Territorial protection utilizing seismic barriers using granular metamaterials

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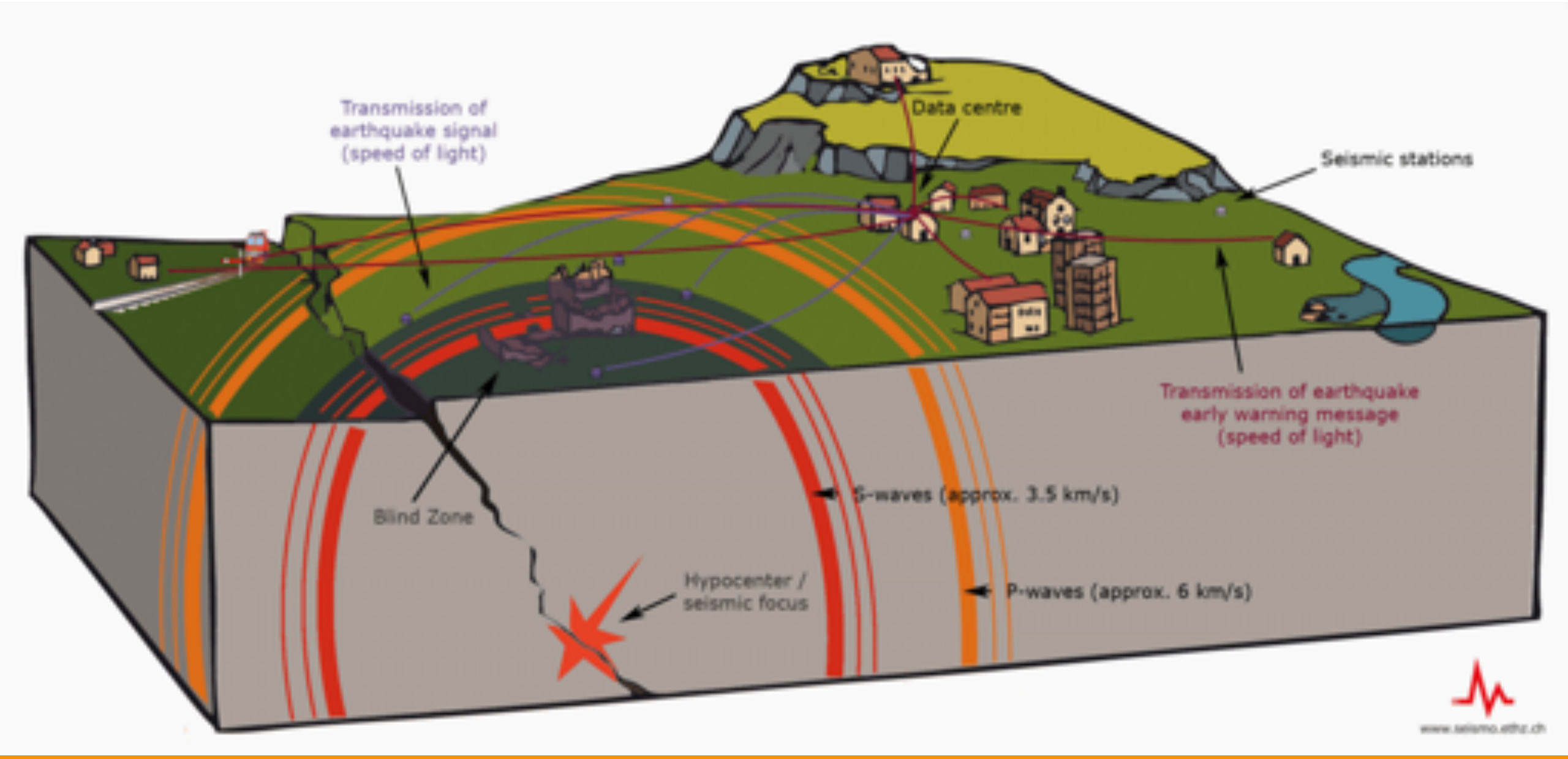
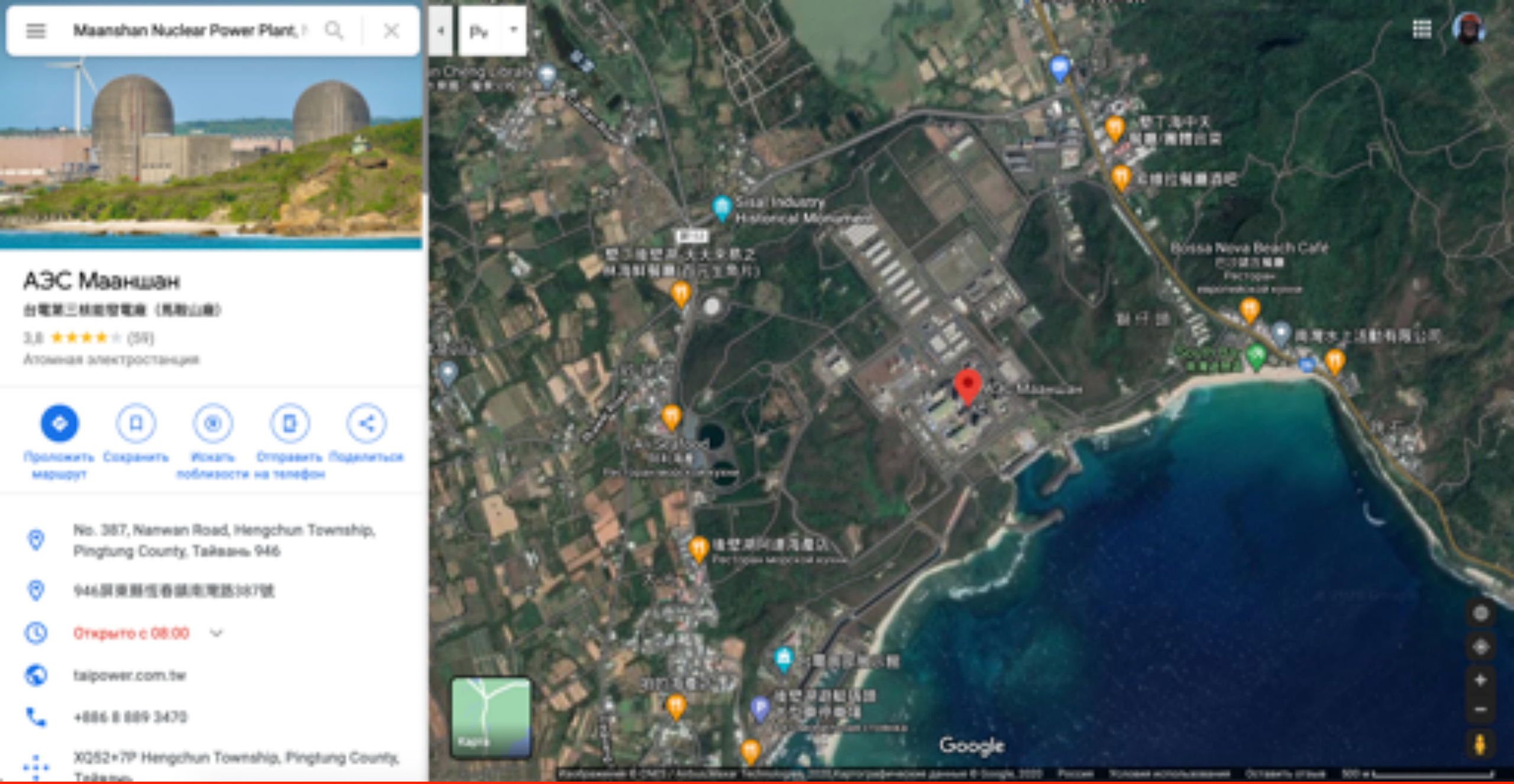

