Elastic-plastic behaviour of cylindrical tanks on soil(*)

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STRENGTH of low-pressure vertical cylindrical vessels used as storage tanks or safety containment structures depends strongly on the behaviour of their shell-to-bottom joints. Increasing the thickness of the plates can hardly reduce the stress level there and, theorefore, some local plastic deformation cannot be avoided, even under service load. Some structural codes take account of this fact allowing for stresses exceeding the standard admissible values. That is justified since structures generally adapt to simple non-alternate loading cycles, their further response becoming purely elastic. However, under some non-proportional cycles alternated plastic deformation and low-cycle fatigue may appear, resulting in many oil tank failures reported.

An approximate analysis presented in this study aims at a qualitative evaluation of the structure response, allowing for a more reasonable formulation of the problem of a numerical treatment of selected cases.

The system's behaviour depends upon the characteristics of the three elements interacting in the joint: cylindrical shell, circular plate and a continuous subgrade. The shell and the plate are considered elastic-perfectly plastic (sandwich). An analytical solution obtained by one of the authors for plates on elastic foundation allows for dealing with the adaptation problem, in spite of the fact that the standard shake-down theorems are not strictly applicable in the presence of a lift-off in the bottom plate. As a matter of fact, separation between the plate and the elastic foundation must appear in any cycle including plastic deformations of the plate. Loading consists of two independently varying forces: a hydrostatic or gas pressure and a vertical edge force, both producing a moment of the shell-plate interaction.

The structure response is studied under different subgrade models: elastic or elastic-plastic Winkler-type and a plastic continuum. The most restrictive loading paths are looked for and corresponding adaptation domains are defined. Different structural configurations (bottom plate diameter superior to that of the cylinder, exterior rings of the plate and/or of the subgrade strengthened, edge anchoring, double shell) are discussed from the point of view of the ability of the system to shake-down.

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Some more general conclusions are also mentioned concerning the analysis of systems composed of elements of strongly different character, some of them having to remain elastic.

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