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WAVE PHENOMENA IN COMPOSITE RUBBER-SANDSTONE STRUCTURES USING ADINA PROGRAM

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Abstract: *In this paper the numerical solution of vibrations damper in form of cube made of sandstone and rubber cross located inside during technological process with the use of ADINA program is discussed. These days there exists many solutions at the market, which allow to reduce the mechanical waves caused by dynamical loads. Despite that fact there is just a few solutions involving composite materials application. By performing the numerical solution with the use of ADINA program significant mechanical wave reduction could be observed in the proposed composite. Moreover presented solution can be applied in the production process with such an ease and it could also be produced in modular form. Adopted sandstone material model to the performed analysis had very similar properties as widely available material, which is utilized in production of the YTONG airbricks. The rubber cross was described with the Mooney-Rivlin material model which is basically implemented in the ADINA program. It should be noted that presented solution can be treated as an innovative product, which not only allow to reduce vibrations from machines on the wall structures without the necessity of use additional anti-vibrations systems but also can be treated as an ecological product made of materials, which can be easily recycled.*

Keywords: Composite structures, wave phenomena, ADINA, rubber-sandstone, vibrations damping

1. Introduction

Wave phenomena due to its wide range of applications, are the subject of interest by many researchers, who in order to describe the problem of wave propagation in various different types of materials used both classical mathematical and finite element method approach. Mathematical models concerning the description of various types of wave phenomena was presented by Coulson (1982). The numerical analysis performed to validate the repaired lightweight steel roof structure, which had an excessive deformations due to the act of static and dynamical forces was presented in (Čajka, Krejsa, 2014). The problem of wave propagation in simple elastic structures was discussed in (Major, Major, 2014a), where authors presented both mathematical description of phenomena and the possibility of numerical solutions with the use of finite element method in the ADINA program. Sam authors afterwards published paper (Major, Major, 2014b), which concerned the comparative analysis of shockwave propagation in rubber material described by Zahorski (1959) and rubber described by Mooney-Rivlin (Mooney 1940; Rivlin 1948). Considerations of wave phenomena description in composite structures were presented by Kosiński (2007), Zhuang, Ravichandran G. & Grady (2003) and Verma (2013), whereas the vast literature overview covering all aspects of wave phenomena was included in (Wesołowski, 1989).

In case of civil engineering the wave propagation in material or structure is a phenomena, which should be strongly avoided therefore in that structures various additional elements reducing the dynamical and acoustic effects have to be utilized such as vibro-isolators and soundproof mats. The disadvantage of the above mentioned solutions is the lack of possibility to transfer significant static loads resulting in the necessity of application additional support components. That additional materials makes the construction more complex and the dimensions of such a structure may increase resulting in reduced usable area of the object.

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In this paper the numerical finite element method approach is presented in order to determine the mechanical wave propagation resulting from impulse load in a raw sandstone material and in a composite sandstone-rubber. Performed numerical analysis is an introduction to the research of this type of composite materials with the further possibility of application in construction industry as low cost material, easy in production as well as ecological product, which can be recycled. It should be noted that presented composite could be applied as the wall structure, which is exposed to the negative influence of vibrations, as a support system under machines, without the necessity of application other additional vibro-isolators.

2. Methods

In order to obtain approximate solutions of effective stress arising along the wave propagation through specified material under the influence of impulse load the ADINA program was chosen. The object of study comprised of the cube and three dimensional cross located at the center of cube gravity. The side of cube was assumed of 10 cm length, while the individual prism with a square base had dimensions 8×2×2 cm. At the bottom surface of the cube all six degrees of freedom were fixed, whereas on the top surface the impulse pressure load was assumed. In the time from 0 s to $1.111 \cdot 10^{-6}$ s the pressure increases from 0 kN/m^2 to 10 kN/m^2, releasing energy of load in the so-called first time step. Adopted model to the numerical analysis is presented in Fig. 1.

