POSSIBLE MEASURES OF TAKING-OVER/ DYNAMIC CONTROL OF SEISMIC ACTIONS APPLICABLE TO URBAN UTILITY SYSTEMS. SEISMIC WAVES DEFLECTION/ DAMPING USING METAMATERIALS

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Abstract: Nowadays, an accurate seismic prediction regarding the date, location and magnitude is still a challenge, thing that implies taking into consideration efficient, preventive, seismic risk management measures, not only for civil buildings but also for urban utility systems UUS. The usually adopted measures regard at the same time conceptual solutions and immediately post-seism measures. At the present, within inhabited municipalities, UUS serve a relatively large number of beneficiaries being developed on relatively large areas with a high duty cycle. These systems may be exposed, during their functional life cycle to seismic effects. Taking into consideration the developing tendency of urbanization process, the preventive protection to earthquake of these city vital lines becomes extremely important. The UUS seismic risks are associated especially with the possibility of tightness loss as well as their integrity, with major consequences on Man-Goods-Environment, respectively: the population and consumers deprivation of vital resources, explosion generation, flooding; additional destabilization of ground; underground water infestation; local eco-system threat, that may lead to important human lives and goods loss. These possible risks must be very carefully managed. The actual technical regulations do not cover the whole area of possible seismic risks of UUS. The recent discoveries regarding the solutions for a real time warning cannot always lead to a protection in due time. The international scientific community is more and more involved in developing several researches regarding efficient taking over measures, respectively dynamic control of seismic actions deflecting the seismic waves from the major risk area of degradation. These measures exploit the present scientific discoveries referring to a. total or partial, invisibility process to waves, of protected structures and, respectively, to the wave magnitude damping. In order to identify the solutions for the preventing seismic protection of UUS components, within the article there is presented a synthesis of possible measure, such as: invisibility cloak, invisibility textile and wave dampers, respectively.
Key words: urban utility systems, seismic risk management, invisibility to seismic waves, metamaterials, antiseismic shield

1. EARTHQUAKE. DESCRIPTION AND SEISMIC WAVES

1.1. Earthquake and seismic waves

The non-homogenous structure of the earth shell and the dynamics of different processes and phenomena that take place within its mass, lead, among others, to a continuous accumulation process of energy within component rocks and deformation/weaken of component materials structure, developed at the earth surface through ”earthquakes” (Figure 1).

The phenomenological support of earthquakes is represented by the elastic waves which are produced within seismic fixed points and disperse in all directions to earth surface.

In order to identify and, respectively, understand the phenomenology of possible measures of earthquake active control, we will briefly present the interest elements in describing/characterizing these waves, respectively the functioning, dispersion, interaction manner with the dispersion environment.

1.2. Seismic waves description

● ***Characteristic measures of seismic waves.*** The seismic waves may be characterized by: *the longitudinal seismic speed within an elastic, solid and finite environment, energy, energy flux and elastic wave intensity,* [4, 6].

● ***Specific phenomena displayed within the wave dispersal process*** through an elastic environment may be explained applying different methods. Important in describing the seismic wave dispersal are: *Huygens Principle (Figure 4)* and *Dopple Effect* [4, 6].

● ***Phenomena which appear at the separation surface between two different elastic environments:*** at the separation surface between two environments, the seismic wave may suffer, according to phenomena authors:

– *reflection* : deflection from the initial direction but remaining within the same elastic environment;

– *refraction*: deflection from the initial direction and passing to the second elastic environment.

● ***Elastic waves interference***, the phenomenon when at a certain point in space the effect of two or several different elastic waves is superposed (derived from different sources). Microscopically, the phenomenon consists in environment particles solicitation to perform simultaneously several oscillatory moves. The composing rules of these movements (positions/elongations, speeds, accelerations) is based on the superposition principle [4, 6].

● ***Seismic waves damping:*** represents the phenomenon of *decreasing the wave intensity and amplitude as a result of interacting with the elastic environment*. As a base for this process there are two main mechanisms which appear when a wave interacts with the elastic environment: *wave/energy spreading* and *absorption*.

Within an elastic environment, the seismic wave amplitude, ”A”, diminishes, in relation to its size when entering the elastic environment, exponentially varying with distance ”x” in comparison to the entering point, according to the relation:

$$A(x)=A_0e^{-\alpha x}, \tag{1}$$

where: ”α” is the damping coefficient of the seismic wave amplitude (it depends on the elastic environment proprieties). The elastic wave intensity, ”T”, is proportional to the amplitude square, A^2 and varies in relation to the distance ”x”:

$$I(x)=I_0e^{-\alpha x} \tag{2}$$

● ***Elastic waves dispersion.*** It appears within the dissipative environments: the phase velocity is according to frequency, so the crests of constant phase of different frequency waves will disperse with different velocities, thing that leads to the conclusion that the dissipative environment is also a dispersive environment (the phase velocity being according to the wave length). The final effect of dispersion within a dispersive elastic environment consists in ***wave package ”decomposition”.***

● ***Waves diffraction:*** the phenomenon of avoiding obstacles by the waves. The diffraction is produced when the size of slit (L) is of the order of wave length size of incident wave $L \approx \lambda$.

