

Development on Integrated Numerical Research System for Prevention and Estimation of Coastal Disaster

Hidenori Shibaki¹, Jong-In Kim², Hiroyuki Iwase¹, and Nobuhiko Hara¹

1. INTRODUCTION

Severe environmental conditions persist along the coast of Japan with huge waves, storm surges and tsunamis. Oceanographical disasters are occurring every year around the coastal and estuarine areas of Japan. In September 1959, an abnormal high storm surge caused a coastal disaster with flooding over a large area around the Ise Bay, which is located in the center of Japan, and with the loss of more than 5,000 lives. This storm surge was generated by the Typhoon number 5915 (named Isewan Typhoon). In May 1960, the Chilian earthquake tsunami caused a coastal disaster with an inundation of large coastal areas facing the Pacific Ocean. Against these coastal disasters, the research on prevention of coastal disaster is actively conducted, and many coastal structures have been planned and built for disaster mitigation. Hard countermeasures, like the construction of various structures as coastal dikes, seawalls and breakwaters, are effective to reduce the damage up to the level of disasters to which the structures were designed. However, the hard countermeasures have a limitation in their disaster prevention capacity against disasters over the design level. To remedy the deficiency of hard ones, soft countermeasures, which mean a provision of the information on the disaster mitigation and evacuation methods, are promoted. The soft countermeasures can be more useful for disaster mitigation than the hard ones, depending on the situation.

To determine design conditions and to prepare disaster-related information, the characteristics of

disaster phenomena must be clarified with scientific methods. The INSPECT (Integrated Numerical research System for Prevention and Estimation of Coastal disaster) system has been developed for coastal protection works composed of hard and soft countermeasures.

2. OUTLINE OF INSPECT SYSTEM

The INSPECT system consists of three numerical simulation models (Wave, Storm Surge and Tsunami models), their supporting sub-systems and supporting databases. Fig. 1 shows the composition and functions of the system. Several systems, supporting sub-systems and databases are utilized for such analyses.

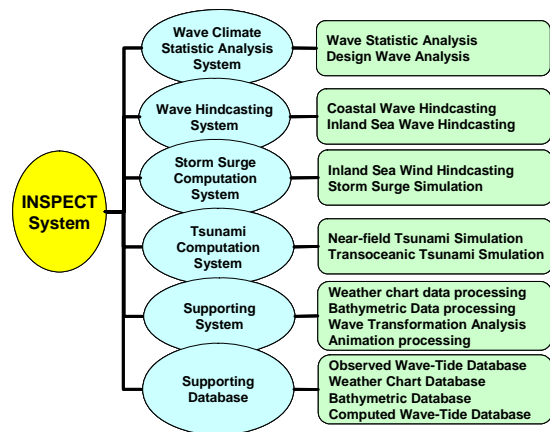


Fig. 1. Composition and functions of the INSPECT system

¹Environmental and Hydraulic Engineering Department, ECOH CORPORATION, Tokyo 110-0014, Japan

²Hydro-Environment Research Institute, GeoSystem Research Corporation, Goonpo 435-824, Korea

3. NUMERICAL SIMULATION MODEL

3.1. Wave Hindcasting Model

The INSPECT wave model is a shallow-water wave hindcasting model, based on spectral calculations, incorporating wave generation, wave decay and wave transformation. The model is able to simulate wave fields composed of wind waves and swells. The governing equation of wave hindcasting is the energy balance equation.

Fig. 2 shows the spatial variation of wave height close to coastline. The processes of wave refraction, wave diffraction and wave shoaling outside the surf zone, and wave decay by wave breaking inside the surf zone, are taken into account.

3.2. Storm Surge Model

The INSPECT storm surge model gives an accurate tide anomaly by incorporating several effects such as multi-level flows, density stratification, wave setup, river discharge and inundation. The magnitude of wave setup can be calculated from the divergence of the radiation stresses. The results of wave hindcasting with a shallow-water wave model are used for the calculation of the radiation stresses. The radiation stresses for each layer are utilized the formulas by Longuet-Higgins and Stewart (1964). The basic equations of storm surge model are the multi-level continuity and momentum equations integrated for each layer. In the momentum equations, the shear stresses (wind stress at the sea surface, inner stress between two layers and bottom shear stress), the pressure gradients (atmospheric pressure, water level and water density) and the divergence of the radiation stresses are taken into consideration. More details about basic equations of simulation model are explained in Shibaki and Watanabe (2002).