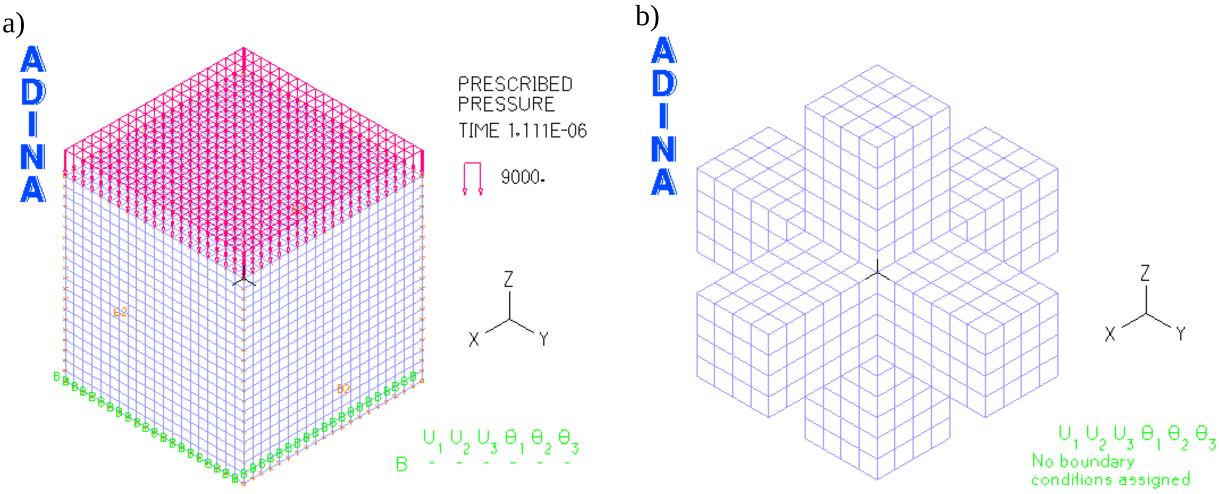

Fig. 1: Numerical model of composite rubber-sandstone cube (a), three dimensional cross made of Mooney-Rivlin material (b), respectively. Cross center of gravity lays exactly in cube center of gravity.

In order to describe cross rubber like material, existing Mooney-Rivlin ADINA program module allowing to describe rubber and foam material models was chosen. The sandstone material was assumed to be simplified to the linearly elastic material model. Properties of both materials utilized in the numerical analysis were shown in Table 1.

Tab. 1: Material properties of rubber and sandstone

Mooney-Rivlin material		**Sandstone material**	
Property	**Value**	**Property**	**Value**
C_1	*62780 [Pa]*	E	*86.00 [GPa]*
C_2	*8829 [Pa]*	ν	*0.125 [-]*
ρ	*1190 [kg/m³]*	ρ	*2650 [kg/m³]*

Discretization of the cube and cross area was done with the use of 8-node 3D-Solid finite elements, 0.5×0.5×0.5 cm each. In the case of model made of pure sandstone without rubber 8345 finite elements were obtained for the whole structure, whereas in the composite 7705 finite elements were described with sandstone material and 640 with rubber material, respectively. In both model cases there were 9265 nodes.

3. Numerical results

In this chapter in Fig. 2 the approximate numerical results in the graph form of effective stress plot concerning the mechanical wave propagation under the influence of impulse load for the pure sandstone model cross-section and composite sandstone-rubber cross-section with the use of ADINA program have been presented. Mentioned cross-sections comprise the transition of YZ plane on X axis at distance equal 5 cm from the beginning of the global coordinate system.

