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# SPLASH EFFECTS IN PROPAGATION OF ELASTIC WAVES IN HETEROGENEOUS STRUCTURES

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***Problem statement.*** In contemporary Civil Engineering, heterogeneous structures and materials are prevalently employed. Illustrative instances encompass multi-span beams, perforated membranes and plates, stringer plates and shells, alongside a diverse array of composite materials.

The phenomenon of splash effects in the transmission of elastic waves within heterogeneous structures gives rise to notable dynamic manifestations. These include phononic band gaps, negative refraction, dynamic anisotropy, waves focusing, acoustically invisible cloaks, waves localization in structures with defects, and splash effects. A comprehensive overview of advancements in this domain can be found in the work by Hussein et al. [1].

***The purpose of the work.*** This study delves into the splash effects observed in the transmission of elastic waves within heterogeneous structures, specifically within a discrete monatomic lattice and a continuous layered structure, under the influence of an external pulse load. A noteworthy aspect of the pulse load scenario is the occurrence of local stresses at the microlevel, surpassing the magnitude of the initial excitation during transient wave propagation. This phenomenon stems from the spatial redistribution of energy due to structural heterogeneity, a phenomenon absent in homogeneous solids.

***Main part.*** Consider a semi-infinite ($x \geq 0$) lattice comprising uniform particles with mass $m$ interconnected by springs with negligible mass and rigidity $c$ (Fig. 1). The lattice experiences a pulse load $P\delta(t)$, applied at its edge $x = 0$. In this context, $P$ represents the force amplitude, and $\delta(t)$ is the Dirac delta function.

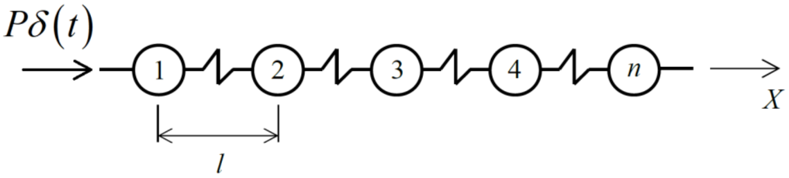

*Fig. 1. Monatomic lattice under consideration*

Colquitt et al. [3] introduced an advanced higher-order triple-dispersive dynamic equation to characterize the macroscopic behavior of the lattice across a broad frequency spectrum. Employing this continuous model, we apply the Laplace transform method [4] to derive an analytical solution for the pulse load problem. Utilizing the Runge-Kutta fourth-order method to numerically solve the original discrete problem. The results, depicted in Figure 2, showcase displacements $u$ calculated under the conditions $P/(cl) = 1$ and $t\sqrt{cm} = 1$, where $l$ represents the inter-particle distance. Remarkably, both the analytical and numerical solutions exhibit a commendable level of agreement.

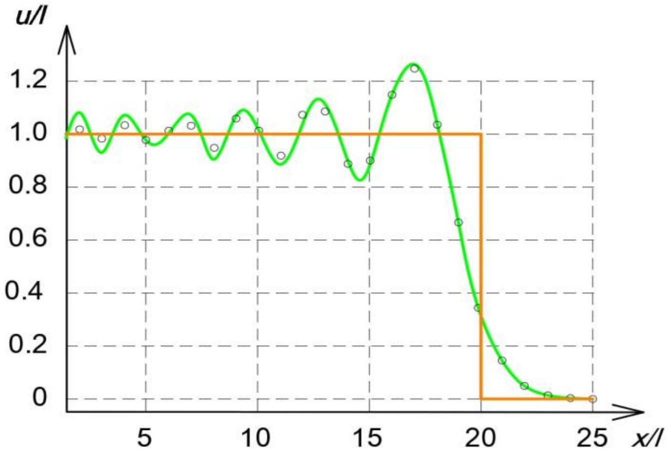

*Fig. 2. Transient waves in the lattice excited by the pulse load. Red – analytical solution; orange – non-dispersive solution for the homogeneous solid; dots – data of the numerical simulation*

Numerical simulations employing ANSYS are conducted to analyze the phenomenon of splash effects during the propagation of elastic waves within heterogeneous structures. Alternating layers of two materials characterize these structures. The model encompasses 50 unit cells, each with dimensions of 2×1×1 m. Each layer possesses a thickness of 1 m, and the overall length of the structure extends to 100 meters, as illustrated in Figure 3.