Fig. 3 shows that the maximum tide level deviations in Kochi Port calculated with the effect of inundation upon attack of a T7010-class typhoon. The change of tide level deviation due to the effect of inundation is about -0.3 m in an inner bay.

3.3. Tsunami Model

The INSPECT tsunami model gives an accurate estimate of wave height and velocity by incorporating several effects such as nonlinear wave dispersion, wave breaking and bottom friction estimated with land conditions.

Fig. 4 shows the tsunami propagation computed by the nonlinear dispersive equation model (Iwase

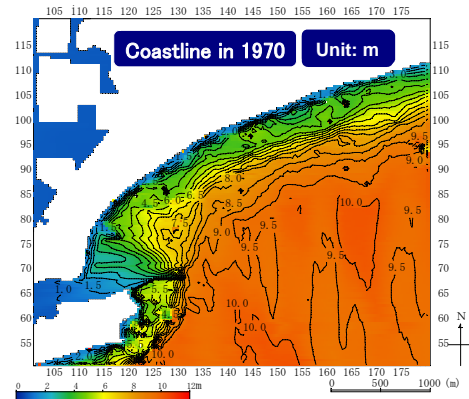


Fig. 2. Spatial variation of maximum significant wave height upon the attack of Typhoon 7010 around the coastlines of Kochi Port

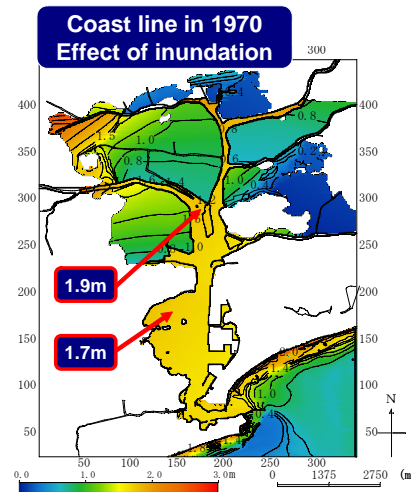


Fig. 3. The maximum deviations of tide level in Kochi Port calculated with the effect of inundation upon attack of a T7010-class typhoon

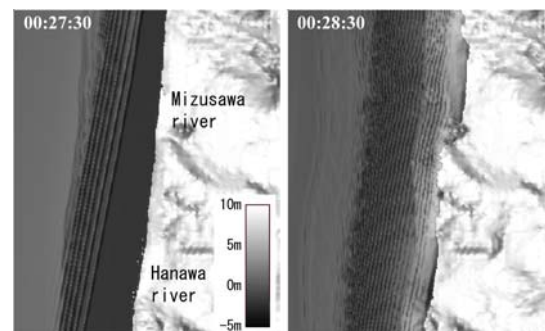


Fig. 4. Tsunami propagation computed by the nonlinear dispersive equation model on the north Akita coast

and Imamura, 2003). The process of generation of soliton fission waves at the point of depth of about 8 m by the leading wave of the 1983 Nihonkai-Chubu earthquake tsunami and the breaking of these waves at the depth from 6 to 4 m is presented in the diagrams. This tsunami simulation has been applied with the Aida fault model (1984) as the initial condition and yielded the results more accurate and stable than the previous shallow water equation models.

4. DATABASES AND APPLICATIONS

4.1. Databases

The INSPECT system includes several databases for numerical simulation on coastal disasters. Fig. 4 shows a three-dimensional view of the sea bottom topography around Japan and land topography of

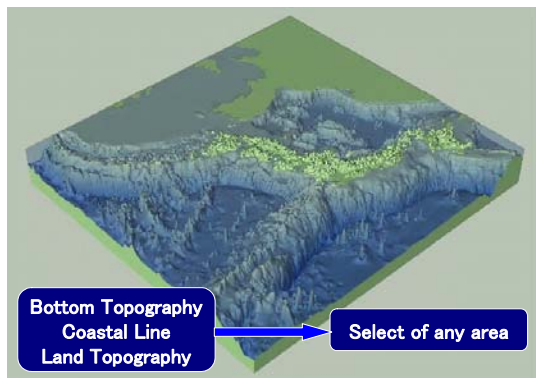


Fig. 4. Three-dimensional view of sea bottom topography around Japan and land topography of Japan



Fig. 5. Three-dimensional view of topography and buildings

Japan. The data around the target area are selected from a topographic database before the performance of numerical simulations in the specific areas.