Transmission of earthquake signal (speed of light)
Data centre
Seismic stations
Transmission of earthquake early warning message (speed of light)
Blind Zone
S-waves (approx. 3.5 km/s)
Hypocenter / seismic focus
P-waves (approx. 6 km/s)

Different types of seismic waves

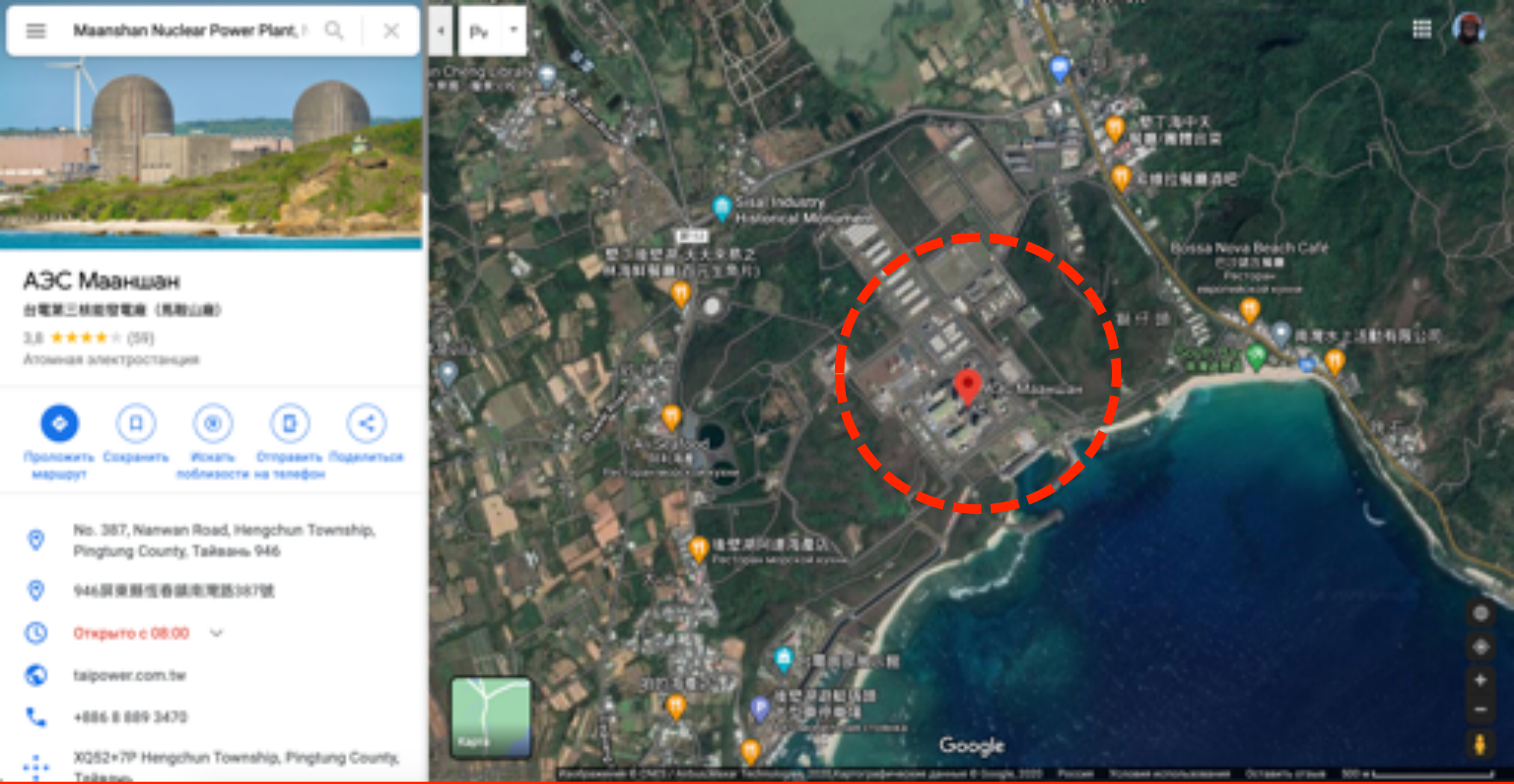
- Bulk waves initiated at the earthquake
- Interface and surface waves initiated at boundaries
- Love waves
- Rayleigh waves
- Stoneley waves
- Rayleigh-Lamb waves
- SH-waves

Traditional approach to seismic protection


Maanshan Nuclear Power Plant
АЭС Мааншан
台電第三核能發電廠（馬鞍山廠）
3,8 (58)
Атомная электростанция
Проложить маршрут
Сохранить
Искать поблизости
Отправить на телефон
Поделиться
No. 387, Nanwan Road, Hengchun Township, Pingtung County, Тайвань 946
Открыто с 08:00
taipower.com.tw
+886 8 889 3470
Sisal Industry Historical Monument
Bossa Nova Beach Cafe
Карта
Google

