Structural Conservation

PHILOSOPHICAL RULES OF THUMB

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1) General Guidelines

- There is no one correct way to do earthquake hazard mitigation. The field is wide open for inventive solutions. It is best to first define the objectives, then to devise the physical solution.
- Avoidance of total or partial collapse is a reasonable first objective.
- Modify guideline of "reversibility" to one of "avoid new work which will not allow future intervention." In other words, the objective on new interventions should be to avoid work that will, in the event of future degradation, impede or prevent future restoration of the extant historical construction. (Example: "Gunite" or reinforced concrete directly applied to one side of traditional masonry as a structural upgrade can frustrate later repair work, whereas reinforced concrete used for a discrete new shear wall does not stand in the way of future masonry restoration.
- Design interventions for extended return period on maintenance and repairs, compared to past traditions because maintenance and upkeep in the modern world is likely to be less frequent than in the past.
- Design for moisture intrusion and deterioration reduction should take priority over all other technical objectives, including earthquake reinforcement. (This is not to diminish the importance of earthquake protection, but if decay sets in quickly, all conservation work, and earthquake mitigation work is compromised.)
- Earthquake hazard mitigation is an incremental challenge. Any thoughtfully produced mitigation strategy can help reduce the risk, even if other strategies cannot be undertaken at the same time, unless that strategy increases a load on, or reduces the strength of, an unmitigated element. Earthquakes of different sizes are possible. Even if mitigation against a great earthquake is difficult to achieve, some mitigation will help against smaller ones, and may avoid total destruction in a great earthquake.
- The temple pagoda form has proven to be vulnerable in earthquakes - particularly large earthquakes. In modern society, the chances of a massive post-earthquake reconstruction of the vast number of extant historical monuments as now exist is less likely than in the past - so protective measures of contemporary design utilizing modern materials of steel, concrete and fiberglass are justified. The alternative may be the more likely permanent loss of the historic structures altogether.

- "*Don't fix what is not broken*." The best conservation work honors and retains what has withstood the test of time, and makes changes to mitigate against recurring decay or damage.

2) Specific Conservation and Upgrade Techniques

The introduction of weatherability and fungicidal/biocidal treatments is beneficial to the long-term conservation of the wooden elements. The introduction of strips of copper in areas where water can enter into the wood fabric may be beneficial in reducing the likelihood of the onset of fungal decay. The UMA MAHEWOR temple (1992 restoration) shows some roof leakage at peg locations in the lower roof. Fungal decay has broken out. Examination of these locations will be instructive so as to avoid similar early roof failures. Longevity is achieved if the roof can last at least 20 years without any repair of the underlayment, so long as the tile surface is maintained in an intact condition - and shifted or broken tiles are replaced.

Rohit's observation that the grass has not grown on the palace large pagoda "DEGU TALEJU" roof below the gold clad copper roof is an important one. Perhaps the introduction of (1) copper cladding on the top level roof, and/or (2) copper edge flashing on all roofs, and/or (3) copper flashing under the ridge tiles, will reduce not only the incidence of fugal attack, but also on the growth of grass on the lower roofs.

It may be worth setting up an experiment at the University or some research center - to see what additives could be placed in the mud setting bed to eliminate grass growth. For example, perhaps copper shavings mixed with the mud would provide a long lasting biocide.

Another possible fungus mitigation measure would be to install a series of copper strips as a series of bands covering all of the peg holes prior to the installation of the waterproofing membrane. This would serve two purposes. (1) It would provide a dimensionally stable cover over the holes and board edges that would reduce the possible breakage of the overlying membrane, and (2) it would impregnate any leaking water with copper oxides, and thus reduce the likelihood of fungal attack in the event that leaks occur. (It is fungus which causes wood to rot, not water alone.)

