaster strikes, countries send out appeals for emergency assistance. While Unesco is neither a relief agency nor a financing agency, it is extremely concerned about the hardships people suffer in these disasters. Unesco’s main contributions are to help with the provision of technical advice on how to avoid future disasters. The materials in this article are drawn from the results of those experiences.

RECIPE FOR DISASTER

The Christian College of the Philippines is a private secondary level institution in the city of San José some 150 kilometres north of Manila. It was created in the late 1960s to provide a low-cost education to some of the poorer children in the area. The owner had constructed the buildings on a limited site and expanded the capacity as funds became available.

Given the land restrictions, the expansion was vertical, beginning with two floors and eventually growing to six. Construction began before the unified building code with anti-seismic measures had been adopted. Costs were kept low which meant outdated building techniques were used. Stop and go building procedures built in structural discontinuities.

The earthquake of 17 July 1990 struck at 5.04 pm, when children were still in school. It reduced this structure to a pile of five concrete floor slabs and the roof resting on top of the ground floor columns which remained intact. In all, 124 children died — it was one of the worst individual tragedies of an earthquake that claimed more than 1,600 lives. The press issued incensed articles. A major inquiry is underway to determine if the fault rests with the owner, the designers or the builders. A technical inspection before the earthquake would have easily detected this “disaster waiting to happen”.

An engineer who visited the 1988 earthquake in Armenia has been quoted as saying “earthquakes don’t kill, buildings do”. In fact, earthquakes are a natural phenomenon that trigger off man-made disasters. It is, consequently, within man’s power to reduce — if not virtually eliminate — fatalities due to earthquakes. Since most school buildings are in the public domain, a ready-made infrastructure of public authorities which can take direct responsibility is already in place.

The twentieth century has brought about a clearer understanding of why earthquakes happen and where they are likely to occur. The well-known Professor Richter has produced a global map showing where shallow earthquakes occur. Active tectonic plates are being carefully mapped and scientists in earthquake affected countries are developing more detailed maps with fault lines and earthquake zones of different intensities.

1. Nepal: In remote areas of Far Western Nepal a school can be from one to seven days’ walk from the nearest road. Materials are usually portered on people’s backs. In these areas there is little choice but to use timber members for earthquake reinforcement. Ring-beams are placed at lintel level. Examples of wood reinforcement can be found in buildings 100 years old.
Thanks to the mass media, citizens are increasingly made aware of the fact that the Richter scale exists to indicate the magnitude of an earthquake. Less well known is the Medredev Sponhever Karnik (MSK) Intensity Scale which describes the types of damage sustained in a local area. Table 1 gives an approximate idea of the interrelation between these two scales.

It should be clarified that the intensity of the earthquake can vary from one locality to the next, depending on soil conditions and other factors. In recent earthquakes in the USSR, USA, Mexico and Philippines, the greatest damage to buildings occurred to those constructed on unstable soils some distance from the quake centres.

To design buildings that can perform well in earthquakes requires an elementary understanding of what earthquakes do to buildings.

An earthquake is basically a wave moving across land. The effects on buildings are usually that the foundations tend to move sideways out from under the buildings and that the ground drops out from under the building. It is fairly easy to imagine how this wave could affect a rigid structure or one that does not have well-bonded joints.

Table 1. Earthquake magnitude and intensity

<table>
<thead>
<tr>
<th>Magnitude (Richter Scale)</th>
<th>Intensity (MSK Scale)</th>
<th>Effect</th>
<th>Felt Radius (Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0 – 4.9</td>
<td>IV – V</td>
<td>Largely observed – Awakening</td>
<td>50</td>
</tr>
<tr>
<td>5.0 – 5.9</td>
<td>VI – VII</td>
<td>Frightening – Buildings damaged</td>
<td>110</td>
</tr>
<tr>
<td>6.0 – 6.9</td>
<td>VII – VIII</td>
<td>Buildings damaged – Some buildings destroyed</td>
<td>200</td>
</tr>
<tr>
<td>7.0 – 7.9</td>
<td>IX – X</td>
<td>General damage of buildings – General destruction of buildings</td>
<td>400</td>
</tr>
<tr>
<td>8.0 – 8.7</td>
<td>XI – XII</td>
<td>General Destruction – Landscape changes</td>
<td>800</td>
</tr>
</tbody>
</table>

(Source: Earthquakes, Don de Nevi, Celestial Arts, Calif., May 1977, p.102)
The solution to compensating for these forces resulting from the acceleration movement generated by the earthquakes is, of course, the application of basic laws of physics. External forces must be compensated by equal and opposite forces coming from the strength of the building itself. Furthermore, as the force is the product of acceleration and mass, it follows that the heavier the upper parts of a structure, the more internal strength will be required.

When dealing with the modest scale buildings relying on traditional materials and skills, there are several crucial elements that need to be achieved.

Vertical tension members need to be introduced bringing forces from the roof rafters down to the foundations.