Fig. 5 shows a three-dimensional view of the topography of and buildings in an area selected for numerical simulation of the inundation. This diagram is made by using GIS data about the information of buildings.

4.2. Applications

Fig. 6 shows a two-dimensional tsunami hazard map with the information of tsunami inundation height, topography, buildings, and routes at urban area. The tsunami inundation heights were calculated by numerical simulation for the purpose of tsunami evacuation planning. Similar maps have been prepared at several tsunami hazard areas in Japan.

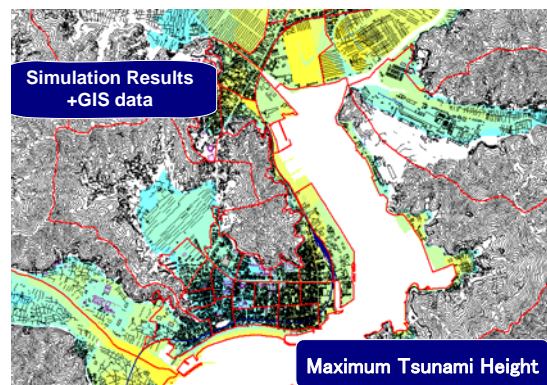


Fig. 6. Two-dimensional tsunami hazard map informed with tsunami inundation height, topography, buildings, and routes at urban area

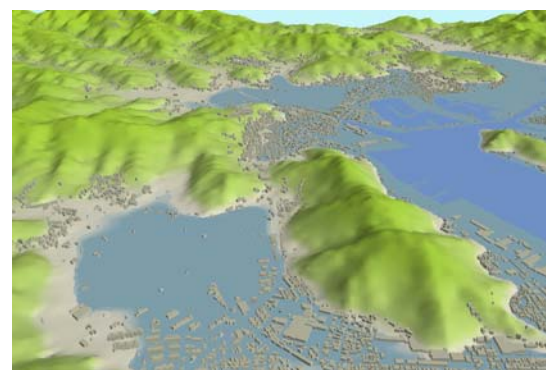


Fig. 7. Three-dimensional view of topography and buildings together with simulated inundation field

Fig. 7 shows three-dimensional view of topography and buildings together with the simulated inundation field. Such an application of numerical tsunami simulation helps citizens to understand clearly the tsunami damage and provides the useful information about the hazardous areas.

5. CONCLUSION

The INSPECT (Integrated Numerical research System for Prevention and Estimation of Coastal disasters) system has been developed for coastal protection works composed of hard and soft countermeasures. The INSPECT system is employed to efficiently perform studies for preventing disasters on Japanese coasts due to waves, storm surges, and tsunamis. The system continues to be upgraded and to be extended for numerical studies of all coastal and estuarine areas of Japan.

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REFERENCES

- Aida, I., 1984. A source model of the tsunami accompanying the 1983 Nihonkai-Chubu Earthquake, *Bull. Eartheq. Res. Inst.*, Vol.59, 235-265.
- Iwase, H. and F. Imamura., 2003. A new tsunami numerical simulation with Boussinesq-type equations applied for the 1983 Nihonkai-Chubu Earthquake Tsunami, *Proc. of the 2nd Int. Conf. Asian and Pacific Coasts 2003*, 12-13.
- Longuet-Higgins, M.S. and R.W. Stewart., 1964. Radiation stresses in water waves: A physical discussion with applications, *Deep-Sea Res.*, Vol.11, 529-562.
- Shibaki, H. and A. Watanabe., 2002. Study of multi-level simulation model for storm surge considering density stratification and wave setup, *J. Hydraulics, Coastal and Envir. Eng.*, JSCE, No.719/II-61, 47-66 (in Japanese).