Seismic Protection Utilizing Barriers

- Protects area the structure is placed on, not the structure itself
- Seismic barriers are not part of the protected structure – degradation and fracture of barriers is not directly affecting the structure strength and stability
- Functionality is not significantly affected by frequency spectrum of oncoming waves (unlike traditional protection that is designed to be effective for certain frequency range)
- Basement slab is protected
- Can be used to protect structures placed on weak soils (prevents from propagation of energetic waves in the protected area)
- Can be retrofitted to protect existing structure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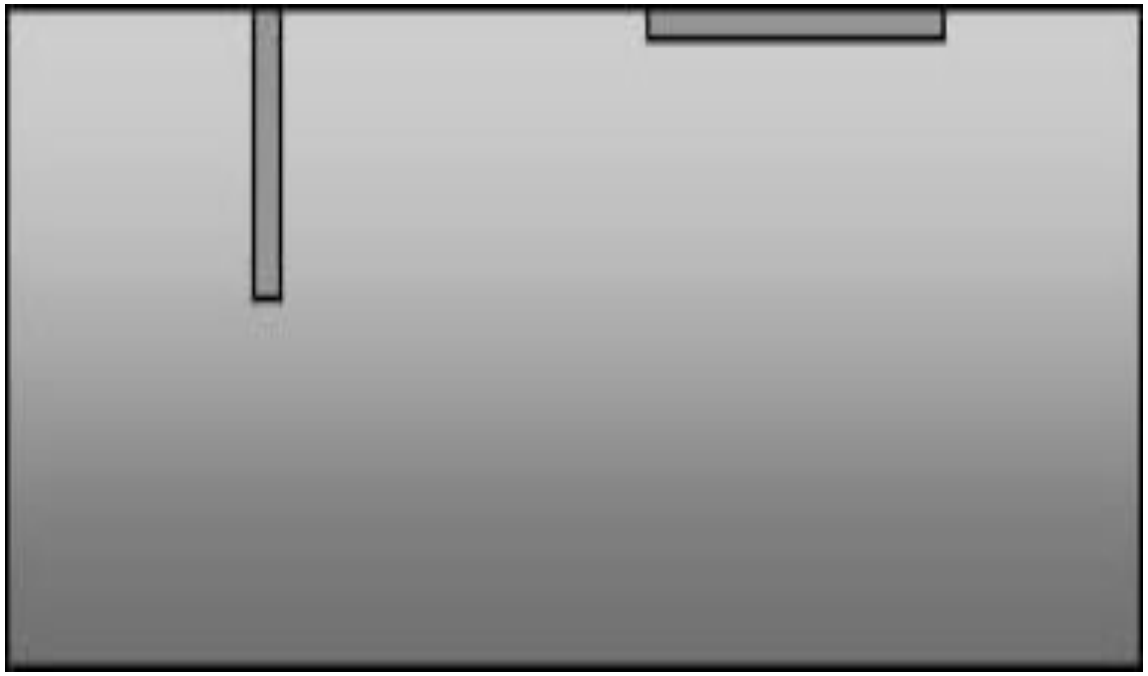
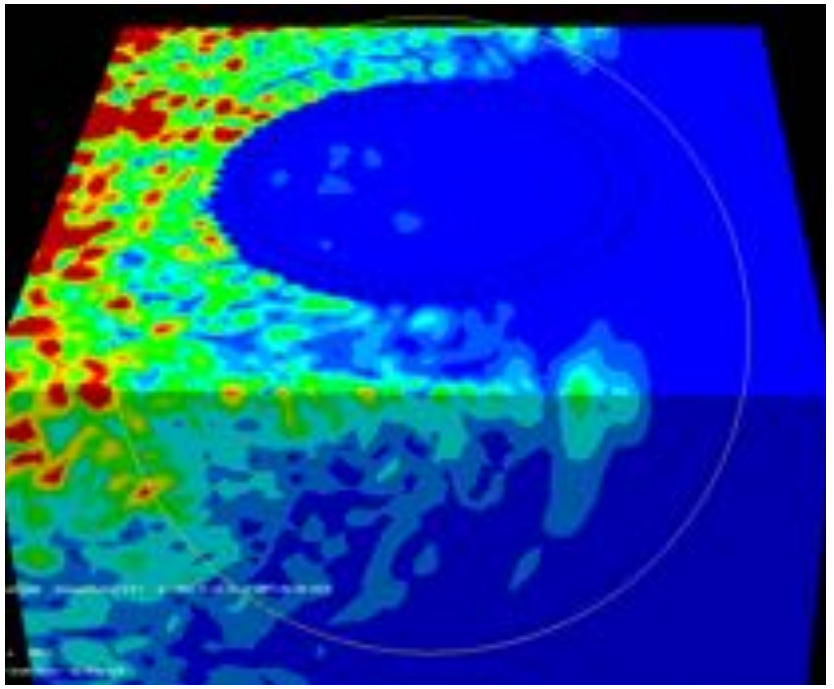
Types of seismic barriers