1.3. Seismic waves description

When the earthquake activates, from the epicenter (Figure 1) shock waves will leave (Figure 2) and these are: a. *body waves* which disperse within the Earth: primary/”P” type and secondary/”S” type; b. *surface waves* which disperse at earth surface or alongside; where *Love, Rayleigh, Scholte*, are briefly described in table 1.

The seismic shock is transmitted through periodical elastic dislocation of material particles and shifts with a velocity that depends on the elastic proprieties and the environment density where the seismic wave disperses. The seismic disturbance is described as a *crest of wave* which is level until far from the source.

The seismic waves, as any type of waves, *reflect* and *refract*, when the features of the material met by the crest of wave change.

A level wave disperses in a direction parallel with its normal line named *seismic ray*. At the border between two environments with contrasting acoustic impedance, the seismic waves P and S are reflected and refracted in other two waves P and S. The theory describing the behavior of dispersion waves at the interface between two materials is based on Huygens principle: *all the points on a crest of wave may be regarded as punctiform sources for producing new spherical waves.* The new crest is the secondary waves envelope. On this principle, Snell and Descartes stated the refraction law, initially proposed in optics but applicable to elastic waves, too: the proportion between the incident angle sinus and the refracted angle sinus is equal with the proportion between the dispersion speeds of the waves within the two environments.

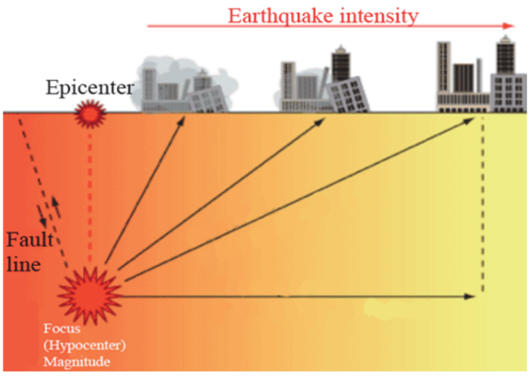


Fig. 1. Earthquake. Features [15].

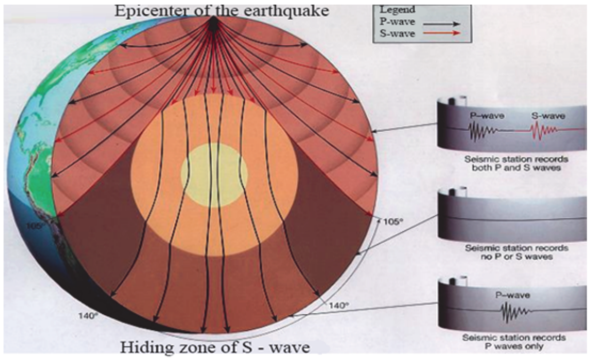


Fig. 2. The dispersion manner of seismic body waves [15].

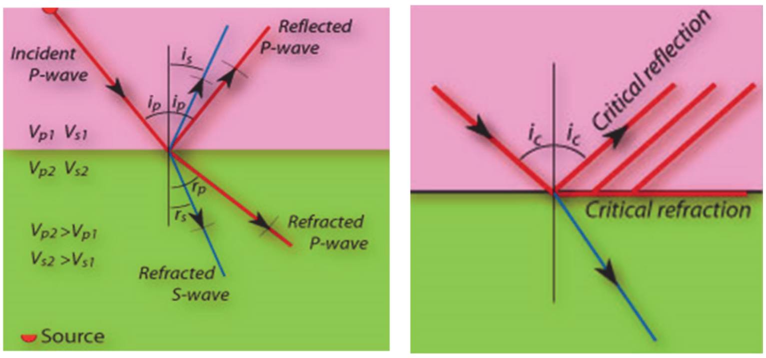
The application of this law for P and S wave reflection and refraction leads to relation 3:

$$\sin[i_p]/V_{(P,1)} = \sin[i_s]/V_{(s,1)} = \sin[r_p]/V_{(p,1)} = \sin[r_s]/V_{(s,1)} \quad (3)$$

where S may be polarized as a result of interacting with a limit (a surface marking an impedance contrast).

It results: SH waves, where the oscillations are perpendicular on the dispersion direction and parallel with the limit line; and SV where the oscillations are perpendicular on the dispersion direction and perpendicular on the limit line.

On a separation limit line between two environments, the reflection and refraction phenomena (Figure 3) may be eventually accompanied by the wave conversion from a type to another (P ↔ S), indicated in Figure 4.



