

DYNAMICS OF
OFFSHORE
STRUCTURES

SECOND EDITION



JAMES F. WILSON

Dynamics of Offshore Structures

James F. Wilson, Editor



John Wiley & Sons, Inc.

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Cover photograph. This historical Argus Island Tower was a U.S. Navy facility, located 39 km off the southwest coast of Bermuda in a water depth of 58 m. Built in 1960, the Tower was used for about 10 years for underwater acoustic research and for submarine detection. The two enclosed levels on top of this four legged jacket structure had space for diesel generators, living quarters, and laboratories. During the first few years of the Tower's existence, it was subjected to storm-generated waves approaching 21 m, which was also the wave height upon which the Tower design was based. The 1969 inspections of the Tower revealed storm damage to many of its subsurface welded brace connections, damage that was deemed too closely to repair and subsequently maintain. Thus, demolition using shaped charges toppled the Tower in 1976, and its remains now rest on the coral floor of the sea.

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Preface

This book is intended for three groups: (1) students and professors of structural and ocean engineering; (2) engineers and scientists in academic institutions, government laboratories, and industries involved in research on offshore installations, especially fluid-structure-soil interactions; and (3) practicing professional engineers who consider conceptual designs and need to employ dynamic analysis to evaluate facilities constructed offshore. The material herein was originally prepared by the three contributors for short courses attended by engineering practitioners, and for university courses taken by engineering seniors and graduate students.

Compared to the first edition, this second edition includes more example problems to illustrate the dynamic modeling, analysis, and solution of deterministic and stochastic responses for a wide variety of structures offshore, which include buoys, moored ships, and platforms of the fixed-bottom, cable-stayed, and gravity-type designs. Also, the extensive references of the first edition are updated, especially source material involving offshore waves, structural modal damping, and fluid-structure-soil interactions.

As in the first edition, this second edition addresses the basic physical ideas, structural modeling, and mathematical methods needed to analyze the dynamic behavior of structures offshore. Chapter 1 summarizes existing installations and points out future challenges. In subsequent chapters, careful attention is given to the many and sometimes subtle assumptions involved in formulating both the structural model and the natural forces imposed by the often hostile environment. The analyses in these chapters focus on plane motions of elastic structures with linear and nonlinear restraints, motions induced by the forces of currents, winds, waves, and earthquakes. Chapters 2 through 5 address single degree of freedom structural models that, together with plane wave loading theories, lead to time history predictions of structural responses. Chapters 6 and 7 extend these analyses to statistical descriptions of both wave loading and structural motion. Chapters 8 and 9 include the analysis and examples of multi-degree of freedom linear structures. Chapter 10 deals with continuous system analysis, including the motion of cables and pipelines. Chapter 11 addresses current practice related to submerged pile design for structures offshore.

I sincerely hope that this book will be useful and serve as an inspiration to engineers and researchers who design and analyze structures for the offshore environment.

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Bruce J. Muga, Professor Emeritus of Civil and Environmental Engineering at Duke University, received his B.S. in Civil Engineering from the University of Texas, and his M.S. and Ph.D. degrees in Civil Engineering (Hydrodynamics) from the University of Illinois.

From 1961 to 1967 he was employed as a Project Engineer in the Port and Harbor Division of the U.S. Naval Civil Engineering Laboratory, Port Hueneme, California. In 1964, he was assigned as Consultant to the U.S. Military Assistance Command, Vietnam, to advise on coastal and harbor engineering projects.

In 1967, Dr. Muga accepted a position in teaching and research at Duke University and was Chairman of the Department of Civil Engineering in 1974. He has served as a consultant to many international corporations engaged in offshore and deep ocean engineering activities. He has written numerous technical papers and for seventeen years served on the North Carolina Marine Sciences Council. Prior to retirement, Dr. Muga was a Registered Professional Engineer in California, a member of the American Society of Civil Engineers and the Marine Technology Society. He is a life member of the Permanent International Association of Navigational Congresses.

Lymon C. Reese is the Nasser I. Al-Rashid Chair Emeritus and Professor, Department of Civil Engineering, The University of Texas, Austin, Texas, and is principal at Ensoft, Inc., a distributor of engineering software. Some of his consulting activities are carried out through Lymon C. Reese & Associates, a subsidiary of Ensoft.

He received his Bachelor's and Master's degrees in Civil Engineering from The University of Texas at Austin and his Ph.D. from The University of California at Berkeley. Dr. Reese has had several years of industrial experience and has been a consultant to a number of companies and governmental agencies. He was formerly Assistant Professor of Civil Engineering at Mississippi State University.

Dr. Reese has done extensive research in the field of geotechnical engineering, principally concerning the behavior of deep foundations. He has pioneered in performing field studies of instrumented piles and has developed analytical methods now widely used in the design of major structures. He has authored over 400 technical papers and reports and presented a number of invited lectures and talks in North and South America, Australia, Africa, Asia, and Europe.

Dr. Reese is an Honorary Member of the American Society of Civil Engineers and was selected as Terzaghi Lecturer in 1976; he received the Terzaghi Award in 1983. He received the Distinguished Achievement Award for Individuals from the Offshore Technology Conference in 1985 and was elected to membership in the National Academy of Engineering in 1975. He is a registered professional engineer in Texas and Louisiana.

James F. Wilson earned an A.B. degree from the College of Wooster, a B.S. degree in Mechanical Engineering from MIT in 1956, and a Ph.D. degree in applied mechanics from The Ohio State University, where he was a Ford Foundation Fellow and a Freeman Scholar. He worked in research and development for several companies and government agencies before joining the faculty at Duke University in 1967.

During his academic career, Dr. Wilson was a NASA-ASEE Faculty Fellow, a lecturer at three NATO Advanced Study Institutes, and a Visiting Scholar at Colorado State University and the University of Melbourne, Australia. He has been active in national committees for the American Society of Mechanical Engineers (ASME) and the American Society of Civil Engineers (ASCE), and received national awards for innovative experimental research (ASME, 1977), and the year's best state-of-the-art civil engineering journal publication (ASCE, 1987). He is a Life Fellow in ASME and a retired Fellow of the National Academy of Forensic Engineers. As a registered professional engineer, he regularly serves as an expert witness, testifying on structural failures, product performance, and vehicle accident reconstruction.

He is author or coauthor of over 200 works, which include technical reports on forensic engineering, refereed symposium papers and journal articles, two books on structural dynamics, a three-volume work on experiments in engineering, and two U.S. patents. His experimental research on robotics was highlighted in the 1989 BBC documentary, *Nature's Technology*.

During Dr. Wilson's career at Duke University, he has taught courses in applied mechanics, structural dynamics, and experimental systems, and was the major research advisor for over 35 graduate students, including postdoctoral fellows. He also served as the Director of Graduate Studies for the Department of Civil and Environmental Engineering. As Professor Emeritus since 1998, Dr. Wilson continues to pursue his research and writing interests and consulting practice.

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