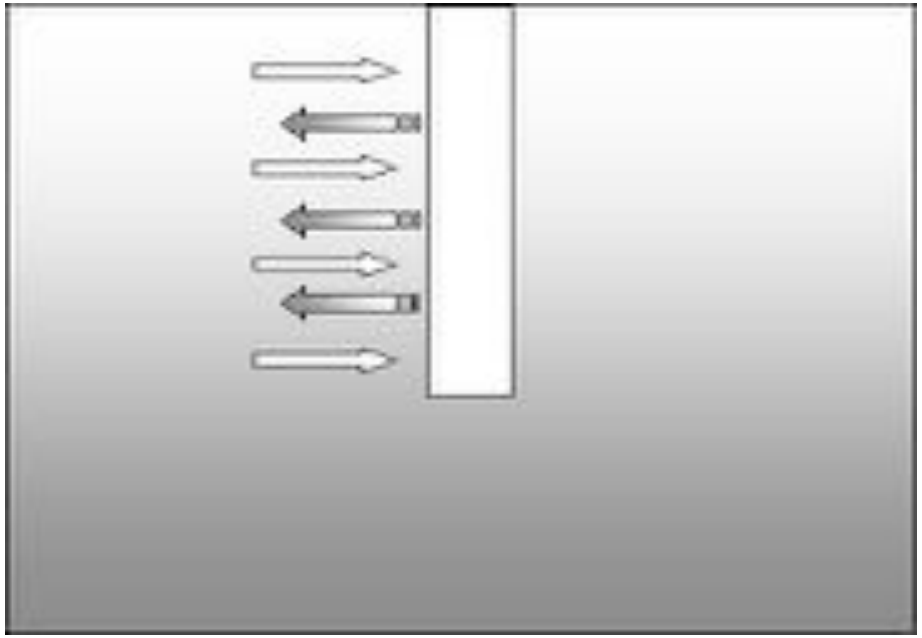


Vertical and horizontal barriers

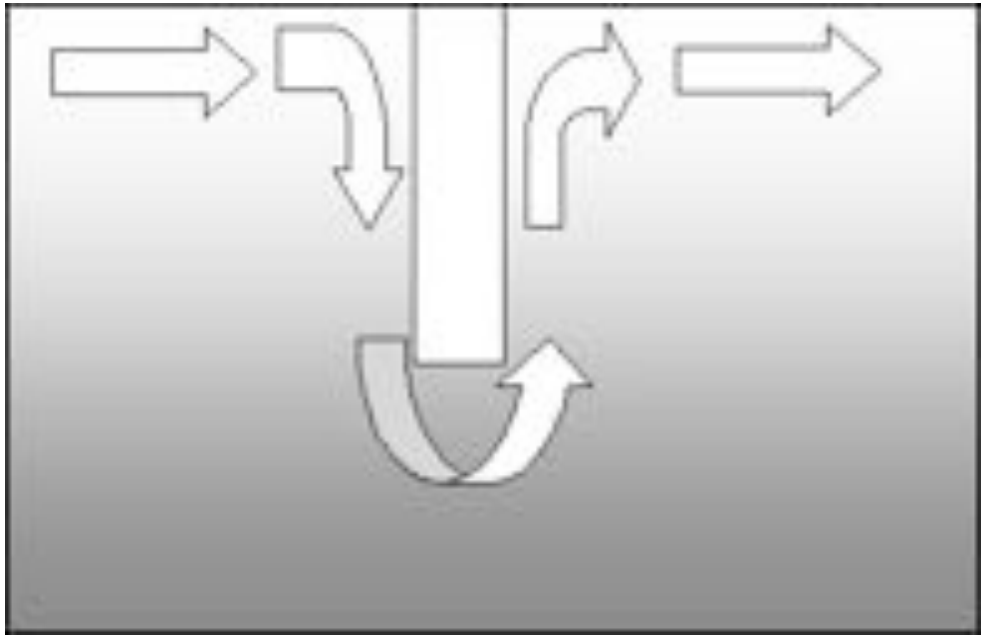


Discrete Barriers

Vertical seismic barriers

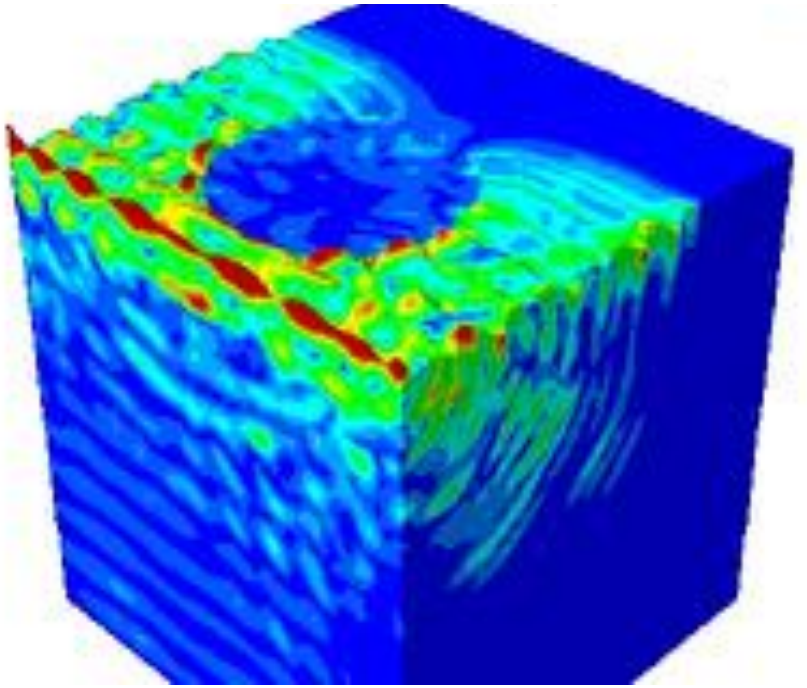


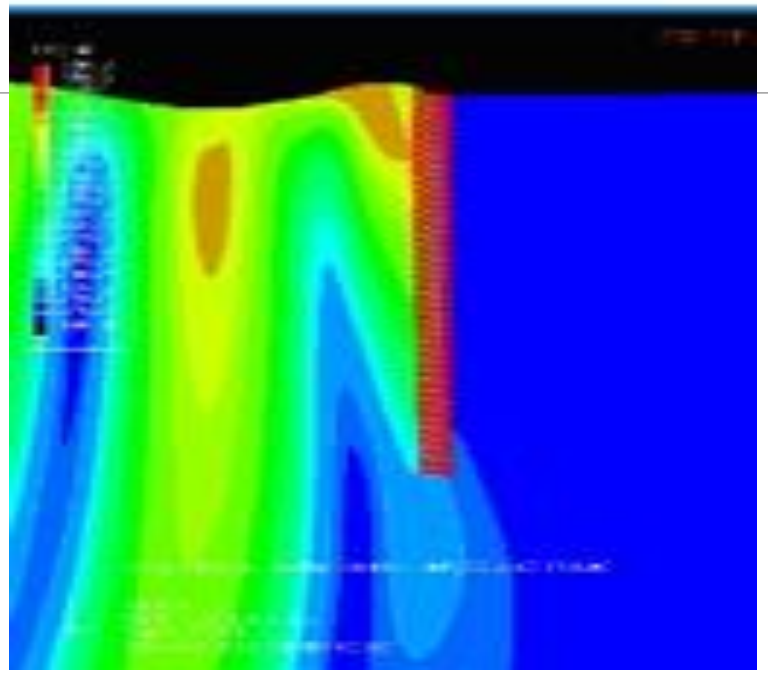
Hollow barrier can be effective against bulk waves



