SHAKEDOWN DESIGN
OF
ENGINEERING STRUCTURES

Dr. R A Ghani, D Sc.

Shakedown Design of Engineering Structures
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In Fond Memory of My Parents

Late Mohammad Ayeenuddin
Late Mosammat Kasirunnessa

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Foreword

I am happy to write this foreword to Dr. R A Ghani's book on "Shakedown Design of Engineering Structures". The Shakedown Method of Design has potential because it is based on most generalized type of loading i.e variable repeated loading to which all structures are subjected.

I have known Dr. Ghani for many years as a dedicated Engineer. He has vast and varied experience including conventional and nuclear structures. Prior to this work no systematic method was there for Shakedown Analysis. Dr. Ghani achieved this distinction of systematic shakedown design method suitable for design office practice. Thus Dr. Ghani made significant and outstanding contribution in the application of shakedown theory. He has proved conclusively that shakedown is most generalized theory which includes both elastic and plastic theories as particular solutions by way of combination of loading. This he has established as corollaries of the generalized Shakedown Theory.

The shakedown design leads to low volume structures, yielding considerable material saving and low cost. The shakedown design involves complete elastic solution; in addition the considerable amount of calculation involved in shakedown design may now be carried out with readily available computers.

I recommend inclusion of this subject in the syllabus of universities. I hope the book will get wide circulation and I wish the efforts of Dr. Ghani a success.

Dhaka
December, 2008

Prof. Dr. Jamilur Reza Choudhury
Vice Chancellor
BRAC University

PREFACE

A theoretical investigation of the classical shakedown theorem for the non-prismatic beam is presented. Analytical expressions for shakedown analysis of continuous beams with variable cross section under statical loading have been derived. The shakedown theorem based on both the simple plastic theory as well as on the strain-hardening material has been developed. The shakedown theorem for preloaded beam has also been determined. The influence of shear force on the shakedown load has been treated. A limited study of the effect of the geometry of the section on the shakedown load is included.

The result of this study provides a theoretical background along with a systematic method of shakedown analysis of structures with prismatic and non-prismatic members. In developing the method only the effect of flexure has been considered. The shakedown analysis for both the stationary and the traveling type of variable repeated loading can be carried out. The method is adoptable for design office use.

In connection with the design of buildings the types of problems that can be treated directly by shakedown analysis are the indeterminate beams supporting crane runway girders, the crane-runway girder itself if the crane lifts the load in the plane of bending of the girder, columns and walls subjected to severe wind load,

The bridges are the type of structures that are particularly suitable for analysis by the shakedown method. The method introduces a new concept in the

design and analysis of continuous bridges, prismatic and non-prismatic,

The method of analysis has been illustrated by several numerical examples both for the case of the stationary and the traveling type of variable repeated loading. As a practical example a three span continuous bridge with parabolic haunches and of wide-flange shape has been analyzed.

The elastic method of analysis is conservative. The plastic theory deals with the restricted case of "proportional loading" only. These theories are not adequate enough to treat the problems of general "variable repeated loading" system.

The shakedown solution includes the elastic and ultimate solutions by some combination of loads as special cases.

The shakedown analysis of beams, prismatic and non-prismatic is rather simple and suitable for design office use. The laborious part of the shakedown analysis is the elastic solution of the problem. Once that is done the shakedown solution is rather easy.

The present practice of analysing structures such as bridges etc. subjected to variable repeated loading by elastic method is highly conservative so as far as the carrying capacity is concerned. On the other hand this method does not consider the very nature of loading in its true perspective. A considerable increase of load is gained by shakedown analysis over the elastic method.

It is justified that the plastic method of analysis has not been applied in designing bridges. Firstly, because it does not take into account the very nature of loading

namely, the variable repeated loading* Secondly, because it over-estimates the load carrying capacity of the structure.

Apart from the quantitative advantage of shakedown analysis, the method promises a more rational basis of analysis of structures with variable repeated loading. Since it is of prime importance to the designer to know the ultimate load carrying capacity of the structure as closely as possible, he is to take into account the actual type of loading and the behavior of structure under such loading. It is towards this end that the shakedown method provides a rational basis of analysis by taking into consideration of the most general case of loading and failure.

The shakedown theory is based on the assumptions valid in the elastic and plastic theories. Its validity in practical application depends mainly on those of the elastic and plastic theories in which considerable work has been done and as such the shakedown analysis may be adopted for practical application without much apprehension even though very limited experimental results are available at present.

The present shakedown method as developed is intended to treat the members of the structure in pure bending and for statical variable repeated loading system. However, the dynamic effect of the moving load can be taken into account by considering an impact factor in a manner similar to the present practice of designing bridges by the elastic method. The cases of dynamic loading such as earthquake and other vibration problems cannot be treated, nor can it treat the cases of axial loading.

An abridged version of this book has been published in the Journal of the Structural Division, American Society of Civil Engineers, Vol. 93, No. ST. Proceedings Paper 5643, Dec. 1967 and also reprinted in the Journal of the Institute of Engineers, Bangladesh, Vol. 8, No. 11, Nov. 1968.

It is usual that there will be some inadvertent printing errors and the author would be grateful if these are pointed out.

December, 2008. Dr. R A Ghani, D Sc.
Dhaka.

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