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The Aid of Models in the Analysis of the Behavior of Structures Within and Beyond the Elastic Range

La contribution des modèles à l'étude du comportement des ouvrages au-delà et en deçà de la limite élastique

Modellversuche für die Untersuchung des Verhaltens von Bauwerken inner- und außerhalb des elastischen Bereiches

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1. The possibility of investigating on scale models the behavior of structures both within and beyond the elastic range has been long proved by the writer analytically and experimentally on a great number of structures. These were, in particular, plain or reinforced concrete structures, for whose design the writer was directly responsible alone or in association with others.

A model is a highly valuable element, and its importance is now universally acknowledged for analyzing structural behavior under elastic conditions in order to obtain the magnitudes of the strains, and hence of the stresses, likely to originate in the full-scale structure under working load. These results are valuable for many reasons. First, they make it possible to compare the values determined experimentally with those obtained by using the conventional calculation methods which, as is known, are impaired by a number of limitations, assumptions and simplifications unnecessary in a model. Second, when the model is used as a clever calculating machine, it can provide the numerical solution of three-dimensional elasticity problems which cannot be solved analytically both because of their extreme complexity (only partly reduced by the use of electronic computers) and, even worse, because of the difficulty encountered in introducing in the theoretical considerations sufficiently accurate boundary conditions.

But, even if the investigation should basically remain within the elastic range, its extension beyond that range, though less rigorous than the former and, under certain aspects, complementary to it, is still always an invaluable source of precious information and training for the engineer who is charged with the high responsibility of designing and erecting the structure.

In fact, this investigation may lead to determine and to locate the weak and less efficient points of the structure. It may also furnish (or at least confirm) the order of magnitude of the factor of safety and thus provide the designer and the commissioning party with an assurance that is final and conclusive or complementary, depending on the individual point of view.

2. In the ambit of structural problems, the following classification for models may be made:

- a) according to the type of problem:
 - 1. static models,
 - 2. dynamic models;
- b) according to the extent of the expected results:
 - 1. elastic models (i. e., valid in the elastic range only),
 - 2. global models (indicating the structural performance also under unelastic conditions up to failure).

The present-day trends of modelling engineering, with respect to the research and experimentation carried out by the writer (especially at ISMES, the Experimental Institute for Models and Structures, Bergamo, Italy), may be summarized as follows:

- The interest in modelling is increasingly being shifted to global models, along with the general tendency to have all designed structures calculated to the breaking point.
- As to elastic models, their use is steadily growing as very rough research instruments for investigating problems wherein the elastic behavior supplies, by interpolation, adequate information regarding also the unelastic performance. Of the recent uses in this branch of research we shall mention in particular the investigation of slabs and bridge decks by the Moiré method.
- The materials for elastic and global models are undergoing constant improvement in relation to the problems being investigated, so as to have them adjusted in the best possible way to the aims pursued.

For elastic models, ISMES has recently succeeded in using epoxilic resins mixed with various materials. This permits to obtain a wide range of elastic moduli, in accordance with the requirements of each individual case, and stress-strain relations that are proportional also when the stresses are high.

- There is an increasing interest on the part of the customers, especially for large hydroelectric schemes, to investigate the equilibrium of vast valley systems affected by the schemes and whose original conditions may somehow be modified by the presence of the hydro plants.

At ISMES there have lately thus been studied on models equilibrium problems of dam and abutment mountain systems, whose geomechanical characteristics have conveniently been schematized on the basis of geognostic investigations.

- With respect to the foregoing paragraph it may be pointed out that, as an aid to studies on models, are increasingly used and recommended in-situ and laboratory investigations of the geomechanical and geotechnical features of the materials.

— Similarly, there is a growing interest in tests dealing with thermal stresses in structures, with particular regard to dams as a consequence of impounding and drawing down the reservoir water in hydroelectric plants. The same is true also with respect to problems relating to the statics of reinforced, prestressed or not, concrete containers for nuclear reactors.

Summary

The writer first recalls the importance of scale models in analyzing the static and dynamic behavior of structures stressed also beyond the elastic range. He then uses the investigations carried out under his supervision, especially at ISMES, Bergamo, to present a classification of the research possibilities now available.

Résumé

On rappelle tout d'abord le rôle important des maquettes dans l'étude du comportement statique et dynamique des constructions sollicitées aussi au-delà du domaine élastique. L'auteur se réfère ensuite aux recherches qu'il a conduites, notamment à l'ISMES, à Bergame, pour présenter une classification des possibilités qui s'offrent maintenant à la recherche.

Zusammenfassung

Es wird zuerst die große Bedeutung der Modellversuche zur Abklärung des statischen und dynamischen Verhaltens von Bauwerken inner- und außerhalb des elastischen Bereiches gezeigt. Anhand der Ergebnisse der Forschungen an der ISMES, Bergamo, welche unter seiner Leitung durchgeführt wurden, klassifiziert der Autor die heute zur Verfügung stehenden Forschungsmöglichkeiten.

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