Not very effective against Rayleigh wave

Vertical seismic barriers

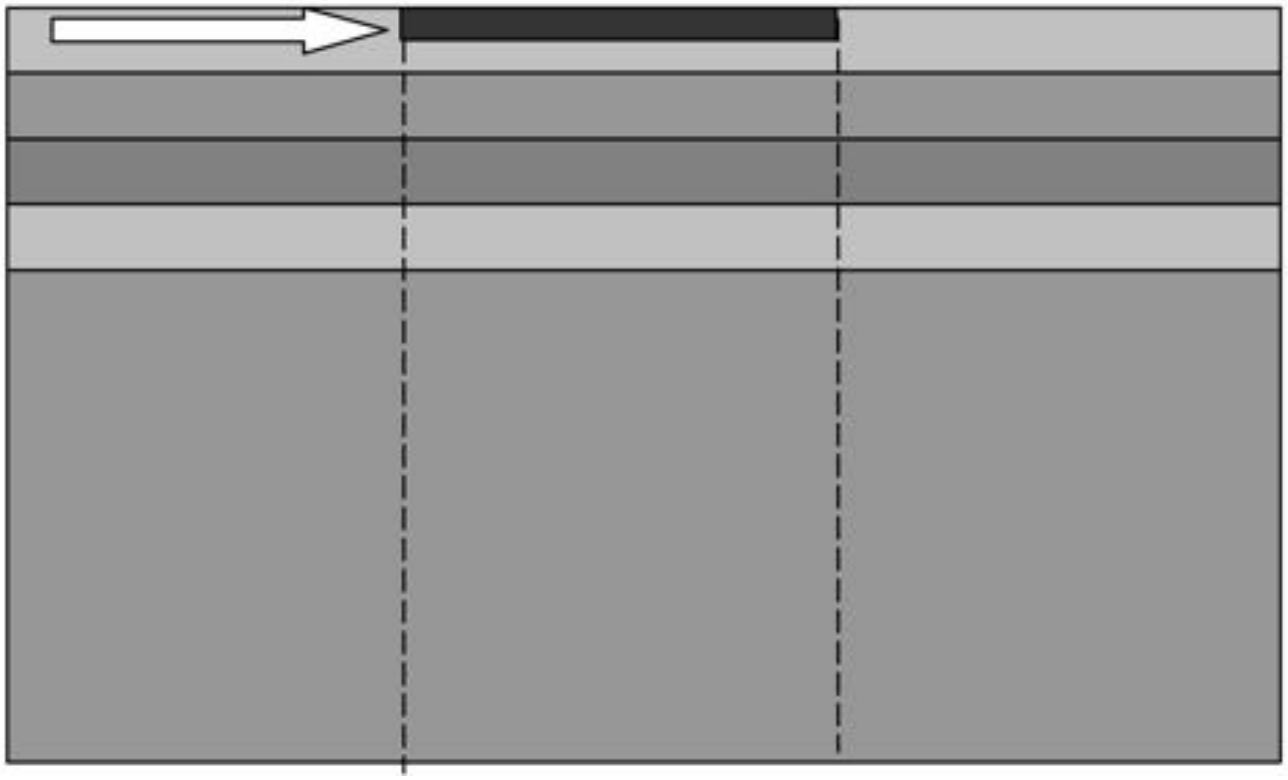




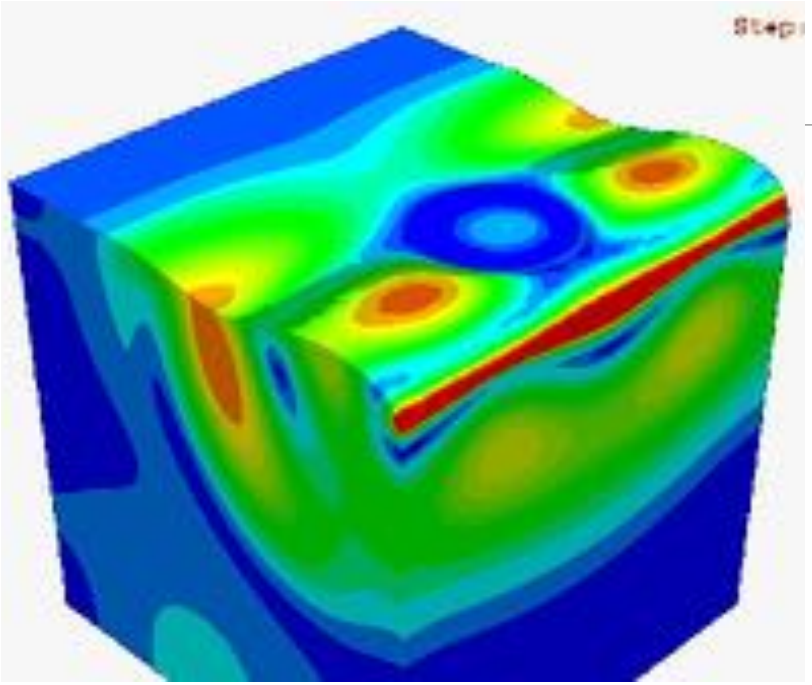
Simulations testify that seismic barrier can significantly (by an order of magnitude) reduce amplitude of displacements caused by an oncoming Rayleigh wave if:

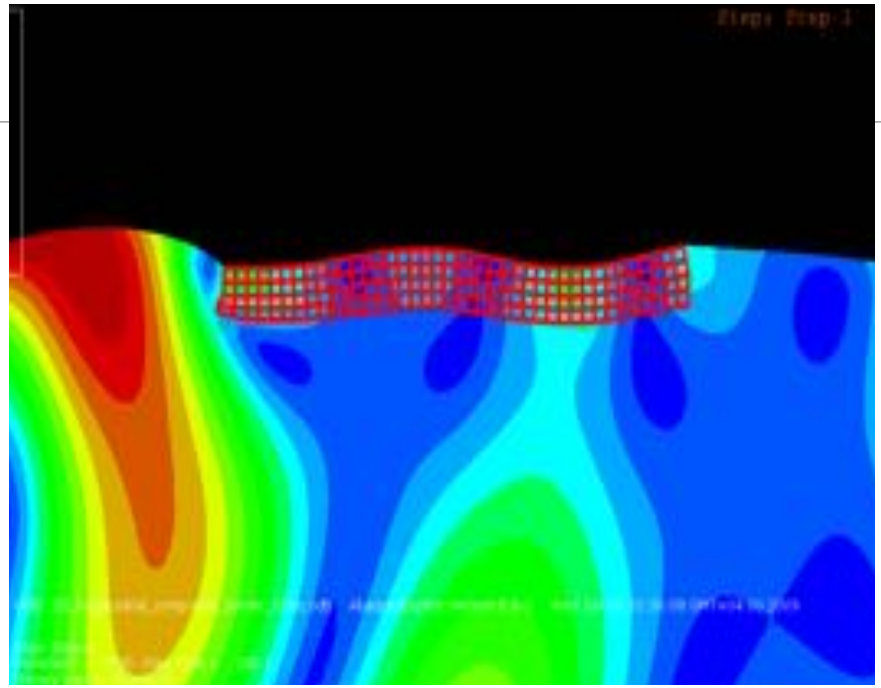
- The barrier consists of several alternating vertical layers with different mechanical properties;
- The barrier depth should be comparable to the seismic wave wavelength
- The protected area should be surrounded by the barrier