General description Critical reflection and refraction

Fig. 3. The reflection and refraction phenomenon of the waves at the separation surface between two environments.

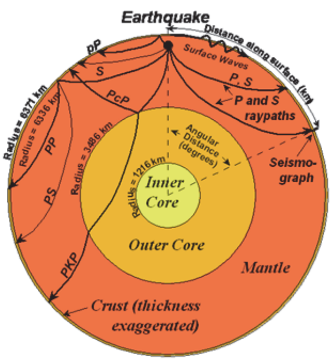


Fig. 4. Applying Huygens principle at the separation interface of two terrestrial layers.

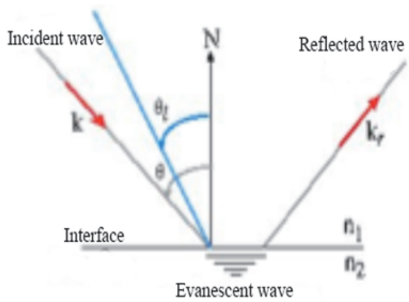
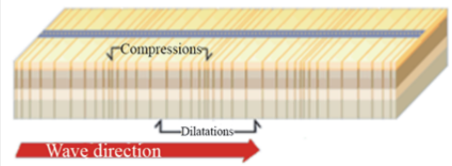


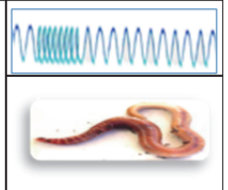
Fig. 5. Generation of evanescent wave.

Table 1. **Seismic wave description [15, 18]**

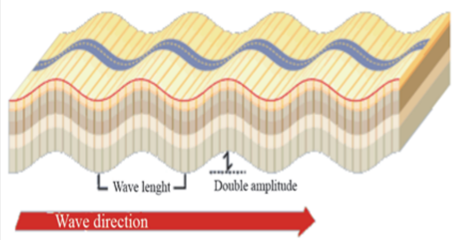
I. "Body waves". *They disperse within the earth shell volume around the epicenter,* with a speed dependent on the crossed material*

1. ***Primary/"P" type/:*** longitudinal, compression waves; disperse with a high speed; reach the surface first; the particles dislocation/shift is parallel with the wave dispersion direction, compression□dilatation, ("push and pull" type, resembling a brandling or a spring oscillation); the dispersion direction is parallel with the normal line at the crest of the wave; the wave amplitude is directly proportional with the earthquake magnitude/energy; it carries approx.. 20% of the earthquake energy; the dislocation manner is similar to the sound through the air; it is not dangerous for buildings; the dispersion speed of "P" waves through the isotropic elastic environment is given by the relation: $V_p = \sqrt{(k+4/3\mu)/\rho}$, where: ρ=density; k=compressibility global coefficient; μ= detrusion module / rigidity**.



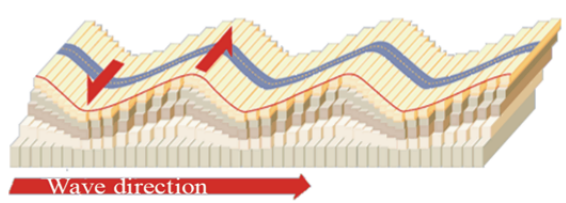


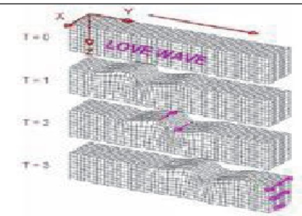
2.*Secondary body waves/"S" type/:* disperse with a lower speed that the primary waves: they reach the surface after them; disperse in a variable thickness layer, in the vicinity of the earth shell; are represented by periodical bendings perpendicular on the dispersion direction; determines the *particles dislocation of the perpendicular (transversal)soil against the dispersal direction;* they are *bending, detrusion waves;* their dislocation is similar to the snake walk (left-right wavy movements towards ahead); it is felt at the surface as a detrusion movement, libration on a horizontal plan; *they do not disperse in liquid environments;* they are usually stopped by the external nucleus of the Earth; their speed is 4,06 km/s; they carry approximately 80% from the total energy of the earthquake; they are dangerous; they cause destructions proportional to the earthquake magnitude and the oscillation length; the buildings collapse because of resonance entering of its own frequency oscillation of the building structure with the incident wave frequency (case when the destructive effect is strongly amplified); the dispersal speed of "S" waves within the isotropic elastic environment is given by the relation: $V_s = \sqrt{\mu/\rho}$, where: ρ=density;***.



