PREFACE

It is an undeniable fact that crude oil is a valuable source of energy that fulfills a substantial volume of the world's energy needs. Nonetheless, its rapid rate of extraction and transportation has made it a causative source of environmental pollution in many parts of the world, particularly in locations where it is thriving. The most significant source of contamination are the oil spills which can occur both onshore and offshore. There have been several inland oil spills round the globe out of which two-third is caused from pipeline breeches and storage leakages. It has jeopardized quality of a vast amount of landmass and have straightforward impacts on its engineering properties. Many oil-fields which have been abandoned or expected to abandon in future, despite of having huge potential for redevelopment, cannot be utilized for new construction practices. Moreover, the availability of suitable construction sites is becoming difficult with each passing day and therefore the engineers are left with no choice than to reutilize such types of sites. Therefore, studying the engineering properties of oil contaminated sites have been receiving a huge attention of the researchers in past few decades. But it is also required to shift the focus from the much discussed static oriented approach towards less considered dynamic oriented approaches. The reason behind is that many of the oilfields like Assam oil fields of India lies in the high risk seismic zone which may amplify the complexities of the problem.

Liquefaction is one such phenomenon which is fundamentally associated with the earthquakes. Liquefaction induced damage is one among the leading causes of the failure of surface and subsurface facilities. Apart from the direct and indirect impact on the structures, liquefaction hazards have also claimed a huge number of lives. Due to the rising population, uncontrolled settlement development occurred amid hazardous geological, geomorphological, and hydrological site conditions, putting the community at risk of severe liquefaction. Therefore, it is pertinent to take into the consideration the liquefaction propensity of such hazardous sites. With the aim of assessing the liquefaction hazards, an attempt has been made to evaluate the liquefaction propensity of hydrocarbon contaminated sand. An intensive set of experimental investigations were carried out meticulously to evaluate the effect of various factors on the pore pressure dynamics and cyclic behavior of the contaminated sand. Apart from that, a sustainable and dependable remediation strategy that can be performed in-situ was also developed to counteract the deteriorating effects of hydrocarbon on the cyclic strength of the sand.

The contents of the thesis have been divided into seven chapters. The first chapter gives the background of the petroleum contamination along with some realistic oil spill data highlighting the frequency of its occurrence and need for its consideration from geotechnical viewpoint. The second chapter presents a detailed review of the documented literature in the field of liquefaction and its mitigation techniques. It also covers the handful of research associated with the dynamic aspects of the hydrocarbon contaminated soils. Various materials and methods employed in the study have been discussed in the third chapter. The test/host sand is the Guwahati sand from Assam, India, owing to its exposure to such types of problems. The impact of crude oil on the geotechnical, mineralogical and morphological properties of Guwahati sand was evaluated. A remarkable deterioration in the engineering properties was witnessed. Following it is the selection of research methodology adopted for further experimental investigations.

The whole experimental investigation was conducted in three phases which has been presented in the form of three separate chapters. Fourth chapter presents a series of bender element tests conducted for an indicative assessment of liquefaction potential of contaminated sand through shear wave velocity (V_s) and small strain shear modulus. The key influencing parameters were crude oil content (2, 4, 6, 8, 10 and 12%) in addition with frequency, confining pressure and depth of contamination. A critical value of oil content has been introduced as the transition point in the V_s profile. The fifth chapter presents a series of systematic shake table investigations to study again the influence of degree and depth of contamination on the pore pressure and settlement response of contaminated sand at a relatively larger scale under harmonic base shaking. Further, the effect of shaking history was also determined by applying consequent base shakings at fixed time interval. The results revealed a substantial improvement in the liquefaction resistance of the sand with an initial increase in crude oil and falloff sharply with further increase, resulting into a single-peaked profile with the highest resistance observed at the threshold point. Coupled effect of degree of contamination and depth of contamination revealed a "zero change point" where no net change in the behavior was recorded.

Enzyme-induced carbonate precipitation (EICP) is an innovative bio-inspired approach that has emerged in recent years, offering a more environmentally sustainable option for soil improvement. The sixth chapter aims at extensively examining the effect of EICP treatment on the cyclic response of petroleum contaminated Guwahati sand for which strain-controlled cyclic triaxial tests were carried out on contaminated sand with and without EICP treatment. Apart from crude oil content, effect of independent variables such as shear strain amplitudes (0.5% and 1%) and curing period (7 days and 14 days) were also considered. Prior to this, a baseline analysis was conducted to determine the effect of EICP treatment solution composition on the efficiency of carbonate precipitation. The effectiveness of the treatment was systematically investigated based on cyclic pore pressure response and degradation of cyclic shear modulus. The results revealed that petroleum contamination moderately increases the cyclic resistance up to a transition point beyond which it falls off sharply. EICP treatment increases the cyclic resistance of oil-contaminated sand up to 1.5 times by suppressing the excess pore pressure build-up. A significant recovery in the degradation parameter, as high as 80%, was also observed. However, with increasing oil content and shear strain levels, the efficacy of EICP treatment exhibited a remarkable decline. The results were validated theoretically using an empirical model. The micro-structural mechanism believed to be responsible for the observed behavior was also discussed.

The last chapter summarizes the major conclusions of the study along with its limitations and future recommendations. While the hydrocarbon contamination had an unswerving adverse impact on the fundamental engineering properties of the Guwahati sand, its effect on the liquefaction behavior was not diametrically proportional to the contamination levels. Further, the aspects addressed in the study would aid in formulating a systematic approach for effective management and utilization of contaminated sites. The proposed EICP technique offers a sustainable technique for stabilization of such soils whose efficacy to arrest liquefaction has been validated through experimental results.