International Journal of Offshore and Polar Engineering
Vol. 7, No. 3, September 1997 (ISSN 1053-5381)

Instability and Movement of Oceanfloor Sediments: A Review

M. S. Rahman
Department of Civil Engineering, North Carolina State University, Raleigh, North Carolina, USA

ABSTRACT

Instability and movements of oceanfloor sediments are potentially hazardous to offshore and coastal structures, and a major geologic process of offshore sediment transport. In addition to gravity, other environmental forces associated with wave storm and earthquakes may cause shear failure leading to oceanfloor instability and mass movements. In this paper, the basic aspects of such instability and mass movements are examined, and the current understanding of underlying mechanics and the available methods of analyses are reviewed. In the framework of simplified analyses, the conditions necessary for such instability will be formulated, which may be used to identify potentially unstable sediments in a given offshore region.

INTRODUCTION

In the past few decades, the economic significance of submarine environments, and the need for land reclamation and waste disposal projects have led to proliferation of engineering activities in the ocean. The activities associated with exploitation of offshore oil, gas and mineral resources require installation of bottom-mounted engineering structures such as pipelines, anchors, gravity structures, and platform structures and communication cables. The use of continental shelves and the deeper-water shelf-slope region is growing and diversifying with technological developments. The instability and movements of oceanfloor sediments are potentially hazardous and constitute important considerations in the planning and design of such facilities (Bjerrum, 1971; Sterling and Strohbeck, 1973).

The occurrence of oceanfloor instability and mass movement is a widespread phenomenon (Moore, 1978; Saxov et al., 1982; Lee et al., 1981). Active landsliding and areas of former instability are being identified by sophisticated geophysical survey techniques (Prior and Coleman, 1984). There is evidence of oceanfloor instability in a wide variety of oceanic environment, from shallow water, near-shore zones, continental slopes and beyond to the deep ocean floors. Oceanfloor instability has been responsible for the damage and destruction of offshore structures (Bea, 1983; Christian et al., 1974).

Also, submarine slope instability is responsible for various deformation structures and bed thickness inconsistencies; in some places it may have been the dominant agent for the sediment transport from shallow water to deeper water. Some recent geologic interpretation of former marine sediment sequence shows that ancient marine slopes had been sites of large-scale mass movements.

The cause of oceanfloor instability is governed by either environmental (load) factors or material (sediment) factors. There appear to be 3 major driving mechanism in the submarine environment of the continental shelf and slope area that may produce instability or movement in oceanfloor soils: (1) gravity forces, (2) hydraulic forces, and (3) earthquakes and tectonic activity. These agents may increase induced stresses. In relation to the material factors, the strength of submarine sediments may be low due to: underconsolidation, gas hydration, and pore water pressure generation due to cyclic loads associated with waves or seismic action.

The traditional approach in identifying failure has been to use geophysical profiling and imaging combined with sporadic core sampling, which provide sea floor morphology and deformational features. This approach, however, does not identify the mechanism of failure, the instability potential of unfailed slopes, or the potential for further instability of the observed failures. A quantitative approach requiring the analysis of environmental forces as well as the engineering properties of the sediments is needed. At present, an evaluation of oceanfloor instability in a precise analytical framework is a difficult task. However, in recent years significant progress has been made towards understanding the mechanics of oceanfloor instability and some analytical methods have been developed to formulate the conditions for some simple modes of instability. A detailed and complete analysis of the complex mode of instability (which usually is the case) and analysis of movement and deformation are still out of reach.

In this paper, the essential elements of oceanfloor instability and mass movement are examined. The current understanding of the mechanics of oceanfloor instability and the available methods of analysis are reviewed. In the framework of simplified analyses, the conditions (in terms of the combination of environmental load, sediment and site parameters) for oceanfloor instability will be formulated. These may be used to identify potentially unstable sediments in a given offshore region. Developments towards the analysis of movements and deformation of oceanfloor sediments will also be mentioned.

CAUSES OF SEAFLOOR INSTABILITY

The conditions that cause seafloor instability in a given situation are quite complex and result from interaction of many variables. However, the basic condition for instability exists when stresses exerted on the sediment are sufficient to exceed its strength; this can be the result of stress increases, strength reduction, or a combination of the two. Prior and Coleman (1983) have summarized the factors and processes responsible for initiation of seafloor instability.

With respect to being a dominant factor in initiating an instability, the following may be considered major agents: (i) gravity forces, (ii) earthquakes and tectonic activity, (iii) wave faction,

Received February 1, 1994: revised manuscript received by the editors November 29, 1996. The original version (prior to the final revised manuscript) was presented at the Fourth International Offshore and Polar Engineering Conference (ISOPE-94), Osaka, Japan, April 10-15, 1994.
KEY WORDS: Seabed, instability, movement, wave, earthquake.