

Tidal Flats DRI: A Geotechnical Perspective

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LONG-TERM GOALS

Our goals are to contribute to the Tidal Flats DRI, which, in turn, has as its goals: developing and improving the capability to predict hydrodynamics and sediment dynamics in macrotidal muddy river-estuary-coastal environments; understanding the link between remotely sensed signatures and geotechnical properties of tidal flats; determining the parameters governing morphologic stability and change; and determining the relative roles of river- and tidal-driven circulation in affecting tidal flat morphology and circulation. We specifically address the following:

Determine the processes and parameters governing morphologic stability and change.

Determine the processes and parameters governing geotechnical stability and change.

Determine links between remotely sensed signatures and sedimentary and geotechnical properties of tidal flats.

Initial planning has centered around a joint U.S.-Korea study of tidal flat dynamics along the shores of Gyeonggi Bay, Korea.

My work is directly linked to a similar effort by Dr. Homa Lee of the USGS in Menlo Park, California.

OBJECTIVES

Our main objective in FY07 was to participate in two planning meetings and help develop a science plan for tidal flat research. We participated in meetings in Honolulu, HI and Incheon, Korea. At the meetings we contributed to the discussions with respect to remotely sensing geotechnical properties and understanding geotechnical and morphologic stability. We contributed to the Draft Science Plan : Joint Korea-U.S. Study of Gyeonggi Bay Tidal Flat Dynamics.

APPROACH

Our suggested approach toward advancing our knowledge of geotechnical aspects of tidal flat dynamics has been the following:

The Gyeonggi Bay estuarine environment, with strong currents and significant tides, favors a diversity of phenomena that influence sediment geotechnical properties and their evolution. From a geotechnical viewpoint, in the study area, muds are deposited, consolidated, strengthened by wave actions, eroded

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by currents, exposed to air and partly desiccated, altered by salinity fluctuations, likely bioturbated and modified by animal activities (e.g. birds), and finally disturbed by the presence of gas and human activities. Slopes along channels must be subject to transient local flow gradients resulting from tide level variations. Among these processes, the following are considered critical in predicting the geotechnical stability of the sediments and understanding morphological stability and changes:

1. Consolidation (*i.e.* sediment formation)
2. Strengthening (post-consolidation processes: seismic, dewatering, cyclic loading, bioturbation, etc)
3. Weakening (effects of gas, animal disturbance, etc.)
4. Erosion (not only re-suspension)
5. Micro-slope processes (*i.e.* dendritic pattern development, evolution and stability of channels).

Studying these processes requires significant efforts in the field, the laboratory and through modeling. Also, other components of the project related to forcing conditions (*e.g.* waves, currents, etc.) need to be integrated with our work. From a brief review of the existing geotechnical literature in the study area, we see a need to first establish a data base related to the various studies that have been involved in land reclamation (*e.g.* Kim *et al.* 2004, Yoon *et al.* 2004). According to Choi and Kim (2006) the contact between the recent (Unit I) mud and the underlying non-marine Holocene deposit (Unit II) is very irregular. The contact between the two is considered to be a transgressive surface as described by Allen and Posamentier (1993). Therefore, the first task will be to generate a GIS geotechnical database for the existing information on the area.

The key factor for all the aforementioned processes is **strength (drained or undrained)**. Measuring strength can be done in various ways, but predicting it with a proxy requires a good deal of soil mechanics knowledge, an excellent geotechnical data base, and robust validation. Therefore, the next part of our proposed approach is divided into two components: (1) measuring the strength, and (2) predicting the strength.

Measuring the strength

Measuring the strength can be done directly in various ways either in the field (e.g. cone penetration tests) or in the laboratory (e.g. fall cone, triaxial, etc.).

Field Measurements

From our experience, the tidal flat environment is quite difficult to investigate. Accordingly, acquiring direct field measurement may require special logistical support (e.g. hovercraft). Since the study area is close to a major waterway, care must be taken to ensure that sediment samples are not contaminated to an unacceptable level.

The in situ strength of fresh mud can be determined using a portable piezocone (CPT), such as have been built for reclaimed land studies. Such equipment can reach a depth of 5 to 10 metres in soft sediments and operates using 12 volt batteries (*i.e.* quite portable). This provides detailed strength profiles, which are essential to any other type of analysis (including erosion and sediment transport). Some devices could also be designed to measure the strength in the first 10 cm (*e.g.* miniature vane,

shear wave measurement device). Measurements obtained with a shear wave sledge (Winsborrow *et al.* 2005) could be linked to strength (Locat and Beauséjour, 1987). Surface samples could also be taken on a very dense grid in order to produce surface values for density, liquidity index and strength that could be linked to the remote methods discussed below.

Another form of field work requires identification of a few (2 or 3) targets of equal size representing various settings and perform repeat surveys with LIDAR or RADAR in order to follow morphological changes as a response to various forcing conditions such as currents, salinity changes or tides.

Laboratory Measurements

Laboratory measurements can be conducted on samples at different states: intact (on excellent quality cores), and remolded or re-constituted (SEDCON tests). Intact sediments provide a detailed profile of strength (intact and remolded), water content, organic matter, grain size and salinity (see for example Locat *et al.* 2002), and shear waves (Levesque *et al.* 2006). Remolded tests serve for basic physico-chemical identification linked with the liquidity index, and the SEDCON test provides a reference curve for estimating the strength as a function of liquidity index and depth in the sediment. In order to provide some values of strength at high water content, a series of rheological tests can be carried out to obtain relationships between yield strength, viscosity and liquidity index and also provide an extension, at high water content, of the strength by extrapolating the relationship to higher liquidity indices (Locat 1997).

Predicting the strength

Predicting the strength is a significant challenge where technological development may have to take place. Predictions could be achieved by using proxies such as: liquidity index vs. depth relationships, backscatter data (Urgeles *et al.* 2002) from remote techniques like SONAR and LIDAR, or other airborne techniques using various wavelengths.

Morphology and morphological changes, as seen from radar or other remote techniques, may have a link with strength via the changes in slope angle and slope height. Another approach, also based on geomorphology, would be to look at a time series of aerial photographs (or satellite imagery) and follow past changes in channel morphology.

WORK COMPLETED

We participated in two planning meetings and actively contributed to production of the Science Plan. We have also been involved in extensive discussions with other participants to properly identify the role and nomenclature of geotechnical engineering in tidal flat research.

RELATED PROJECTS

Locat is funded by the National Science and Engineering Research Council of Canada to understand the development of strength in recent sediments. The development of this project benefited from approaches developed with ONR support. We have been very active in establishing IGCP-511: a UNESCO International Geological Cooperation Program on submarine mass movements and their consequences (2005-2009), also related to previously funded ONR work.

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