Buttresses can be used to help push the walls together.

Tension members may be added at grade, lintel and plate levels to tie walls together so that they move in unison.

Thick masonry walls need through elements to ensure that both faces oscillate in unison.

Select internal or external walls may be specially strengthened to prevent the building from shearing apart when the lower part tries to move out from under the upper part.

There is an equally basic list of things not to do:

Don't leave columns unsupported and unbraced. Particularly at the lower levels of a building.

Don't use excessive cantilevers.

Don't count on gravity to keep in place such things as chimneys and parapet walls.

Don't assume the builder always knows best. Supervise to make sure:

- enough cement is used in concrete
- not too much water is used in concrete
- that there are no air pockets in structural elements – particularly where reinforcement rods are close together.
- that mortar is placed in the vertical joints of masonry walls.

These pointers are, of course, intended only as a general guideline for the simplest and most routine situations where small buildings are located on bedrock or well compacted soils. The problems created by fault lines and unstable soils that undergo
liquefaction are so great that only the most sophisticated earthquake engineering can guarantee a building's survival. Imagine designing for these conditions:

Along fault lines the earth comes apart and changes location vertically or horizontally.

When liquefaction occurs the earth acts as a liquid into which heavy objects sink and buoyant objects (such as underground storage tanks) float to the surface.

The easiest solution is to build somewhere else.

**Building details**

Unesco (Bangkok) has published a handbook for use by designers and builders that will enable them to design small one or two storied educational buildings that can resist earthquakes. It also presents earthquake zone maps for countries in the Asia and Pacific region. The suggestions are such that they propose ways to achieve required strength without fundamentally violating the basic design concepts of traditional structures.

The easiest and most elementary advice is to create triangles, the uniquely stable geometric shape, within structures. Securely attached diagonal bracing is the way in which the more functional rectilinear building shapes can be transformed into triangles. Obvious and inexpensive as diagonal bracing is, it is usually missing in traditional structures. Diagonal bracings in bamboo structures may be held in place with lashlings or through inter-locking slots and pegs.

The second point to investigate is that of structural continuity - both vertically and horizontally. Small metal connectors are increasingly available that can be simply introduced between elements of wood.

Steel reinforcement bars protected with

a minimum five centimetres of concrete are a small element easily embedded into thick masonry walls of rubble, stone or brick. Professor Arya makes a number of suggestions on how vertical reinforcement can replace a half brick or part of the random rubble thrown in between facing stones.

Integrating 'ring-beams' into traditional structures is also easily done. Wooden plates can be stiffened and joined longitudinally, most easily by using two planks nailed or dowelled together with offset joints and diagonal corner bracing.

Brick, block or stone masonry can provide its own framework for inserting the required steel and concrete or alternatively an RC beam can replace a course of masonry.

The most challenging situation, perhaps, is where steel is not available and one is obliged to reinforce masonry structures with wooden timbers. This is feasible - indeed long timber segments have been used in the Arabian peninsula to reinforce thick walls of mud and masonry. Professor Arya suggests that timbers be inter-connected to ensure longitudinal continuity and overlapped at the corners to provide bracing.

If existing buildings need to be reinforced and insertion of a ring-beam is not feasible, then the addition of an external buttress or constructing an internal shear wall can provide reinforcement.

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1 BUTTRESSES

External buttresses and shear walls are important parts of earthquake resistant design as they push walls together and help to avoid collapses of walls and roofs.

USE OF BUTTRESS

2 BELTING

Building walls need to be strapped together. Ring beams are best located at floor, lintel and wall plate levels. Any material that has tensile strength can be used.

3 STRUCTURAL CONTINUITY

Designers should imagine what would happen if the building was hung upside down. Anything that would fall off is vulnerable to being displaced in an earthquake. The footings should be tied to the base plate which should be tied to the walls which should be tied to the top plate which should be tied to the rafter. If the various elements have tensile strength, connectors at critical junctions can provide structural continuity. Alternatively steel bars can be embedded into the vertical structure.
4 TRIANGLES

Adding reinforcements that sub-divide structures into a series of triangles, in horizontal and vertical planes alike, is the easiest way to make a building volume rigid.

Without verandah

BRACING OF WOODEN BUILDINGS

The biggest challenge: disasters waiting to happen

Within three weeks after the earthquake of 17 July 1990 the Philippines estimated it would take $56 million to repair the damaged educational structures. This is tragedy enough, but an earthquake of the same intensity could occur anywhere along the Philippine fault that runs the length of the country. China, another country faced with frequent earthquakes, has many schools of sub-standard masonry. The government has undertaken a survey and concluded that up to 45,000,000 square metres of their educational buildings will be unsafe in time of a major earthquake.

The challenge, therefore is much greater than to incorporate earthquake resistance in the new educational buildings. Countries and communities must also get on with the inglorious task of reinforcing existing ones.

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