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Giuseppe Failla

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AN EXACT MODAL ANALYSIS APPROACH TO VIBRATION ANALYSIS OF STRUCTURES WITH MASS-SPRING SUBSYSTEMS AND ROTATIONAL JOINTS

Giuseppe Failla
Department of Civil, Energy, Environmental and Materials Engineering (DICEAM)
University of Reggio Calabria, Via Graziella, 89124 Reggio Calabria, Italy
Email: giuseppe.failla@unirc.it

ABSTRACT

A novel exact modal analysis approach is presented for vibration analysis of plane continuous structures, which are coupled with discrete mass-spring subsystems and include elastic rotational joints modelling local flexibility. Using the theory of generalised functions to handle the discontinuities of the response variables, every continuous member with any number of mass-spring subsystems and joints is treated as a two-node element, for which a 6×6 exact dynamic stiffness matrix is obtained in closed form. As a result, the global dynamic stiffness matrix is built by a standard finite-element assembling procedure, with size depending only on the number of nonzero nodal degrees of freedom of member-to-member nodes. Upon deriving pertinent orthogonality conditions for the modes, the system response under arbitrary loads is obtained by modal impulse and modal frequency response functions, under the assumption of proportional damping. The solutions are exact and can be used as benchmark for classical finite-element solutions. The approach is formulated for various mass-spring subsystems, acting in transverse and axial directions relative to every member.

KEYWORDS: Modal Analysis, Dynamic Stiffness Matrix, Euler-Bernoulli Beam, Mass-Spring Subsystem, Elastic Rotational Joint.

1. INTRODUCTION

The dynamics of continuous structures coupled with discrete mass-spring subsystems is of strong interest in structural and mechanical applications. Mass-spring subsystems are used to model engines, machineries and, more generally, secondary structures whose motion is coupled with that of the primary continuous one (e.g., see ref. [1] and list of references therein). Combinations of beams with multiple mass-spring subsystems are involved in passive vibration control [2-6] and