

# Field Instrumentation Assessment of Offshore Land Reclamation Works

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## ABSTRACT

The Changi East Reclamation Project in the Republic of Singapore necessitated offshore land reclamation for the future airport and associated facilities. Ground improvement works in the project comprise the installation of prefabricated vertical drains and the subsequent placement of sand surcharge to accelerate the consolidation of the underlying soft marine clay. In such ground improvement projects in soft soil, the degree of improvement attained by the marine clay has to be ascertained to confirm whether the soil has achieved the required degree of consolidation to enable surcharge removal. This analysis can be carried out by means of observational methods for which continuous records of ground behavior can be monitored from the date of instrument installation. The Case Study Area conducted in the reclamation site consisted of a Vertical Drain Area and an adjacent untreated Control Area. Both areas were fully instrumented and monitored to compare the degree of consolidation of the areas close to the surcharge removal period. Instruments installed, monitored and analyzed in the Case Study Area include settlement plates, deep settlement gauges, pneumatic piezometers, electric piezometers and water stand-pipes. This paper discusses the methodology of land reclamation as well as the suitable types of field instrumentation for such projects.

## INTRODUCTION

Reclamation of the seabed foundation of marine clay necessitates ground improvement works in order to negate future settlement under the projected dead and live loads. The simplest method is to preload the foundation soil with a load equal to or higher than the future load, and preconsolidate the soil to gain the required effective stress. In the case of thick deposits of marine clay, it is necessary to accelerate the consolidation process. The use of prefabricated vertical drains with a preloading option is the most widely used ground improvement method for such cases. After accounting for submergence effect and settlement, surcharge of equivalent working load is next placed until the required degree of consolidation of the marine clay is obtained. As such, the assessment of the degree of consolidation of the marine clay is of paramount importance prior to the removal of preload. The most suitable means of carrying out this assessment is by means of field instrumentation. Prior to the installation of vertical drains in the Changi East Reclamation Project, an instrumentation programme was implemented, which included the installation of settlement plates, deep settlement gauges, piezometers and water stand-pipes. During the process of consolidation, the instrument monitoring data were analyzed by the Asaoka and Hyperbolic methods for settlement gauges to determine the ultimate settlement and degree of consolidation of the underlying soft marine clay due to the embankment load. Piezometer monitoring data were used to determine the excess pore water pressures and degree of consolidation of the marine clay.

## LAND RECLAMATION AT CHANGI EAST, SINGAPORE

Since the early 1990s, the still ongoing Changi East Reclamation Project in eastern Singapore has involved the filling of approximately 200 million cubic feet of sand for the reclamation of a total land area of about 2500 hectares. Land reclamation is carried out using fill materials derived from dredging granular material from the seabed at the borrow source.

Land reclamation requires permanently submerged areas to be raised to levels that are permanently above sea level. The choice of material for land reclamation on marine clay is well-graded, free-draining sand with fines and shell contents of less than 10%. When the fill is placed by pumping, fines may also be released with the draining water when flow velocities within the area of reclamation are sufficiently high to maintain fine particles in suspension. When fill is placed hydraulically without containment bunds, the free escape of draining water normally removes most of the fine particles. Choa (1985) has reported on an earlier phase of reclamation in the Changi East Reclamation Project.

## Characteristics of Dredging Plant

The principal type of dredging plant used in the land reclamation works at the Changi East Reclamation Project employs cutter-suction dredgers, a trailing suction hopper dredger and a bottom-opening hopper barge. The characteristics of these dredging plants are explained in British Standard 6349 (1991).

*Cutter suction dredger.* In the project, non-self-propelled cutter-suction dredgers were positioned at the borrow area in neighboring countries as well as at the rehandling pit in the project site. Cutter-suction dredgers stationed at the borrow areas were utilized to load bottom-opening hopper barges, which were then towed to deepwater rehandling pits in the reclamation site. The

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