論 文 の 内 容 の 要 旨

論 文 題 目 ：

Use of Fine soil for Oil Contamination Control and Its Mechanical Properties
(細粒土を使った油汚染の抑制とその力学的性質)

氏 名 ： カジ ウマール ファルーク
(Qazi Umar Farooq)

Leakage of oil through pipe lines and storage tanks is a common phenomenon due to corrosion and accidents. The US Environmental protection agency has reported around 180 confirmed oil releases each week since 2000. These leakages even in very small quantity can create an environmental hazard by contaminating soil and groundwater. For example An Exxon Mobil pipeline that runs under the Yellowstone River in Montana ruptured on 02 Jul 2011, leaking hundreds of barrels of oil and causing a 25-mile (40km) plume that has fouled the riverbank (Guardian). Or a crack of about 17mm was found on the Capline pipeline that runs through Dyersburg in Tennessee on 12 April 2008, leaking about 37.8 liters of oil which contaminated the surrounding soil (Dyersburg State Gazette). As per American Petroleum Institute during the period from the year 1999 to 2011, crude oil accounts about 42% of the total toxic liquid spills form the pipe lines.

Unfortunately the petroleum industry and the oil pipeline operators are more concerned about their economic losses rather than environmental issues. Currently the industry is focusing on sophisticated leak detection system, but even the best leak detection system has limitation of 0.5-1% of flow rate. Hence there are several undetectable small leaks which pose no economic loss but have potential of environmental damage. Despite the fact that, there is always an environmental risk associated with these types of small leaks, they are often ignored. So far there is little or nothing has been done to prevent the infiltration of oil from these small leaks in to the natural ground. The oil and gas industry with oil storage tanks also have similar problems with much smaller infiltration rates. The common leakage solutions such as asphalt lining and plastic sheets are not practical in this case as asphalt being itself a part of crude oil is soluble in petroleum hydrocarbons. On the other hand due to the high temperature of flowing oil in a pipeline (about 140oC or more) the plastic or rubber membranes can be easily damaged or cracked.

The basic purpose of this research is to develop an economical oil containment system made of natural geo-material such as fine soil. The system must have sustainable retention capacity, should act as a barrier between oil facility and the natural environment, remains mechanically stable after absorbing the oil, and should not absorb any in contact water.

In order to achieve above mention goals water repellent clay has been prepared in the laboratory by using automobile wind screen water proofing technique. This was done by chemically treating Fujinomori clay with the liquid mixture of n-Dodecyltrimethoxysilane, Propanol, Polydimethylsiloxane, and H-Cl. The solution is than air dried to have permanent coating of hydrophobic layer over each soil particle.

The most important requirements for the proposed system are its oil containment capacity, and its ability to prevent infiltration of oil in to the natural ground. These parameters are determined by using retention capacity tests. The saturation point of the oil retention curve of water repellent Fujinomori clay will reflected the maximum volumetric oil content that can be theoretically contained for the given degree of compaction. The prevention of oil infiltration in to the natural ground can be made by utilizing naturally occurring capillary barrier. However, for the barrier to be effective the natural ground soil must be coarser than the Fujinomori clay. In this research the natural ground is assumed to be made up of Toyoura sand. For the evaluation of capillary barrier between water repellent Fujinomori clay and Toyoura sand the drying part of oil retention curve of water repellent Fujinomori clay is compared with wetting part of oil retention curve of the Toyoura sand, since during the breakage of a barrier the clay layer will be darning and the sand layer will be saturating. The ability of water repellent clay to withstand hydrostatic pressure was determined from the retention curve of water repellent Fujinomori clay with water. The water entry value during wetting phase will give the maximum value of hydrostatic pressure that can be sustained.

The ability of proposed system to resist the infiltration of water and contain the oil infiltration is scrutinized by flow model tests and image analysis. The sand box model was prepared with the water repellent clay layer at center. The model is than dripped with oil, water and oil water mixture. The oil and water content at different positions on clay and sand is determined by using image analysis technique, which involves certain calibration equations.

The risk associated with loss in bearing capacity and over settlement, due to absorption of oil was checked by consolidation and tri-axial shear tests.

In the light of test results it can be said that, the proposed system can contain a reasonable amount of oil. The phenomenon of capillary barrier is very effective between sandy soil and water repellent Fujinomori clay. In case the natural ground resembles the Toyoura sand the water repellent Fujinomori clay can safely tackle about 50% of volumatric oil content at interface. The value is almost equal to the volumatric oil content at full saturation. Hence, almost all the clay pores can be utilized for oil containment.

The water repellency function is quite effective against infiltration and can divert any in contact water. This will keep the absorption capacity available for oil leakages. Oil water mixture infiltration model test reveals that, if the oil containment system encounters a reasonable quantity of oil-water mixture, the separation of fluids occurs and water will be rejected by the system. Or in other words, as desired the system will only absorb the oil pollutant.

On absorbing oil fine soil may lose strength, however, at a particular stress level, it settles less than non contaminated soil. These facts suggest that the proposed system can be practically used for oil contamination control. However, if the proposed oil containment system is required to bear heavy foundation loads, reduction in factor of safety against shear should be considered.

However, the system is designed to cope with only small leakages and may not be effective in case of a major breach. The inability of water repellent soils to withstand hydrostatic pressure is another limitation and system needs further modifications if it is required to be used in humid regions.