BEAM ENDS IN MASONRY: Wood end grain is most vulnerable to moisture intrusion, and thus decay. Beam-ends buried into masonry are most vulnerable to hidden decay, and their unseen weakening can be harmful to the seismic safety of the structure. A rule of thumb can be to (1) avoid termination of beams in masonry wherever possible by extending the beams all the way through the wall, or (2) installing a copper "shoe" over the beam ends sufficient to cover the end grain. In all cases, avoid physical contact between the wood end-grain and the masonry. Allow an air space between timber ends and the masonry. The copper should be in contact with the end grain.

TIMBER COLUMN BASES: In the case of columns, an air space is not possible. Solutions can be the following - and experiments may be made to see what works best long term. (1) Install a cross grain block at the foot of each column where it rests on masonry. This block will avoid end grain contact with masonry, and also provide a sacrificial element that can be easily replaced if it is decayed without damaging the column. (2) Cut a black rubber piece the size of the column - say from an old tire - and place it under the column where it rests on the masonry. (3) Cut a piece of copper and place it under the column. (The copper may be best done in combo with the rubber. Install the copper in contact with the wood, and the rubber in contact with the stone.)

3) Seismic Retrofit Measures

55 WINDOWS PALACE ISSUE: On the conflict over the concrete diaphragm that is already planned, if you encounter a similarly insoluble conflict again, there is a wood based alternative. Utilizing the "Special Procedures" of the USA <u>Uniform Code for Building Conservation</u>, you could install an engineered wood diaphragm which might avoid a conflict such as has been experienced. In the case of 55 Windows, so long as the bond breaker is installed beneath it as described below, it is possible that concrete can be a better replacement for the mud than nailed plywood because it avoids the nail holes into existing timbers, but this methodology does allow you to broaden the debate. In general, with wood floors it may provide a better alternative to the installation of a stiff concrete diaphragm.

If concrete is used, it is important to install a new layer of some other material as a pouring surface - with a bond breaker between the concrete and the protected original sub floor. This layer will help to protect the historic timbers from condensation from the differential temperature in the concrete, and can allow for the future removal of all or a portion of the concrete should it later be necessary or desired.

If plywood is used in any structure for structural strengthening, pressure treated plywood should be used to avoid attack by termites. I have seen evidence that termites in California particularly like plywood, and will eat it out from between other more resistant cut timbers.

WOODEN TEMPLES:

(1) The Bernard Feilden approach of using stainless stranded cable tucked into mortar joints with stainless steel plates and clamps on the corners may provide an excellent barrel-hoop strengthening of the brick shafts and columns. The corner plates would be visible (unless in the attic area), but the cable would not be visible.

(2) Some temples may have such a narrow base, and tall height as to be more vulnerable to flexural failure (tipping over), than shear failure (collapse of the lower walls). If this is the case, the seismic retrofit response will need to be different. Lowering the center of gravity by lightening the top may be necessary in such cases.

(3) The walls are so thick and diaphragms are so small that diaphragm strengthening in the temples may not be particularly important.

(4) The structural upgrade measures already taken that we have been shown all appear to be beneficial. These include the anchoring of the brackets, the strapping of the roof timbers, the bolting of the roof timbers to the roof plates, the steel straps holding the terra cotta corner ornaments, etc. These measures also are valuable in reducing the rate of damage from ordinary time and use, not just earthquakes.

(5) The installation of the redundant interior frame appears to provide added life safety to the PATUKVA AGACHE Temple. One element of caution in the design of an added frame is the following: The installation of a timber frame must avoid any possibility, either by jacking during installation, or from subsequent differential settlement, that the weight of the upper story masonry is transferred onto the timber frame and off of the underlying masonry wall. If this happens, vulnerability could be increased. A significant component of seismic resistively is the action of the overburden weight of masonry. If this disappears during an earthquake, an underlying masonry wall could fall out, then leading to the collapse of the structure. Installation of secondary timber frames can be efficacious if used in the manner of a "strong back." The original masonry must continue to function structurally as a continuous masonry bearing wall. (It is my understanding that the Patukua Agache Temple design has not interfered with the bearing of the masonry.)