Collapse Risk Assessment of Strengthened Concrete Bridge Pier under Flood Loads

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A FLUID STRUCTURE INTERACTION USING PARTICLE FINITE ELEMENT METHOD FOR THE FULL SCALE REINFORCED CONCRETE BRIDGE IS BUILT TO SIMULATE THE DEFORMATIONS OF BRIDGE PIERS UNDER FLOOD LOADS. THE CRITICAL PIER WILL THEN BE TESTED USING 6-DEGREE OF FREEDOM SYSTEM, FROM WHICH THE FINITE ELEMENT MODEL OF BRIDGE MODEL WILL BE CALIBRATED. FRAGILITY ASSESSMENT OF BRIDGE PIER BEFORE AND AFTER STRENGTHENING WILL BE PERFORMED TO STUDY THE EFFECTIVENESS OF STRENGTHENING FOR ENHANCING THE RESILIENCE OF BRIDGES UNDER FLOOD LOADS.

Waves and Tsunami forces – Coastal bridges

The forces on coastal bridges are classified into three main types, hydrodynamic or slowly varying forces, impact or impulse-type forces and hydrostatic forces. The hydrodynamic forces, which are initiated by the wave action on bridge deck, include the uplift, downward, drag and moment. In general, the wave vertical uplift force is higher than horizontal forces. The literature shows that vertical forces can be up to 20 times the horizontal forces. This is attributed to the fact that the coastal bridge width is usually much larger than the wave height. The impact or impulse-type forces are also termed 107 slamming forces. The main two causes of the impact forces are the air entrapment and the transfer of momentum between the water and structure once the waves impinge on the deck. The hydrostatic forces are mainly in the form of buoyant forces resulting from the submergence of deck and air entrapment between girders. Inertia forces are initiated by the structure resistance to change in velocity, and their effect is usually prominent when the structure has a flexible movement in the direction of the wave force. Wave height has been reported among the most influential factors in design, retrofit and vulnerability assessment of coastal bridges.

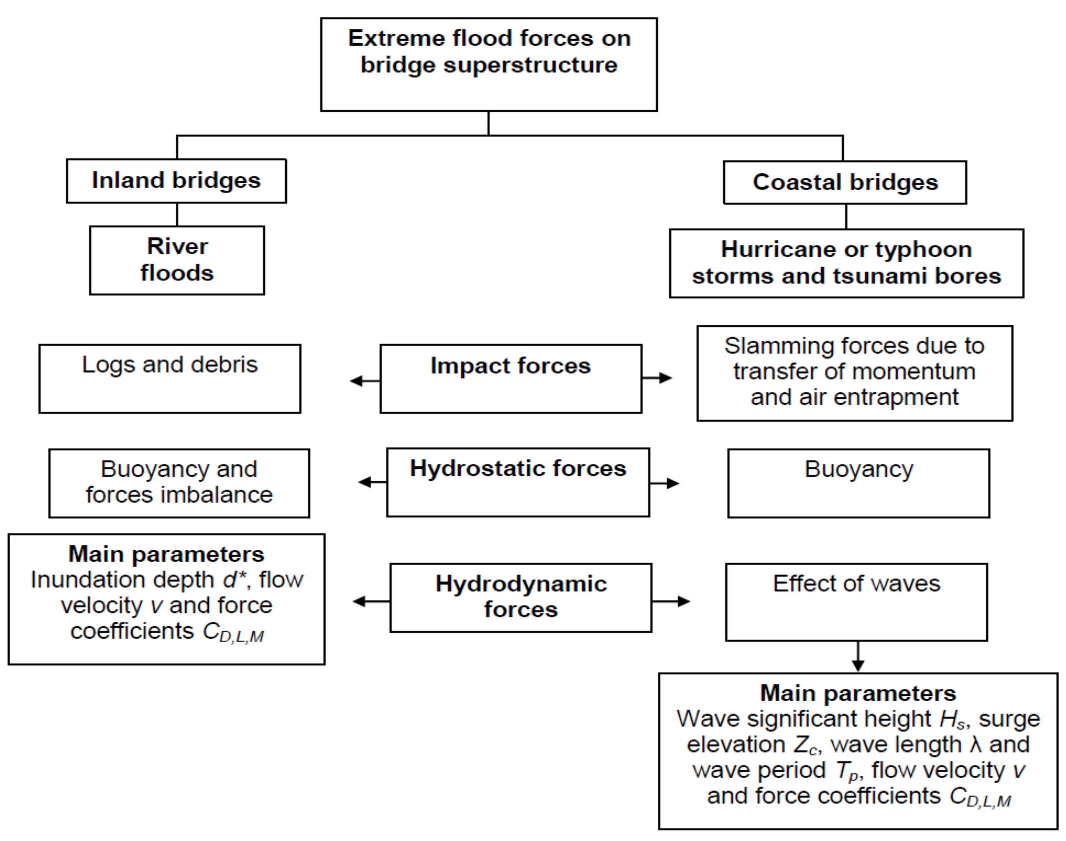

Figure 1: Classification of main forces on bridges and their main parameters

River floods forces – Inland bridges

In surging free surface, drag and lift forces are the resultant of shear and normal stresses at the fluid-structure interface, respectively. The pressure distribution of the flow also contributes to the magnitude of the drag forces. As the drag and lift forces act on the bridge, a moment is initiated along the centreline of the superstructure.

