Sustainable Structural Systems

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What are sustainable structures? The answer, as with sustainable development, is that no new structure is sustainable in every sense. The question that should be posed is that of whether or not the impact of creating the structure leads to an unsustainable result in terms of Environment, Society or Economy. In the past the measure of sustainability has been in the narrow field of economic sustainability. In the modern world, sustainable structural systems may be defined by structures that are designed and maintained to minimize risks threatening their sustainability and that of the broader world in terms of all three considerations.

The approach to increasing sustainability can be conveniently addressed in terms of the four "R's"; Reduce, Refurbish, Reuse, Recycle.

Reduction is the key to any consideration of sustainability. In terms of structural sustainable systems it means building less and using less material with less impact. In sustainable systems it is often measured in terms of reduced cost energy and environmental impact. Energy efficiency is of course one of the most important aspect to achieve sustainability.

The option for Refurbishment should be considered before development; can an existing structure be brought up to an enhanced standard without extensive new building? If development proceeds the structure should have sufficient space and flexibility of layout to be used differently in the future.

Reuse refers to the ability to take parts of the structure and employ them elsewhere. A sustainable structure can be made to enable it to be dismantled with the elements taken to be re-used on other structures.

Recycling is the least desirable outcome; it refers to taking elements of the structure and turning them into other products. This requires the most input of energy of the four "R's" but should be kept in mind for both the whole life to the structure and for the materials used in creating the new structure.

There are measurable risks in terms of physical, social, economical and environmental issues. For example, if a structure is strictly designed to be used as an office building, it would be costly in economic and energy terms if we need to convert the building into, say, a condominium. Thus there is a risk of unsustainability in social terms. Regarding earthquake hazards, if a structure is not well designed to survive against an extremely large earthquake, sustainability with respect to the safety will not be satisfied and the resulting destruction is costly in economic and social terms. In addition, the survivability of surrounding environments against such hazards should be also considered.

Managing the risks is categorized into two, risk mitigation and risk hedge. They are fundamental strategies to deal with any risks. Technologies to support earthquake resistant design such as dampers and durable structural framings are practical solution to mitigate the risks against earthquake hazards. They can lead to structures that are more efficient in materials and also survive to be used without the need for new development. Flexible structural systems may reduce the costs for converting a structure for other purposes, thus reducing the social risk. The design philosophy called "damage control" can be a fundamental tool to control numerous risks associated with physical damage.

However, in order to select an optimized approach, we need quantified information on the risks. By understanding all the risks relevant to sustainability, we are then able to take the best approach.

Quantification requires monitoring the risks and to stock them as a database to derive the stochastic models of the risks. A structural health monitoring system that monitors structural health of a building may be one of the solutions to gather stochastic and quantified physical data online. The system works as sensors, nerves and brains. Some of the risks are similar to human diseases. Accumulating the symptoms and relevant remedies for diseases are the doctors' most important role. We need systematic approaches to deal with this aspect.

Finally, we can not forget financial approach. The natural hazard risk for Tokyo is the largest in the world among mega-cities. The amount of the risk is much larger than the capacity of all the insurance companies. Thus, the most of the hazard risk of Tokyo is not hedged at present. We need to develop new and sophisticated financial technologies to overcome this fact in addition to technologies that mitigate the risks.