Horizontal seismic barriers



Horizontal seismic barriers





Simulations testify that a horizontal seismic barrier can significantly (by an order of magnitude) reduce amplitude of displacements caused by an oncoming waves if:

- The barrier length should be comparable to the seismic wave wavelength
- To secure efficiency against Rayleigh waves the barrier should have higher density as compared to the soil
- To secure efficiency against Love waves the barrier should have higher transverse wave propagation speed as compared to the surrounding soil

Noise/Acoustic Barriers

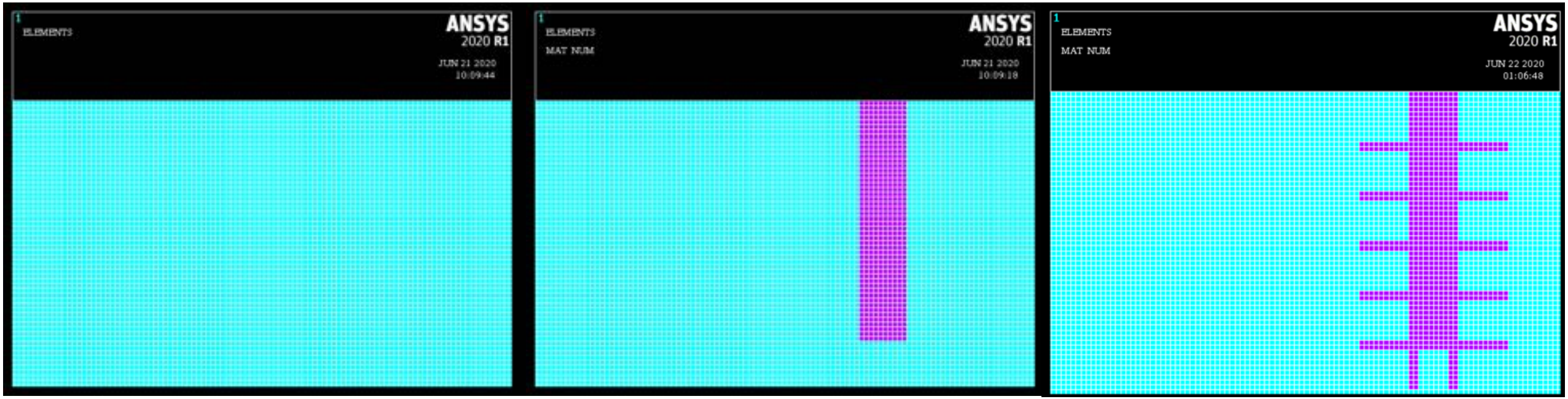
Mukhady Sh. Israilov (2019) Theory of Sound Barriers: Diffraction of Plane, Cylindrical and Spherical Waves on a “Hard-Soft” Half Plane May, *Mechanics of Solids,* 54(3):412-419, DOI: 10.3103/S0025654419020043