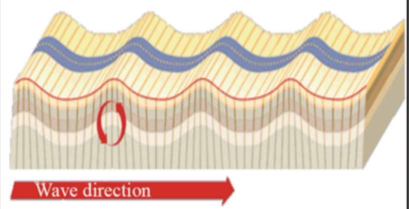
II. At the Earth surface. Their effect may be compared with the wavelets on a lake surface. Their dispersion speed is lower ($1 \sim 3\ km/s$ with several variations according to the wave depth and length) in comparison with the body waves, but their amplitude is usually higher and decreases exponentially to the depth. The wave lengths are of order of $100m$ and the frequencies are almost $10 \sim 30Hz$, representing the inferior end or under the acoustic frequency. They induce the soil waving and emphasize the destructive effect of the secondary waves. They disperse slower than the depth waves and are the most destructive because of the low frequency, long period and large amplitude.

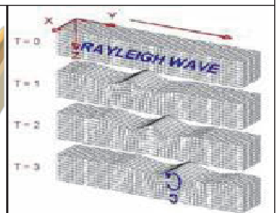
3. *Love wave*: the polarized detrusion wave, guided by an elastic layer; the movements are longitudinal and transversal, side in horizontal plan, similar to the "S" waves without vertical movement; it disperses with a speed of approx. 4km/s; it induces an horizontal shimmying which is the cause of multiple damages.



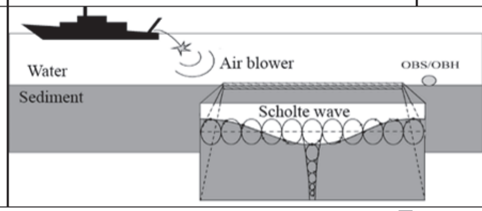


4. Rayleigh wave: its movement is complex: transversal; elliptical in vertical plan; it is similar to the dust carried by a wave, being composed of vertical and horizontal movements.





5. Scholte waves: waves that disperse at the limit between a liquid and a solid (Eg. sea soil).



Scholte waves produced by the interaction of acoustic / seismic waves with the solid-liquid interface on the ocean bottom.

*the speed increases with the deepness, because the crossed material becomes denser** for the majority of rocks k∈ (30GPa, 150GPa); ***for the majority of rocks μ□ (20GPa, 80 GPa)

Passing from a denser environment (with a higher refraction index) to a less dense environment, the refraction angle is higher than the incidence angle. Starting from a normal incidence and increasing gradually the incidence angle, a certain value is reached, named *critical angle* or *limit angle*, where the appropriate refraction angle has the value of 90°, that is the refracted ray becomes tangent on the separation surface between the environments. In the same time, the refracted energy decreases to zero. Increasing the incidence angle, refraction cannot be produced, the whole incident energy is reflected.

The Earth may be described as a pile of geodesic layers whose density increases with depth. A seismic ray which leaves from the surface will be refracted at every interface until it reaches the critical reflection angle. In its way back to the surface, the ray passes successively through the same layers, but in a direction that decreases the wave dispersion speed and layers density. Symmetrically, the ray reaches the surface at an angle equal to the initial incidence angle. Snell-Descartes law applies successively for each refractions:

$$\sin[i_n]/V_n = \text{constant} = p \tag{4}$$

Constant line p, respectively the ray parameter is characterized for a certain ray with emergence angle i_l and speed V_l on the layer's surface. If V_m is the speed of the deepest layer, then the value of p must be: p=1 / Vm.

2. TAKING – OVER / DYNAMIC CONTROL MEASURES OF SEISMIC ACTIONS

*Within the paper the authors present some recent and innovative measures for taking –over, dynamic control respectively of seismic actions effects which interact with the urban utility systems, solutions that have not been proposed for this purpose until now and these are **wave deflection measures or their decrease:***

- ***Anti-seismic shield.*** It carries out the partial or total deflection of seismic waves, using different invisibility principles and respectively different methods (*invisibility cloak, invisibility textile*, and others) and specially designed structures from metamaterials or similar to them.
- ***Wave damper***. It acts on seismic waves, transforming mechanical, vibration energy in sounds and thermal energy.

2.1. Anti-seismic shield

2.1.1. Mathematical solving of the equations with partial derivatives which describe the seismic wave dynamics

In order to practically accomplish the invisibility process a major contribution has been brought by the mathematicians [6], who solving the equations with partial derivatives describing the seismic wave dynamics, respectively their pathway and simulating on computers the elastic wave behavior in different dispersion environments, they could prove how the wave pathway which disperses in a given environment may change in order to avoid a given obstacle.

2.1.2. Meta-materials

In order to form the invisibility textile, the materials have to be designed and the principles that are at the base of the designing method combine different fundamental researches on the wave dispersion in order to obtain some foreseen results.

There have been exploited the transformational optics principles [1], and those of mathematical method to accomplish geometrical transformations of space which allow bringing on a disk all the waves dispersing to infinite.

The idea of invisibility may be expressed as follows: *if a region in the space distorts, the luminous wave pathway distorts, too.* So if the radiations are deflected in order to avoid an area, all that is in the area becomes inaccessible, so invisible.

