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Development and verification of wall-flap-gate as tsunami inundation defence for nuclear plants

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ABSTRACT

A wall-flap-gate is automatic watertight door, and it works by buoyancy without powered machineries and human operations. In the Tohoku Earthquake tsunamis, serious damages were caused by inundation from ventilators of outer walls in power plants. The wall-flap-gate is estimated to be effective in keeping sustainability of nuclear plants against extreme tsunamis. The present study examines the hydrodynamic characteristics of the wall-flap-gate by hydraulic model experiments and verifies its capability of flood prevention for nuclear plants through various prototype tests.

The experimental results proved that the wall-flap-gate had sufficient strength, watertightness, and durability against tsunamis and that its motion was not disturbed by debris. The viability of the wall-flap-gate as an inundation defence structure for nuclear plants was confirmed through this study. As a result, practical wall-flap-gates are installing on Hamaoka nuclear power station in Shizuoka prefecture, Japan.

1. Introduction

A flap-gate type seawall, which usually lies down on ground surface, rises up by buoyancy due to tsunamis, surges, or flooding. It remains lying flat in usual conditions not to disturb traffic. In an emergence time, the flap-gate type seawall protects a target area from inundation without powered machineries and human operation. The seawall is called NEORISE (No Energy and no Operation RIsing Seawall, see Kimura et al., 2015).

In the Tohoku Earthquake tsunamis on March 11, 2011, serious damages were caused by inundation from ventilators of outer walls in power plants. For sustainability of nuclear plants against unexpected huge tsunamis, damages due to water leak from these ventilators must be prevented. Especially in Hamaoka nuclear power station, various measures in order to enhance functions and to guarantee a power supply in emergency including earthquakes and tsunamis are implemented (Yasuda et al., 2015). The present study develops an automatically closing gate attached to the outer wall (called wall-flap-gate, hereafter) by improving the previous NEORISE, and verifies its capability of preventing inundation for the nuclear power station.

This study carries out hydraulic model experiments and demonstration tests using a prototype wall-flap-gate. Data of tsunami forces for the structure design are collected through the model experiments. Strength and watertightness against water pressure, durability for repetitious motions, and influence of debris are examined through the prototype tests.

2. NEORISE

The NEORISE is expected to be implemental as part of a lock gate installation in gaps in inundation defence. Although a normal lock gate as a slide-type gate requires powered machinery and control system, the NEORISE requires neither since it is moved by buoyancy of the inundation water. The NEORISE consists of a gate serving as a float, side-walls and tension-rods, as shown in Fig. 1. A counterweight is equipped inside each side-wall and it is hung by a wire rope connected with pins, inserted grooves in the side-walls, through a pulley. These pins are set on both sides of the top. The counterweight assists the lying gate in rising up and it also brakes the moving gate before upright by turning

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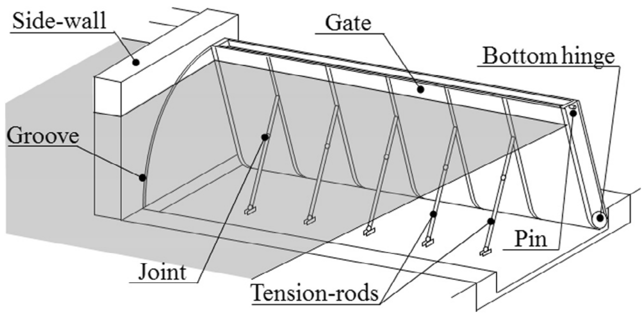

Fig. 1. Equipment for NEORISE.

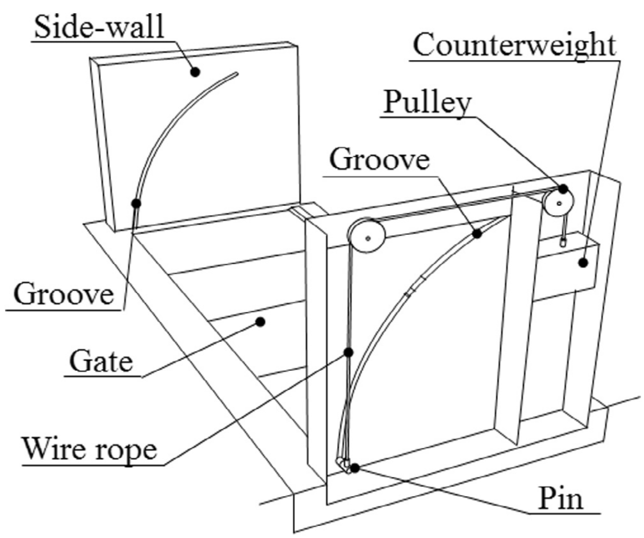

Fig. 2. Arrangement of counterweight.

direction of force by the counterweight according to an angle of the gate, as shown in Fig. 2.

