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Application of Gravity Base Structure Technology to Bridge Substructures

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Summary

In Japan there is ongoing preliminary design on several ultra-long span bridges for strait crossings in deep open waters. This paper mainly discusses the performance of the proposed substructure subject to earthquake effects for these bridge projects.

1. GBS Technology for bridge foundation

The large offshore concrete structures, so called GBS (Gravity Base Structures), have successfully been applied to the oil and gas developments in the North Sea for the last 25 years. Later also in Canada and Australia. Through these experiences the typical features of GBS technology are characterised as follows.

① Construction completely in dry dock or on land and afloat inshore
② Installation in deep open water on the seabed without any preparation prior to installation
③ Applicability to various soil condition from hard to soft by utilising skirt foundation
④ Utilisation of cell and shaft structures with durable high strength concrete

Although previous GBS has been installed in waters without significant seismic action, the concept of the GBS is found applicable to a bridge foundation in a highly seismic area.

① The typical structural configuration of existing GBS consists of shafts above cells, as shown in Fig.1, which minimise the hydro-dynamic force and the overburden pressure on subsoil because of reduction in displacement and selfweight.

② The skirt foundation frequently employed in concrete GBS is also applicable to bridge substructures installed on a thick sedimentary soil.

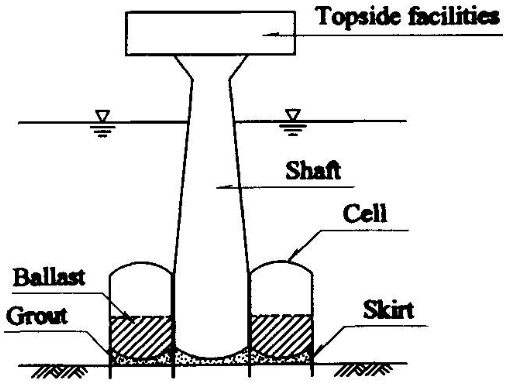

Fig.1 Schematics of GBS

2. Outline of bridge substructure with GBS technology

The conceptual design of bridge substructure for ultra-long span bridge crossing deep strait has been conducted with due consideration to seismic effects. The substructure installed in a water of 70m depth supports the main tower for suspension bridge with 2,400m center span. The soil profile at the site is shown in Fig.2, where the tip of the skirt is penetrated into the mid-depth of the Upper Diluvium.

Two levels of earthquake, L1 and L2, have been considered. L1 is the design earthquake of 150 year return period, and L2 is the ductility level earthquake which means the maximum credible earthquake at the site.

Fig.3 illustrates the dynamic analysis models including the structure-soil interaction to evaluate the earthquake effect. Model for L1 uses soil springs devived from the elastic half space theory. On the other hand model for L2 includes non-tension soil springs allowing the redistribution of subgrode reaction.

The analysis shows that due to allowance of some displacement of soil the medium dense sand considerably reduces the response, because the overall stability of the structure at L2 has the safety margin of 1.1 for both sliding and bearing capacity. This means that the critical area for stability appears at the interface between them. This is due to a large eccentricity and inclination in resultant loads caused by the earthquake.

The structural analysis for the concrete cells subject to seismic effects demonstrates in-plane shear forces together with thrusts rather than flexures dominate the amount of reinforcement as well as concrete section properties and strength, as shown in Fig.4.

The above analysis illustrates the excellent seismic performance of skirt foundation, because only moderate response takes place at even L2 earthquake due to large damping effect of loose soil and flexible structure and soon.

Toward more rational design detailed engineering will be incorporated with attention to site specifics and construction method.

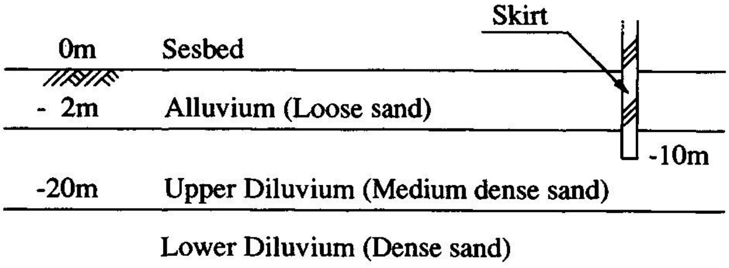

Fig.2 Soil profile

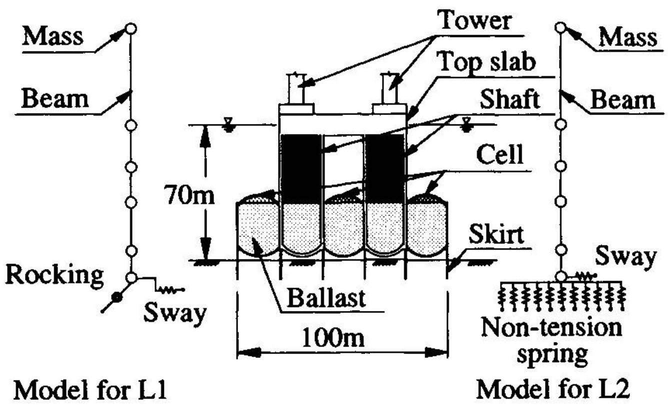

Fig.3 Lumped mass model for dynamic analysis

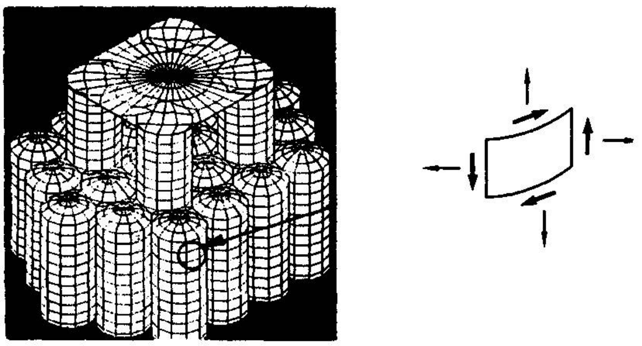

Fig.4 Structural behavior under seismic effects