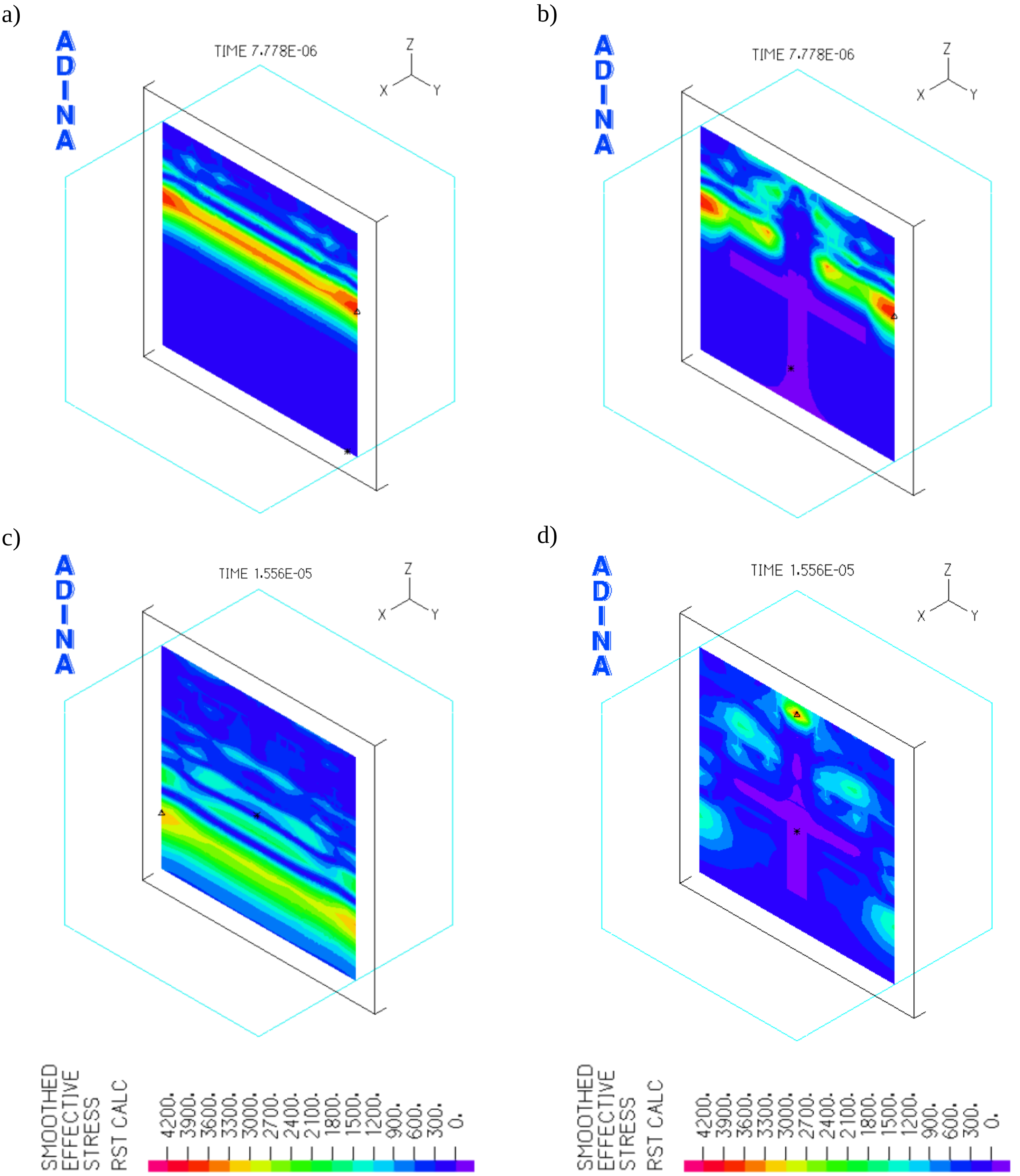

Fig. 2: Wave propagation under the impulse load for a different time steps in the sandstone material (a, c,) and in the composite rubber-sandstone (b, d), respectively. Scales presented in Pa units.