More published data for hydrodynamic forces can be found in literature compared to other types of forces. The hydrodynamic forces depend mainly on the flow velocity, inundation depth and bridge shape. The methods used to evaluate the drag and lift forces are based on the fundamental theories for a flow over an immersed plate. It should be mentioned that lift forces can act in any direction, although they are usually shown as upward forces. The hydrodynamic forces can be obtained for a stream flow using the depth of flow, stream velocity and force dimensionless coefficient. The dimensionless coefficients depend mainly on the shape and geometry of bridge.

Research Method

Phase 1 (Bridge-flood interaction)

Particle Finite Element Method (PFEM) is employed to simulate the bridge-flood interaction using OpenSees software. In many bridges, strong connections between the super- and sub-structures transfer the forces from the decks to the piers, resulting in more complex failure modes. The presented PFEM captures the significant pier deformations at different inundation levels.

Phase 2 (Multi-axial testing)

A hybrid simulation facility that is capable of applying 6-degree of freedom movements is used in this stage. The pier design details are shown in Figure 2.

Research Method (Cont'd)

The column is connected to a concrete pedestal from top through four 16 mm diameter dowel bars to represent the connection in the real bridge. The full numerical model of bridge is coupled with OpenFresco and xPC-Target as a link between the bridge model and experiment. High soil friction around the foundation of pier is assumed, and hence the pier base is assumed to be fixed to the bottom concrete pedestal. The FRP wrap is applied at the zones that will show inelastic behavior (failure), and the specimen will be tested again.

Phase 3 (Strengthening and Fragility analysis)

A simplified fragility analysis is conducted based on a single degree of freedom model. The response of the column is used to calibrate numerical model. A single degree of freedom model of the pier is built to remove the effect of other bridge elements. In order to capture the combination of flexure, shear and axial collapse, a unidirectional model is used. The unidirectional model is calibrated from the hysteresis parameters of Ibarra-Medina-Krawinkler model, at plastic and post capping displacement, which have major contribution to the collapse of the member.

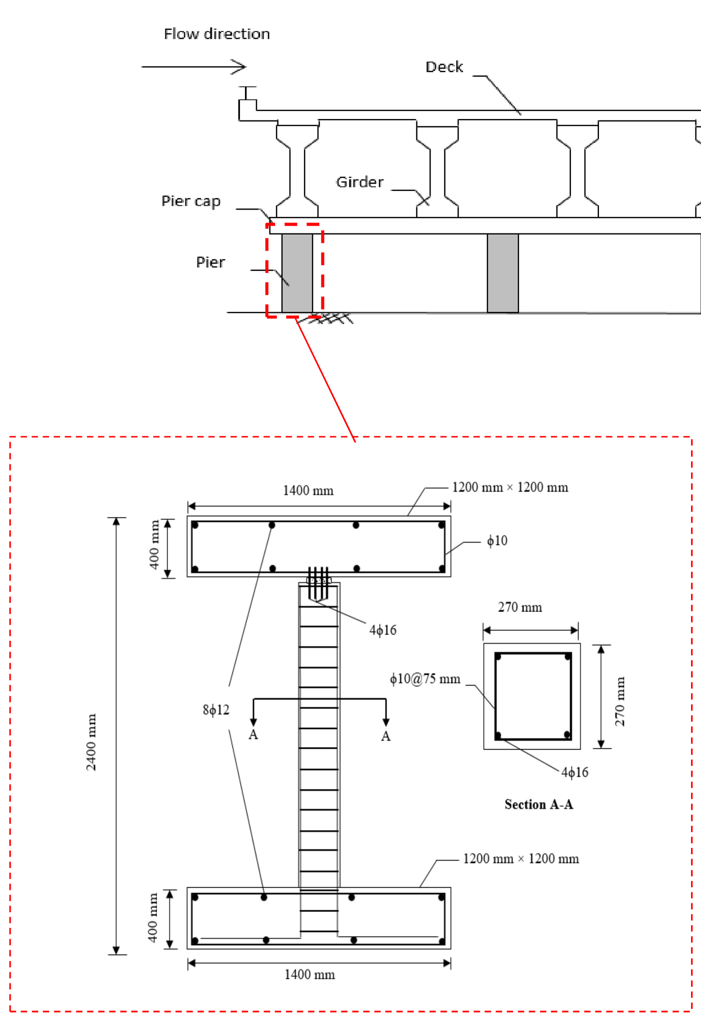

Figure 2: Details of bridge pier

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