OPERATIONAL FEASIBILITY OF LIQUEFACTION REMEDIAL TECHNIQUES UNDER GAS PIPELINES IN URBAN AREAS, AND COMPARING ITS COST CONSIDERING THE WORN-OUT URBAN TEXTURE

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During an earthquake, liquefaction occurs especially on the loose water-saturated silts and sands region and causing heavy damages (Chung, 1996). A severe earthquake can provoke liquefaction-induced ground deformations and settlements, and also may significantly cause serious damage in urban including foundation settlement of houses and bridges, lifeline's damage (electricity, telephone, water and gas pipes), ground slide and the most important one is gas pipeline due to the possibility of explosion and fire (Ballantyne, 2008).

Numerous studies have been done in this field in order to identify, investigate and develop different techniques of preventing liquefaction or reduction of its risks and consequences.

Liquefaction remediation technique in buried gas pipeline are introduced and compared in this paper and lateral spreading of liquefaction are also elaborated in details

In the beginning, the philosophy of liquefaction is discussed then philosophy of dealing with it is described and different liquefaction remedial techniques are presented. Required special machinery in any technique and their availability are studied which eventually leads to the operational feasibility results of different methods using constraints and features matrix. Flowingly, based on gas pipeline sensitivity to deflection, remedial techniques are categorized in two fields: live gas networks and unconstructed lines and on the same basis, we have more focused on operative gas lines.

In the next part of paper, urban distressed areas, which imposes special executive conditions, is particularly considered, and the matrix of constraints and features has been studied about the feasible executive techniques in order to determine a general algorithm for selecting of optimized technique (or feasible executive technique) based on the defined flowchart.

At the end of the paper, in order to prepare comparison condition basis of economic analysis for different liquefaction remedial techniques on gas pipeline and their estimated cost are presented. Therefore, approximate formulas for initial estimating of the operational costs have been provided by simplifying the influent factors, for example, the cost of jet grouting is estimated as follows

$$R = \frac{(4 + .3h + 1.2t)}{16} \times h \times C_L \times F$$

Results are shown at different depths of the given geotechnical condition as a graph, which shows application of demonstrated algorithm. The results of the studies indicated that the most important factor in selecting of the liquefaction remedial technique is the liquefying layer depth and the layer's thickness comes after that (Fuchida et al., 1996). The best technique is rapid dynamic compaction for depth less than 3m, also dynamic compaction with cylindrical weights for depth between 3 to 12m and finally Ultra Dynamic compaction, for depth more than 12 m, but not exceed 15m. In case of loose top and middle soil, soil replacement method would have a higher priority.

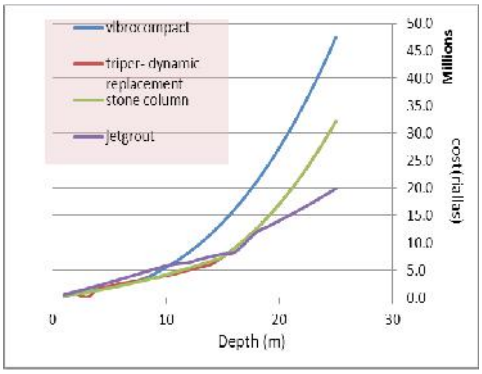

Figure 1. Economic comparison of different options in urban texture without pipeline

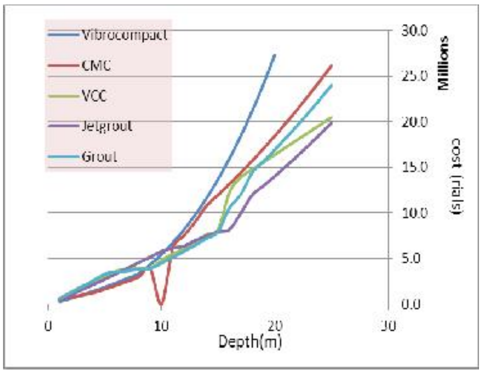

Figure 2. Economic comparison of different options in urban texture with pipeline

In existing urban areas and under construction pipelines , where gas pipeline network has a distance of thirty meters or more with the buildings, or there are single-story buildings (Maximum of two stories) with non-loose foundation , the above methods may be used by adding seismic isolation through digging trench across the compacted track. At the same conditions for the buildings of more than one story, methods based on large displacements are disqualified and other approaches would have better economic results, such as vibrocompaction technique for liquefying layer depths below 7.5 m, Dynamic Replacement, Triper and Vibro Stone Column Techniques for depths between 7.5 m to 15 are appropriate, and for more than 15m Jet Grouting will give economical outcomes.

Studies and calculations in existing urban and existing pipelines have shown that the most economical method for the liquefying layer depth less than three meters, is vibrocompaction technique , for depths of 3 to 8 m, Controlled Modulus Columns is preferable, and in depths of 8 to 15 m, Vibro Concrete Columns Method, and finally for depth of over 15 meters, Jet grouting method is economical.

Studies about the urban distressed areas s suggest that in addition to the above considerations, putting flexible joints at distances up to 150 meters may prevent axial stress effects during vibration.

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