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Size effect and dynamic properties of 2D lattice materials

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Abstract
The dynamic analysis of two-dimensional (2D) periodic material structures is proposed via a novel mechanical approach. General assumptions include: i) the representative unit cell of the square lattice can be modeled by means of a defined number of straight micro-beams; ii) both shear/flexural and axial strains are locally accounted for; iii) a microstructure-dependent scale length is introduced as an intrinsic parameter of the micro-beams, with possible different scale lengths for different considered beams. All these features allow to detect the influence of the characteristics of the lattice at the local scale on the global dynamic behavior. Moreover, the existence of frequency band gaps is also predicted.

Key Words
Periodic materials; 2D Lattices; band gaps; microstructure; FEM

Notation

Ω	global reference system (origin),
$\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3$	global reference system (unit vectors),
a	lattice constant,
$\mathbf{a}_1, \mathbf{a}_2$	generating vectors ($\mathbf{a}_i = a\mathbf{e}_i$ i=1, 2)
$\mathbf{b}_1, \mathbf{b}_2$	reciprocal unit vectors,
$\mathbf{i}_1$, $\mathbf{i}_2$, $\mathbf{i}_3$	local reference system (unit vectors) - $\mathbf{i}_1$ aligned with the beam axis,
$\mathbf{k}$	Bloch wave vector,
$\mathbf{E}$	symmetric part of the displacement gradient,
$\boldsymbol{\kappa}$	symmetric part of the curvature tensor,
$\mathbf{S}$	Cauchy stress tensor,
$\mathbf{M}$	couple stress tensor,
$\bar{\mathbf{m}}$	deviatoric part of $\mathbf{M}$,
l_1	length of the primary micro-beams ($l_1 = a/2$),
l_2	length of the auxiliary micro-beams ($l_2 \leq a\sqrt{2}/2$),
A	cross-section area per unit length along $\mathbf{e}_3$,
A_s	cross-section shear area per unit length along $\mathbf{e}_3$,
I	flexural inertia per unit length along $\mathbf{e}_3$,
E	longitudinal normal modulus,
G	shear modulus,
ν	Poisson ratio,
l	microscale characteristic length,
ρ	mass density,
N	axial force,