Japan Academy Prize to:

Nobuo Shuto
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for “Comprehensive Research on Tsunami Hazard Mitigation”

Outline of the work:

Tsunamis are induced by earthquakes, volcanic eruptions, or coastal submarine or subaerial landslides. Among these, underwater earthquakes are the primary cause of major tsunami events. Because several major tsunamis have occurred recently, the topic of tsunami hazard is of great concern to us.

Since the 1960 Chile Earthquake and Tsunami, Dr. Nobuo Shuto has devoted himself to tsunami research, including creation of the field “Tsunami Engineering.” His research is well recognized both nationally and internationally, and he has contributed to tsunami hazard mitigation and reduction for many communities.

Dr. Shuto’s research can be classified into two categories. First, his development methodologies used to predict tsunami characteristics and behaviors in the near-shore environment where human activity is directly affected. Second, his quantification of tsunami damage.

In the rebuilding from the 2011 Tohoku Earthquake and Tsunami, a combination of these two research categories is being utilized to guide the optimal siting of residential zones as well as the structural requirements for residential buildings.

1. Establishment of Tsunami Numerical Method

1.1 Identification of Tsunami Characteristics

Tsunamis are long waves, with wavelengths much longer than the water depth. Even if wave amplitude were 10m high in deep water, the wave height can be considered small in comparison to its wavelength and the water depth. Therefore, linearized water-wave theory is appropriate for the tsunami modeling. However, wave height increases as tsunamis advance into shallow water, so now nonlinear water-wave theory should be applied in the shallow water. Furthermore, the nonlinear dispersive wave theory should be used to model a tsunami when its leading wave takes the form of undular bore (i.e., a series of shorter waves with the period of approximately 10s riding on a long heave of a tsunami).

Observing the 1983 Nihon-Kai Chubu Earthquake and Tsunami, Dr. Shuto recognized that the appropriate theory used to model tsunamis depends on a tsunami’s evolutionary behavior. The 1983 tsunami event exhibited the formation of undular bores when advancing into the rivers, and even in the open coastal sea.

1.2 Controlling Errors Associated with the Numerical Computation

Most numerical algorithms involve the discretization in space and time. Accuracy depends on the size of the discretized grid; the finer the grid size, the smoother the solution will be. Nevertheless, the discretized finite differences produce the accumulation of truncation error. As a result, the numerical computation could result in unreasonably flat wave profiles when an inadequately coarse grid size is used.

To examine the truncation error, the numerical results are often compared with the analytical counterpart.

However, because tsunami runup motion is highly nonlinear, the analytical approach is complex. By carefully examining the basic water-wave formulation, Dr. Shuto derived a simplified analytical solution. Based on his solution, he developed the criteria to achieve improvement in computational accuracy. Specifically, he developed the criteria for the spatial grid size to circumvent unwanted numerical dispersion so that a tsunami would maintain its waveform in a constant water depth: namely, *there must be at least 20, possibly 30, spatial grid points to cover one tsunami wavelength.* In addition, Dr. Shuto established the criteria to control numerical instability for simulations of a tsunami's dry-land runup.

All of these criteria for numerical computations developed by Dr. Shuto are now widely used, not only in Japan, but also around the world.

1.3 International Contribution

During 1990's, Japan and Morocco made a joint proposal that was unanimously approved by the Member States of the United Nations and proclaimed the International Decade for Natural Disaster Reduction (IDNDR). As one of the cooperative projects, the International Union of Geodesy and Geophysics (IUGG) and the UN UNESCO Intergovernmental Oceanographic Commission (IOC) formed a partnership to develop a methodology to produce tsunami inundation maps; this project is called TIME (Tsunami Inundation Modeling Exchange). Dr. Shuto led this project, making the numerical model of Tohoku University accessible without fees. Soon, his numerical model became the standard for UNESCO/IOC, and was transferred to 24 countries and 52 organizations, including the United States, Korea, Turkey, and Mexico. This model-share program has three basic conditions. First, participants must be a nonprofit organization. Second, the TIME project must be acknowledged in publications. And third, any problems arising in the modeling must be reported to Tohoku University. The last condition is intended to assure credibility in the computational results and also to share the technical expertise of Tohoku University.

In recognition for his research and other activities that span more than 30 years, Dr. Shuto received the International Coastal Engineering Award from the American Society of Civil Engineers in September 1996, and the 14th Japan Water Prize/International Contribution in July 2012.

2. Quantitative Measure for Tsunami Strength

To express the significance of tsunamis, we often use the scale commonly referred to as "tsunami magnitude". But this parameter represents the total energy of a tsunami event as a whole. Tsunami effects, however, depend on local conditions. The idea of expressing a tsunami's local effects was not new, but descriptions had been mostly qualitative; for example, "the tsunami strength was at such a level, because the boats offshore were washed away".

Dr. Shuto systematically studied historical data and information, correlating tsunami damage with inundation depths. Such damage included buildings, ships, and aquaculture rafts, as well as the effects and limitations of coastal forests, and the extraordinary sound generation due to tsunamis near the shore.

For example, Level-1 Tsunami Strength, which is equivalent to a tsunami height of 2m, induces total destruction of wood-frame buildings. This tsunami strength level is the basis for issuing building permits in residential development lands in the areas affected by the 2011 Tohoku Earthquake and Tsunami: building permits are currently issued to cases where the predicted tsunami inundation depth is less than 2m.

As described above, Dr. Shuto has made tremendous contributions to quantitative modeling of tsunamis in coastal waters and lands. His leadership in working to categorize local tsunami strengths has set the direction for tsunami hazard mitigation and reduction practice. Dr. Shuto has continually played a leading role in planning national and international communities for tsunamis, and his contributions to tsunami science and hazard mitigation are truly invaluable.

List of Publications

I-1. Basic Theory

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