Effect of Barrier Geometry

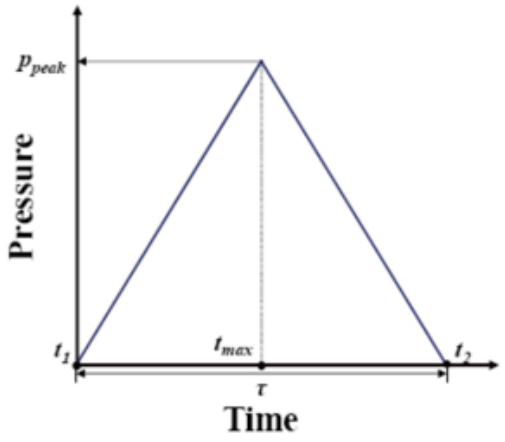
No Barrier

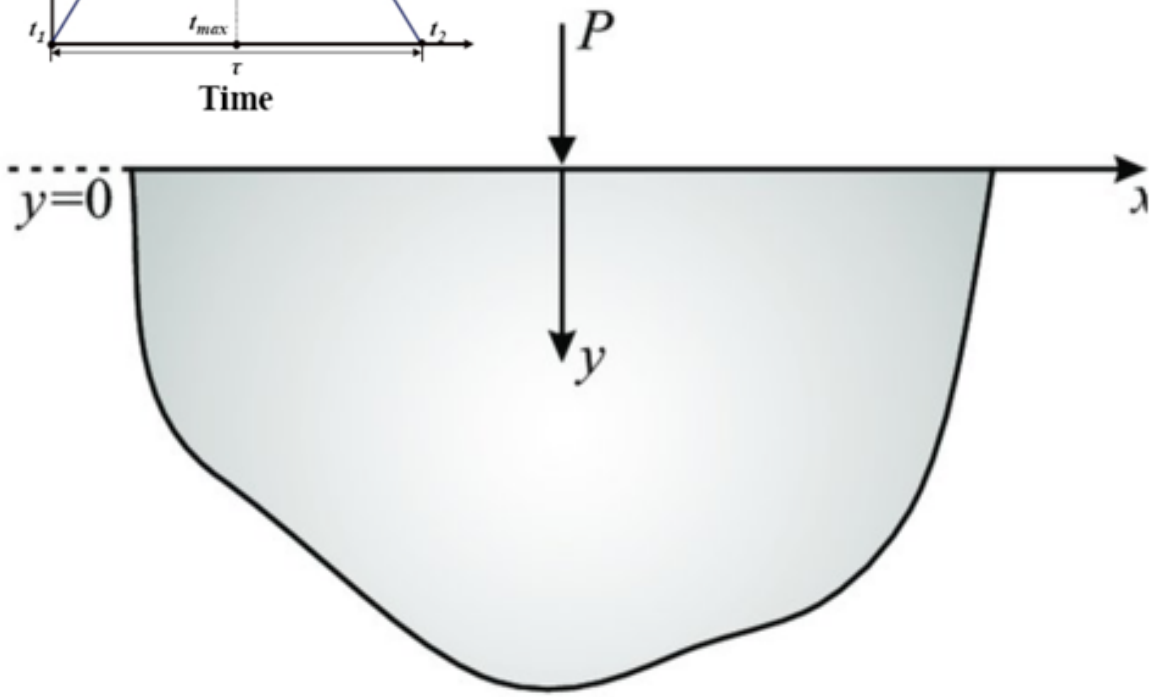
Barrier

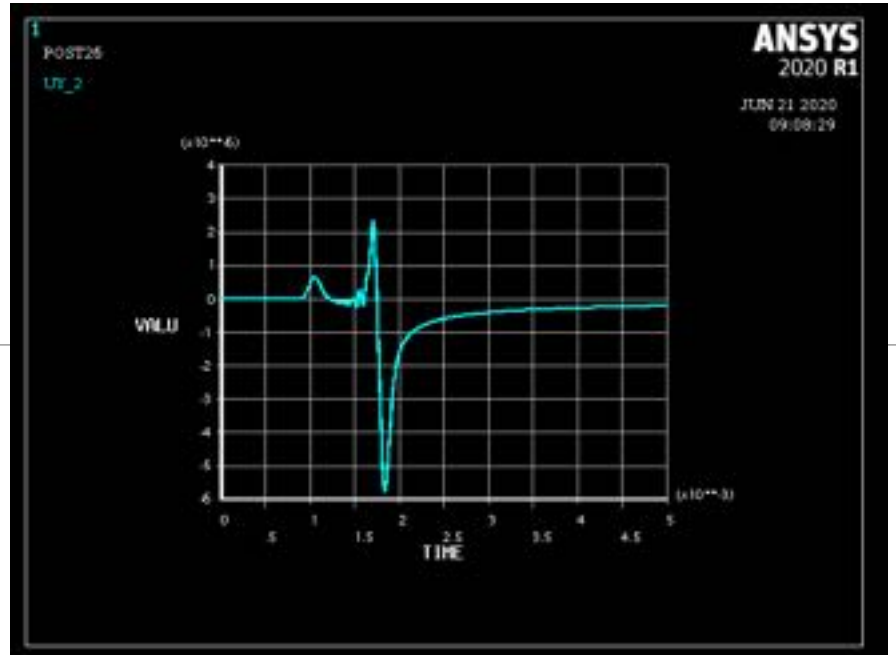
Complex Barrier



No Barrier


p_{peak}
Pressure
t_1
t_{max}
t_2
τ
Time


P
y=0
x
y


POST26
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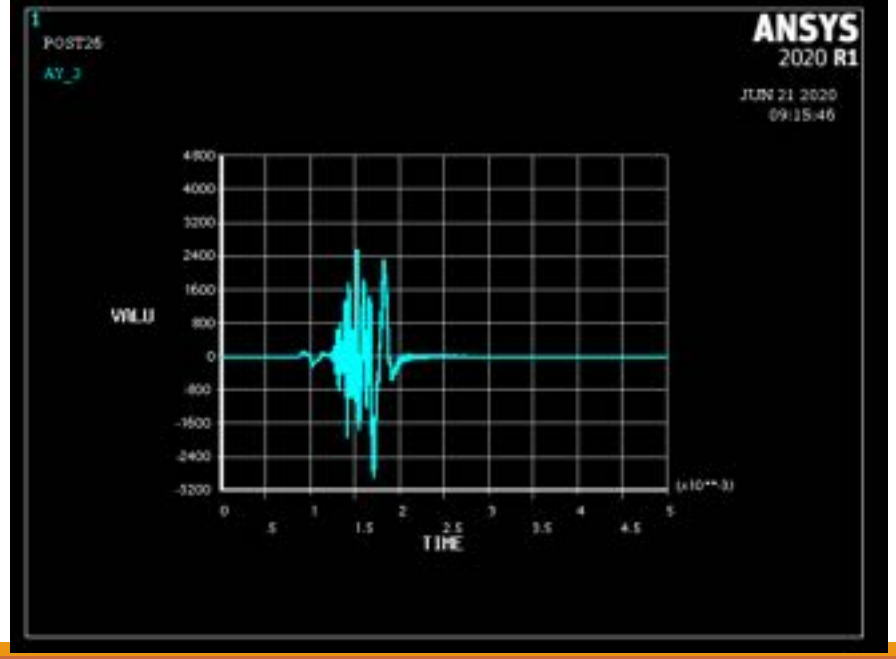
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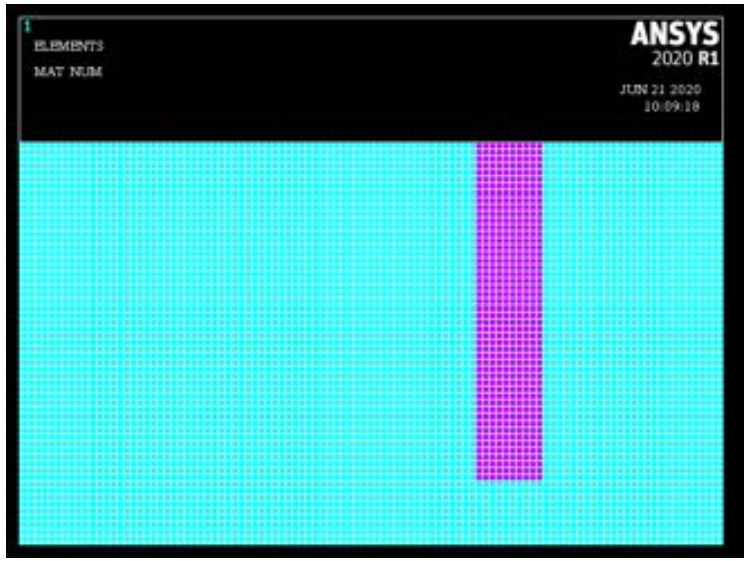
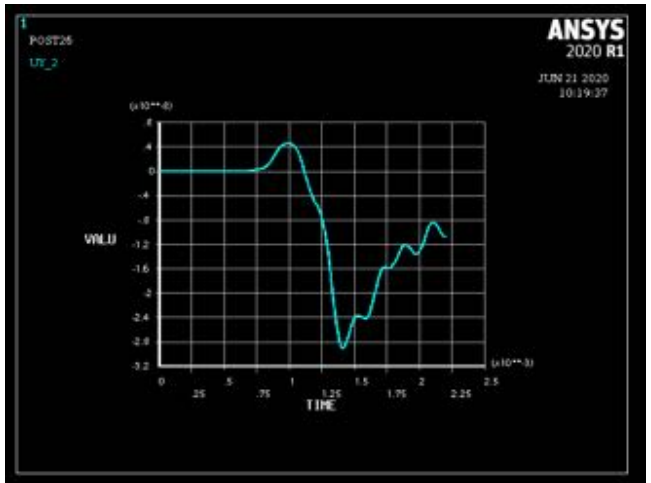
JUN 21 2020
VALU
TIME