By analysis of the obtained numerical results, it can be clearly visible that at the $7.778 \cdot 10^{-6}$ s time step in case of the composite material (Fig. 2b) characteristic refraction of the effective stress distribution was obtained where wave pass through rubber material and wave propagate almost only in the sandstone material in comparison with the homogeneous cube made of sandstone (Fig. 2a). Moreover the value of effective stress near the outer part of cross-section area is almost the same in presented composite and pure sandstone, however in the inner area of the composite (Fig. 2b) near the rubber, cross wave propagation is damped around twice. Comparing both numerical models at the time step equal $1.556 \cdot 10^{-5}$ s it can be observed that in the composite, the mechanical wave propagation is significantly reduced (Fig. 2d) and values of presented effective stress are four times lowered than in the homogeneous sandstone cube (Fig. 2c).

Significant differences between homogeneous sandstone cube and the composite allow to conclude that the presented composite is a well vibrations damper, while the rubber cross structure allow to reduce vibrations for about the same value with the assumption that the value of dynamical force placed on any surface of cube is exactly the same. An additional advantage of the presented solution is fact, that in the realization process of any structure, which have to reduce vibrations, the problem of correct positioning of element can be neglected due to the utilized plane symmetry in all three mutually orthogonal planes passing through the cube center of gravity.

4. Conclusions

In this paper the finite element method approach was presented in order to obtain approximate solutions of wave propagation phenomena in two different materials – pure sandstone and composite made of sandstone and rubber.

Performed numerical analysis allowed to observe the dispersion of mechanical wave resulting from impulse load in the composite model in comparison with the homogeneous cube made of sandstone. Due to the significant reduction of dynamic effects and the ability of transferring the static load, presented solution may be treated as desirable to utilize from the civil engineering point of view in any construction which is exposed to soil vibrations, machines vibrations or it is necessary to reduce the acoustic waves and also it is required to transfer significant values of static load. Moreover applied plane symmetry of discussed composite allow to utilize it in the building structures without the risk of incorrect placement of the element. It should also be noted that connection of sandstone and rubber material allow to obtain environmental friendly elements since both materials can be easily recycled. It is also important that despite of obtained satisfactory results from the numerical analysis, it is recommended to make the experimental studies which would confirm the validity of presented solution.

References

Čajka R. & Krejsa M. (2014) Validating a computational model of a rooflight steel structure by means of a load test, Applied Mechanics and Materials, 501, pp. 592-598.

Coulson C.A. & Jeffrey A. (1982) Fale. Modele matematyczne. WNT, Warszawa.

Kosiński S. (2007), Fale sprężyste w gumopodobnych kompozytach warstwowych. Wydawnictwo Politechniki Łódzkiej, Łódź.

Major I. & Major M. (2014) Modeling of wave propagation in the ADINA software for simple elastic structures, Advanced Materials Research, 1020, pp. 171-176.

Major M. & Major I. (2014) Comparative analysis of the distribution of effective stress in Mooney and Zahorski materials using ADINA software, Advanced Materials Research, 1020, pp. 165-170.

Mooney M. (1940) A theory of large deformations, Journal of Applied Physics, 11, pp. 582-592.

Rivlin R.S. (1948) Large elastic deformations of isotropic materials, I Fundamental concepts, Philosophical Transactions of the Royal Society of London A 240, 822, pp. 459-490.

Verma K. L. (2013) Wave propagation in laminated composite plates, International Journal of Advanced Structural Engineering, 5:10, Springer Open Journal

Wesołowski Z. (1989) Akustyka ciała sprężystego. Państwowe Wydawnictwo Naukowe, Warszawa / Poznań.

Zahorski S. (1959) A form of elastic potential for rubber-like materials, Archives of Mechanics, 5, pp. 613-617.

Zhuang S., Ravichandran G. & Grady D.E. (2003) An experimental investigation of shock wave propagation in periodically layered composites, Journal of the Mechanics and Physics of Solids, 51, 2, pp. 245–265.