Space distortions may be carried out modifying the physical features of the environment, respectively intervening on the refraction index.

The natural materials do not have qualities necessary for this purpose, reason for which it has been tried, with the help of nanotechnologies, to invent some composite materials with features as closer as possible from the wanted ones. The designing of a metamaterial which allows the accomplishment of a cloak perfectly invisible was not succeeded, but it was succeeded the acquiring of some metamaterials which allow the sound wave, tide wave and seismic wave deflection.

Meta-materials are *compound artificial materials which comprise features that are not normally found in natural materials.* The newly formed structure may be a periodical structure, if the same ”pattern” is identically repeated several times (Figure 6).

Meta-materials have negative permittivity and permeability. They are called *left hand materials,* that is *with negative refraction index (obtained by periodical structure of the material)*.

The consequences of this behavior is best described using Snell-Descartes law for metamaterials with *negative refraction index* (Figure 7).

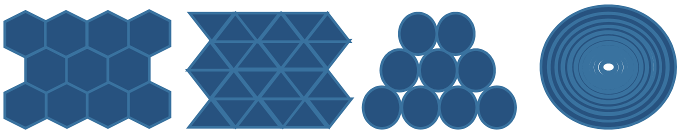


Fig. 6. Different types of mate-materials.

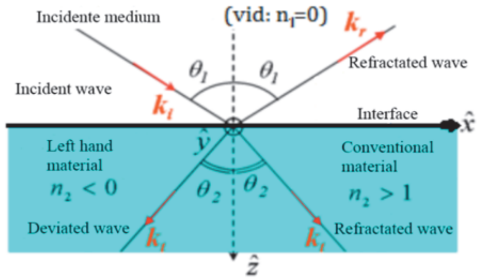


Fig. 7. Application of Snell-Descartes law.

In the case when the wave makes contact with a metamaterial this one gains a negative refraction index and will be refracted, without crossing the material in the normal direction. It changes in the same time the environment.

2.1.3. Possible behavior of interaction between seismic wave – meta-material

When meeting a meta-material, the seismic waves may suffer *reflection, refraction or interference* processes. Waves with the same frequency and the same amplitude may interact, derived from the same source.

There may be a. *constructive interferences,* case when the two waves “gather” and b. *destructive/ misphased interferences,* when the two waves “delete” one another.

The simplest method to interact with a seismic wave is to modify the general features of the dispersion environment, acting on the soil density and implicitly on the wave speed. The solution proposed by the French specialists consisted in modifying the soil features in the area around the protected objective, with a certain arrangement of the materials. The arrangement is conceived by some numeric patterns which solve the equations of seismic wave emissions from the epicenter towards the objective, testing different solutions and configurations.

Meta-materials conceiving for seismic wave deflection may be accomplished with computational environments of softwares as: Gmhs, GetDP, COMSOL multiphysic, ChemCad, ANSYS, SchetcUP, etc.

2.1.4. Functional principles

The anti-seismic shield has as a base the wave deflection principle, promoted at the beginning for electro-magnetic wave deflection. The solution was announced in 2006, proved in August 2012 by a panel of European specialists (S. Guenneau, C. Amra, S. Enoch, and others) and developed on two distinct technologies: *invisibility cloak; invisibility textile.* The shield is recommended for the protection of I importance category buildings. *The deflected waves may affect the buildings behind the deflected crest of wave.* There have not been researched the application methods for the building preponderantly developed on one dimension (streets, networks).

The process of invisibility may be accomplished on different principles and with different methods. Until now two relatively distinct solutions have been researched/experimented: invisibility “cloak” or invisibility “*textile/carpet*”. The invisibility process consists generally in wave deflation by special conceived/designed materials, named *metamaterials* or other mechanisms which modify the structure of some environments in the vicinity of the protected objectives (example of soil) with the purpose of homogeneity deconstruction.

The ”*invisibility cloak*” represented in Figure 8 implies its total transparency. So “the cloak” must force the incident waves to avoid the area they protect. In order to make an objective invisible / to hide it in the way of the waves this one must be covered with a material which does not reflect the respective waves and does not absorb the waves energy, determining to avoid the objective.

The “invisibility textile/carpet” represented in Figure 9 consists in hiding an object located in front of a level surface: in this case, the light reflection on this surface is not modified by the presence of the object. Normally, a surface which is not level, reflects the light in multiple directions. In this case, *the invisibility principle consists in the variation of the wave dispersion speed* so that, at the output, the reflection wave crest to be as level as possible, respectively, not to be distorted by the object presence. In this case the wave speed is slowed down.

In Figure 9 the numeral simulation is indicated for a tri-dimensional structure conducted at Karlsruhe Institute, in Germany. It may be observed how, a dished surface, which seems level, hides everything under it. The radiation/ incident wave (red) is reflected (in bleu) as if it meets a mirror. The metamaterial had inexistent features in nature and the objects shape make them invisible and inferior to observation methods.

