RAISING OF A SEMI-CIRCULAR VAULT

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The aim of this paper is to obtain a solution of the following engineering problem: to construct a heavy circular vault on a smooth rigid horizontal base by layerwise accretion along the internal surface of an initial arc-shaped structure (see Fig.). It is assumed that the fixation of the vault to the base prevents its separation but allows for free sliding. The case under consideration is that of plane strain. The material is assumed isotropic, uniformly aging, and elastic or viscoelastic. Presented research results are based on the ideas of growing solids mechanics and mathematical theory of accreted solids (see, e.g., [1–8]).

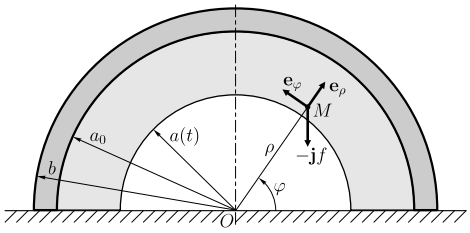

Figure. Semi-circular vault under accretion

Initial boundary value problems are formulated, in order to describe quasi-static deformation of this structure subject to its own weight combined with an arbitrary variable load on its external surface prior to, during, and after the process of its piecewise continuous accretion. These problems take into account the possibility of using prestressed structural elements in the process of accretion. For these problems analytical solutions are constructed in terms of series and quadratures. Numerical calculations are demonstrated by results obtained for various problems connected with different types and modes of raising of thin-walled and thick-walled vaults made of thin-walled elements, as well as the reinforcement of initially thick-walled vaults. It is shown that the stress-strain state of raised heavy objects essentially depends on the technique and the regime of their construction, and that the characteristics of their stress state in the process of construction may attain values that greatly exceed those at the end on this process.

The effect of creep, aging, and material weight on the deformation of a heavy vault under accretion by stress-free structural elements is studied. We single out and analyze the main tendencies whose continuous interaction determines the stress-strain state formation in the object being accreted. From the standpoint of these tendencies, some limiting regimes of accretion are considered.

Thus, if the accretion of a vault is fairly fast, a very strong load-relief if observed in its original part. However, on the initial stage of this accretion process, the vault experiences stresses that greatly exceed the original ones. In the case of a thin-walled original arc, the difference between these stresses is substantial. However, if the accretion process is slow then the material added on the final stage remains practically stress-free. In this situation, the stress level in the original part of the structure becomes much greater than the initial one. If the original arc is sufficiently thin, it is subject to very high stresses at the initial instant, and therefore, the final structure will have regions with stress levels greatly exceeding the maximal level calculated on the basis of the final configuration.

Therefore, if one fails to take into account gravity forces during the entire process of raising a heavy object, one may come to an entirely wrong picture of its current and its final state, in particular, one may obtain greatly overestimated values for the strength and the operational bearing capacity of the structure.

It is shown that for a gradually accreted vault on a sufficiently thick original arc, the final structure may have much smaller stresses than those calculated for a ready-made structure immediately installed on the base. For a vault with a thin original arc, it has been shown that if one varies the accretion rate in a suitable manner, the stresses in the final structure can be substantially decreased

relative to the initial state of the original arc, so that the admissible stress values in the accretion process are never achieved.

In the course of these investigations, it was found that even a fairly thick-walled original arc, being installed on a smooth base, tends to separate from the base in peripheral regions of its bottom due to its own weight. Without taking some special measures, it is impossible to get rid of these regions of separating (negative) contact stresses by subsequent reinforcement of such an arc.

Another problem under investigation is that of accretion of a vault using prestressed elements. For a vault accreted in this way, it is also impossible to ensure forces that would permanently prevent separation of the vault from the base. However, using layerwise accretion with suitable initial stresses, one can ensure a much better resulting stress state in the total structure than in the case of accretion by stress-free elements, i.e., one can minimize negative pressure on the base and the general stress level in the body.

One also considers an accretion process in which the vault vertex is fixed by suspension with controllable tension that compensates a given part of the current weight of the vault and vanishes at the end of the process. This technique leads to substantially smaller stresses in the final structure than those obtained by common accretion in the same temporal regime. In this case, it is also possible to obtain a much better final contact stress diagram than that for a ready-made vault installed on the same base. If, in addition to suspension, the elements used for accretion are subject to some initial extension, then it is even possible to construct a thin-walled vault that will exert positive pressure at all points of the base.

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