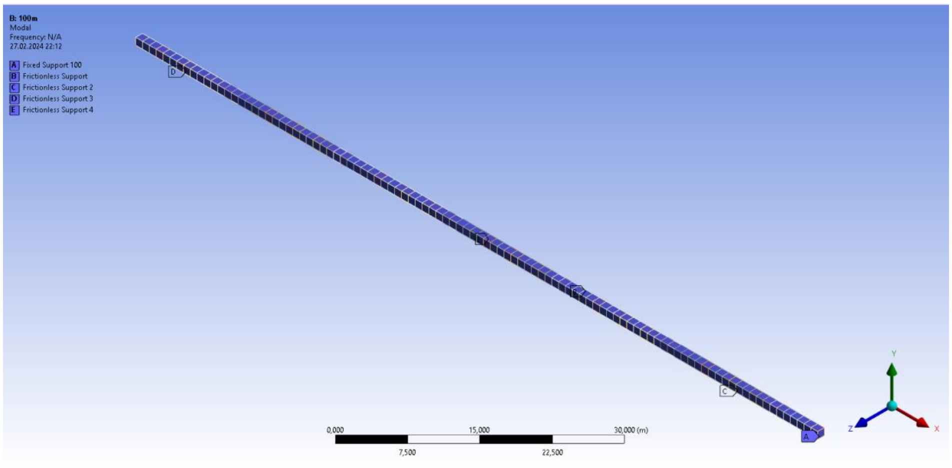

*Fig. 3. Basic geometry of the continuous layered structure*

Investigation pertains to the analysis of transient waves propagating along the x-axis. Macroscopic boundary conditions encompass a fixed support located at one extremity of the structure, a pulse load of 1000 N applied in the x-direction at the opposing edge, and a continuous support along the longitudinal facets. To elucidate, consider a composite structure comprising concrete and rubber, a prospective design for novel vibration and seismic isolation systems [5; 6]. The material characteristics are delineated in Table. Figure 4 visually represents the time-dependent solution for the normal strain in the cross-sectional area, specifically at a distance of 40 meters from the loaded edge.

*Table*

| Layer | Material | Density, kg/m$^3$ | Young’s Modulus, Pa | Poisson`s Ratio |
|---|---|---|---|---|
| 1 | Concrete | $2.3\times10^3$ | $3.1\times10^{10}$ | 0.33 |
| 2 | Rubber | $1.3\times10^3$ | $5.8\times10^5$ | 0.46 |

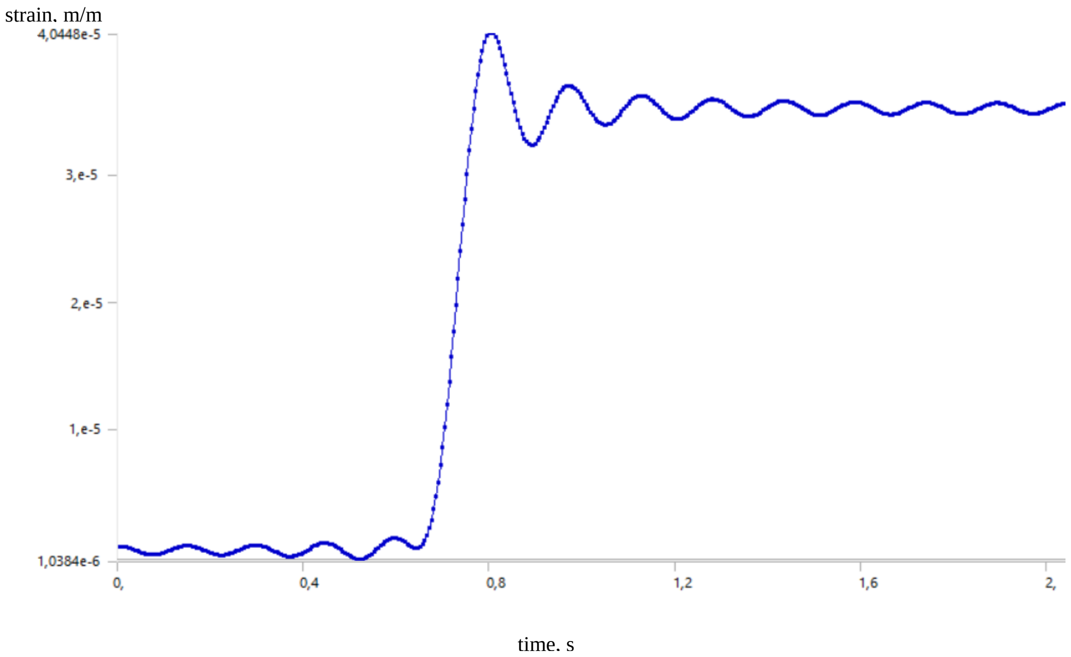

*Fig. 4. Normal strain in the layered structure induced by the pulse load*

***Conclusion.*** Examination of the findings depicted in Figures 2 and 4 reveals that within heterogeneous structures, there are instances where localized perturbations in both displacement and strain fields surpass the mean values observed in homogeneous conditions by a range of 17 % to 24 %. This phenomenon holds considerable significance in the context of dynamic failure and proves to be of paramount practical relevance in the formulation of novel designs for heterogeneous structures and materials. Furthermore, the methodologies devised in this study can be extrapolated to address multi-dimensional problems.

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