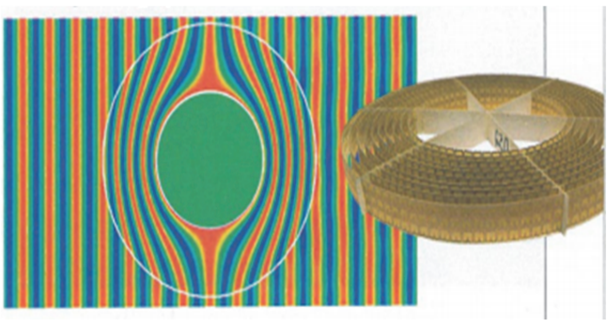


Fig. 8. An invizibilisation cloak/disk [18] .

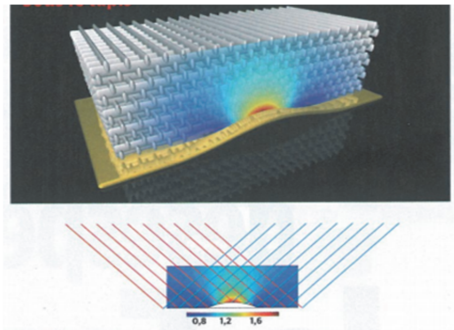


Fig. 9. Invizibilisation textile/carpet [16].

A solution to damper the seismic waves has been proposed by the French specialists Mohamed Farhat, Sebastien Guenneau and Stefan Enoch. The solution consists in concentric rings ranges, from plastic, cooper and other four materials, different in hardness and flexibility, which may substantially damper the seismic waves deflecting them around the protected objectives. The imagined device has effect on the seismic surface waves (the most destructive), which dampers them.

2.1.5. Practical methods to implement the anti-seismic shield

The shield pattern and the functioning scheme are presented synthetically in Figure 10 and Figure 11. The idea of this shield belongs to Sebastien Guenneau, who after getting used to the basic principles which may generate the invisibility effect (at the Imperial College in London), by deflecting electro-magnetic waves, subsequently proved that the principles may be applied similarly for the deflection of any kind of waves (tide, sound, thermal, mechanic).

The first experimental project of deflection shield for seismic waves was accomplished at Grenoble, France, in 2012 by the researchers from Fresnel Institute in Marseille, Ménard company and a specialist in soil densification.

Using the antiseismic shield may become in the future the most appropriate solution to prevent the risks of disaster generation due to earthquake impact on urban utility systems.

2.1.6. The wave damper and Seismic wave guide

The solution seems to eliminate the disadvantage of antiseismic shield, practically acting on seismic waves, whose mechanical, vibration energy practically transforms it in sounds and thermal energy.

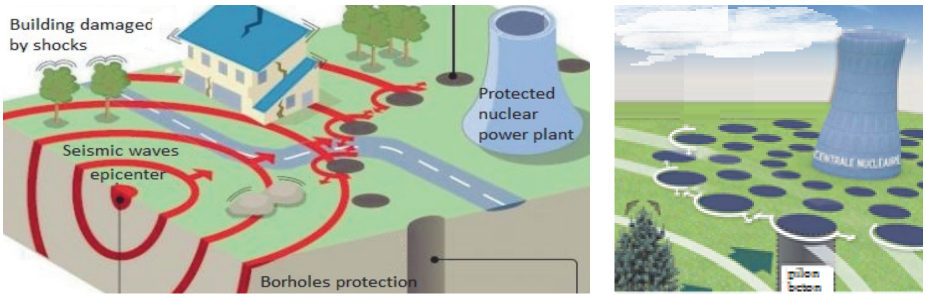
The device has been proposed by specialists Sang-Hoon Kim and Mukunda P. Das [2] and it is a cylindrical capsulated wave guide which creates a stopping band of seismic wave, converting the seismic wave in an evanescent wave (Figure 5) for a certain frequency level without reaching the protected objective.

Recent development in metamaterials science opens a new direction in order to control the seismic waves. Farhat et al. proposed a protection pattern in order to control the waves distortion dispersed within thin heterogeneous isotropic plates. The system of elastic detrusion waves crosses easily the material than reflects or disperses at the material surface.

They propose a metamaterial that acts as a damper converting the destructive seismic wave in an evanescent wave using the imaginary speed of the wave stopping band.

It was proposed the execution of a seismic wave damper introducing some resonators in the soil around the protected objective.

The amplitude of the seismic wave which passed these resonators, with the role of wave guide, is exponentially decreased by the imaginary part from the wave vector, at frequency levels of negative module. Waves damping with different frequencies may be obtained mixing several types of resonators.