The gate is formed from a hollow stainless steel box. The upper face of the NEORISE can be installed at the same level of the land surface; therefore, it does not prevent vehicles from passing over it. The hollow box is designed to support the weight of passing traffic whose wheel load is within 1 MPa. Hydraulic experiments have confirmed that the NEORISE can rise up correctly even when its upper surface matches the level of the surrounding ground. Fig. 3 shows a response of the NEORISE against tsunami flow running up the ground. These figures proved the reliability of the gate behavior against tsunamis (Kimura and Mase, 2014).

Water pressure acting on the upright gate is supported by both tension-rods and bottom hinges. The tension-rod has a joint between upper and lower connecting points, and it is folded below the gate when in its horizontal position. In order to prevent the leakage of water, rubber tubes are installed between the gate and side-walls and rubber sheet is covered on the bottom hinge. Each rubber materials are continuous at both sides of the bottom hinge.

3. Wall-flap-gate

The wall-flap-gate was developed to restrain water leak from ventilators on outer walls by improving the previous NEORISE.

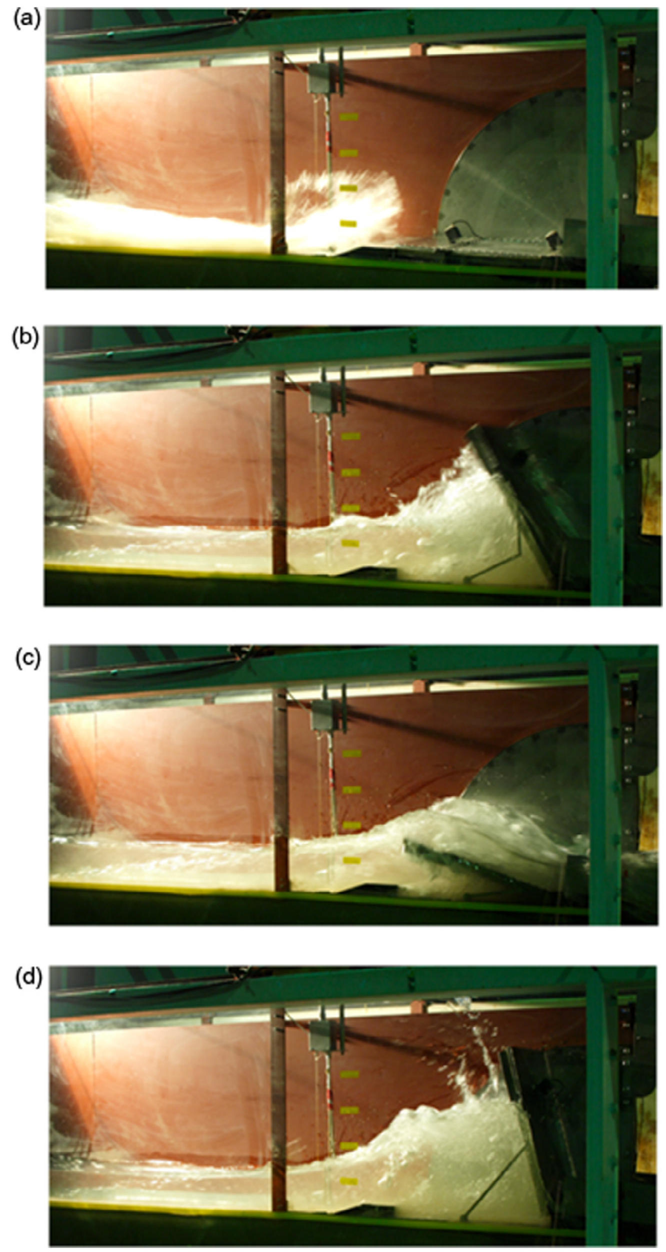

Fig. 3. Response of NEORISE against running up tsunami.

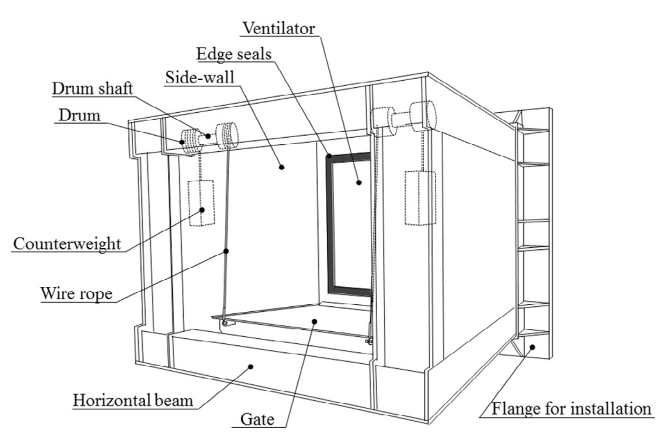

Fig. 4. Equipment for wall-flap-gate.