The anti-seismic shield is made of concrete pillars, deeply grounded (several meters) and disposed in concentric circles around the protected objective.

a. Experiment conducted at Grenoble [19] b. Experiment conducted at Lyon [12]

Fig. 10. Models of anti-seismic shields for buildings .

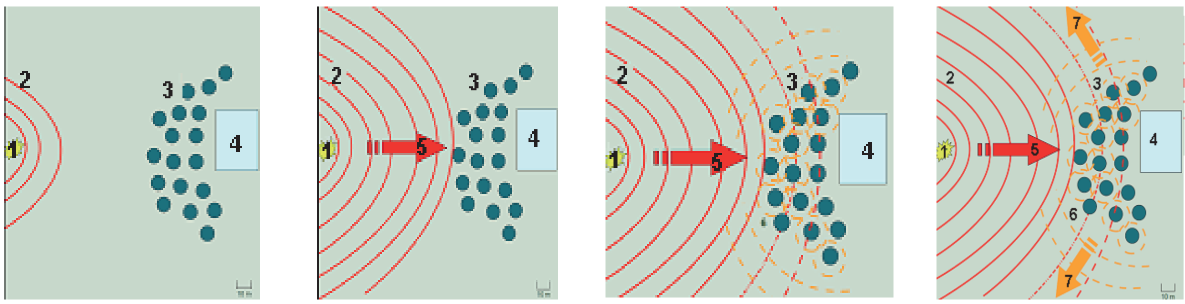


Fig. 11. Presentation scheme of the composing and functioning principle of anti-seismic shield [20]: *1* – epicenter/shock area; *2* – shock waves; *3* – anti-seismic head (protective holes); *4* – protected objectives; *5* – seismic wave dispersion; *6* – wave interference; *7* – wave deflection.

For a level seismic wave, with wave length λ, dispersing in direction *x*, the wave amplitude is reduced exponentially with distance x, according to the below relations:

$$Ae^{ikx} = Ae^{i2\pi nx/\lambda} = Ae^{-2\pi|n|x/\lambda}. \quad (5)$$

The final amplitude A_f (final magnitude M_f), for the outcome moment/ point „i" of the wave in wave guide M_f it may be calculated its amplitude function A_i for magnitude M_i from the moment/initial point/income, "0", of the seismic wave in the wave guide, according to equation 6.

$$A_f = A_i e^{-2\pi|n|x/\lambda}. \quad (6)$$

The amplitude of seismic wave is exponentially reduced passing through the wave guide of metamaterials.

If in the amplitude relation it is introduced the magnitude relation, we will obtain the Dependence relation between the final and the initial, expressed according to the magnitude:

$$A_0 10^{M_f} = A_0 10^{M_i} e^{e^{-2\pi|n|x/\lambda}}. \tag{7}$$

The wave guide width, $x \rightarrow \Delta x$, may be obtained using the logarithm of the two members of the liaison relations final magnitude/initial magnitude.

$$\Delta x = \frac{\ln 10}{2\pi}\frac{\lambda \Delta M}{|n|} = \frac{0.366\lambda}{|n|}\Delta M, \tag{8}$$

where, $\Delta M = M_i - M_f$.

In order to have a narrow wave guide a material with a high refraction index is desired.

The specialists have designed a wave damper relatively easy to make and build (Figure 12).

The cylinder size may be estimated using the analogy between the electric circuits and mechanic pipes.

$$L = \rho l'/S, \qquad C = V/\rho v^2, \tag{9}$$

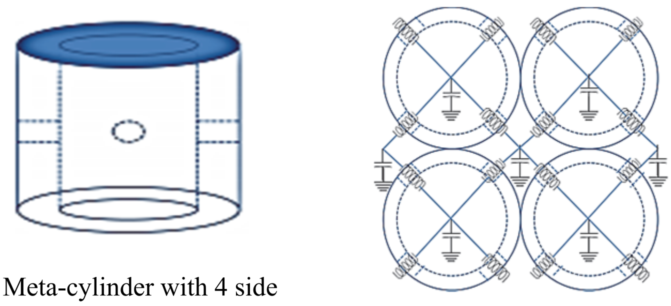
where: ρ is the density within the volume, l' is the effective length, S is the cross section area, V is the volume and v is the inner speed.

The resonance frequency is given by relation:

$$\omega_0 \simeq 1/\sqrt{LC} = \sqrt{Sv/(l'V)}. \tag{10}$$

Within the meta-cylinder, l' is the effective length which is given by the relation $l' \cong l + 0.85d$, where l is the hole length or the cylinder thickness, and d is the hole diameter.

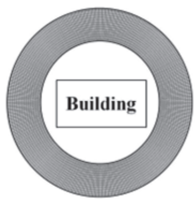
Meta-cylinders may be concrete cases, of any shape, with different side holes. Different models of resonators may cover different types of resonance frequency of seismic waves. That way it is produced a dissipation of seismic wave energy in the wave guide and the absorbed energy will be transformed in sound or heat. This aspect makes that the wave guide temperature to increase according to the energy magnitude which reaches the wave guide.



a. Meta-cylinder with 4 side holes (the cylinder size is lower than the wave length of surface waves)

b. A combination of 4 meta-cylinders and electric analogy

Fig. 12. Wave damper [2].



c. Seismic wave guide with several meta-cylinders. Top view

Fig. 13 [2].

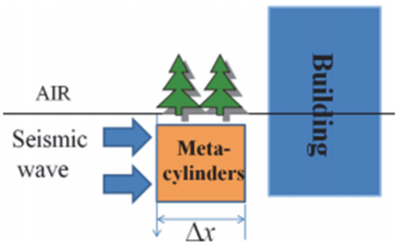


Fig. 14. Anti-seismic barrier with metamaterial (MTM) for building protection [2].

A vertical overview of the metamaterial barrier with several meta-cylinders is in Figure 13. The depth of wave guide must be at least equal with the depth of the protected building base but it is not necessary to be higher than the wave length of the surface waves. The complete form of the wave guide is the aseismic cylindrical cover of several concentric rings (Figure 13).

3. URBAN UTILITY SYSTEMS

The urban utility systems are vital systems for an urban locality in the event of an earthquake. According to the provided functions, the number of persons and the served objectives, tightness loss and their integrity, as a result of some seismic actions on components, it may be the cause of some disasters. The analyses and the researches conducted by authors on the behavior of these systems (old or new) to seismic actions and respectively the possible consequences of tightness loss and / or their integrity [8, 9], correlated with the active control techniques of wave deflection process, revealed the necessity of identifying some efficient measures of dynamic control of UUS behavior. In order to identify some efficient solutions it is recommended to use the concept ”Symbiosis in Development”/SID [20].

4. CONCLUSIONS

In this paper there are presented some recent measures regarding the decrease of major earthquake effects on the utility urban infrastructures, applying invisibility methods assisted by innovative technologies, respectively anti-seismic shield and seismic dampers.

The paper describes the basic principles of the invisibility methods of seismic waves, with details regarding the metamaterials and emphasizing the possibility of applying these measures with the purpose of decreasing the earthquake effects on the urban utility systems existing within urban area with a high seismic hazard.

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MĂSURI POSIBILE DE PRELUARE/CONTROL DINAMIC AL ACȚIUNILOR SEISMICE APLICABILE SISTEMELOR DE UTILITĂȚI URBANE. DEVIEREA/ATENUAREA UNDELOR SEISMICE CU AJUTORUL METAMATERIALELOR

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Rezumat: În prezent, predicţia exactă a seismelor, rămâne un deziderat, ceea ce conduce la luarea în considerare a unor măsuri eficiente, preventive, de management a riscurilor la seism, atât în cadrul structurilor de clădiri civile cât și în cazul sistemelor de utilități urbane [SUU]. Măsurile uzuale adoptate au vizat a. soluțiile/metodele conceptuale (valabile pentru construcții noi sau modernizări structurale); precum şi b. soluțiile imediat post seism (gestiunea operatorie s.a). La ora actuală, în municipiile populate, SUU deservesc un număr relativ mare de persoane, se întind în spațiu pe areale relativ mari, fiind proiectate cu durată mare de funcționare. Riscurile la seism ale SUU sunt legate îndeosebi de posibilitatea pierderii etanşeităţii precum și a integrității lor, cu consecințe majore asupra Omului-Bunurilor-Mediului, respectiv: privarea populației și consumatorilor vitali de resurse utile/vitale (apă, căldură, gaze, energie); generarea de explozii, inundații; destabilizări suplimentare ale terenului; infectarea pânzelor freatice; afectare eco-sistemelor locale; pierderi importante de vieți omenești și bunuri materiale. Recentele descoperiri privind soluțiile de avertizare în timp real nu conduc totdeauna la o protecție în timp util. Comunitatea științifică internațională se implică din ce în ce mai mult în dezvoltarea unor cercetări privind măsuri eficiente de preluare/control dinamic al acțiunilor seismice, prin devierea undelor seismice din *zona cu risc major de deteriorare*. Aceste măsuri exploatează descoperirile științifice recente, referitoare la a. procesul de "invizibilizare la unde, totală sau parțială, a structurilor protejate", sau la cel de b. atenuare a magnitudinii undelor. În vederea identificării soluțiilor de protecție seismică preventivă a componentelor *SUU,* în articol se prezintă o sinteză a măsurilor posibile: a) "*cap de invizibilizare*", b) "*țesătură de invizibilizare*" și c) "*atenuatoarele de unde*", procesul de identificare și respectiv selecție a soluțiilor fiind realizat în baza conceptului "*Symbiosis in Development"/SID.*.