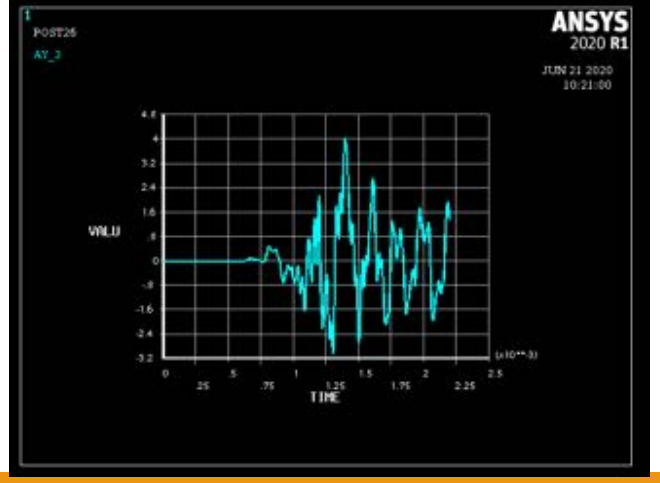
Soft barrier





Displacement

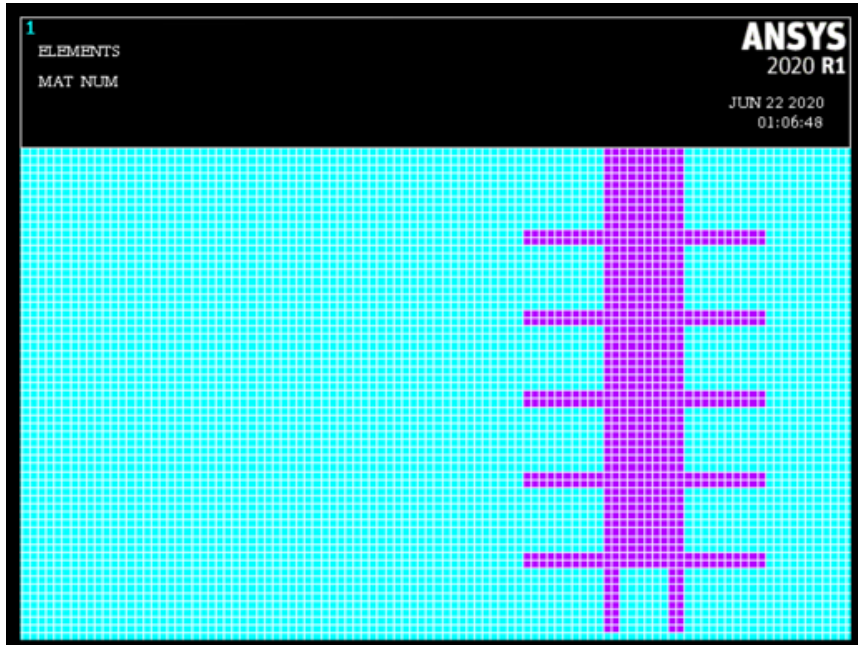
PF=2,1

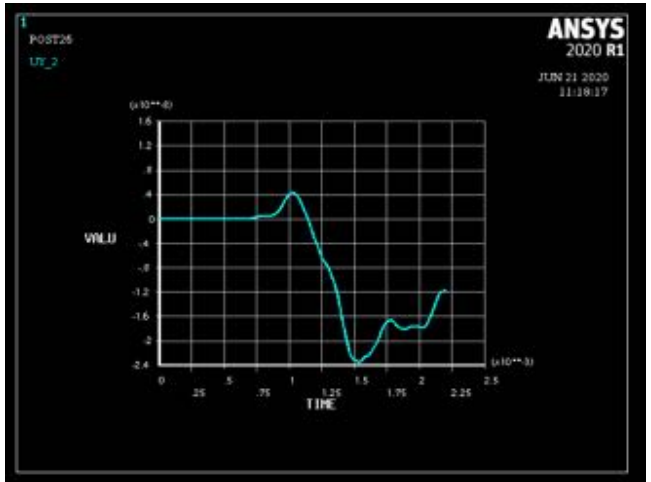


Acceleration

PF=10,6

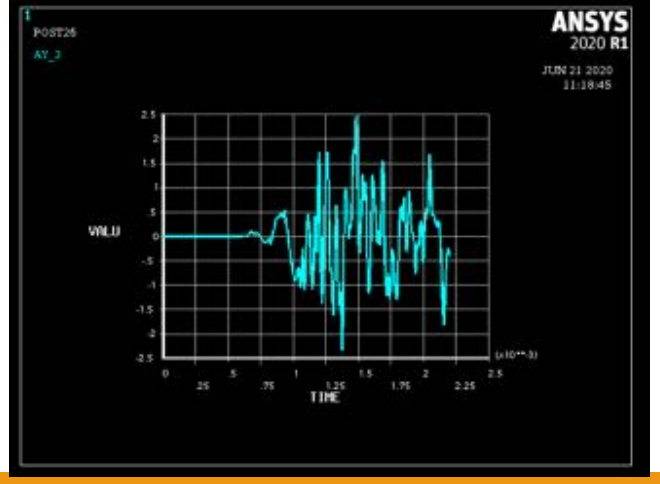
Soft barrier with diffusers





Displacement

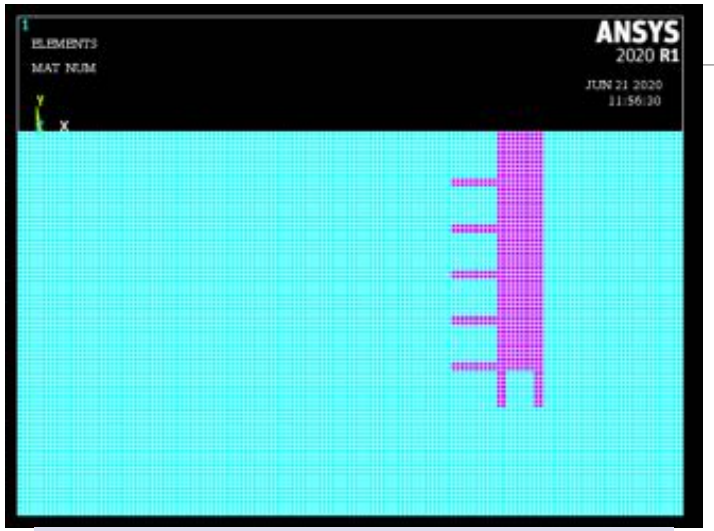
PF=2,6

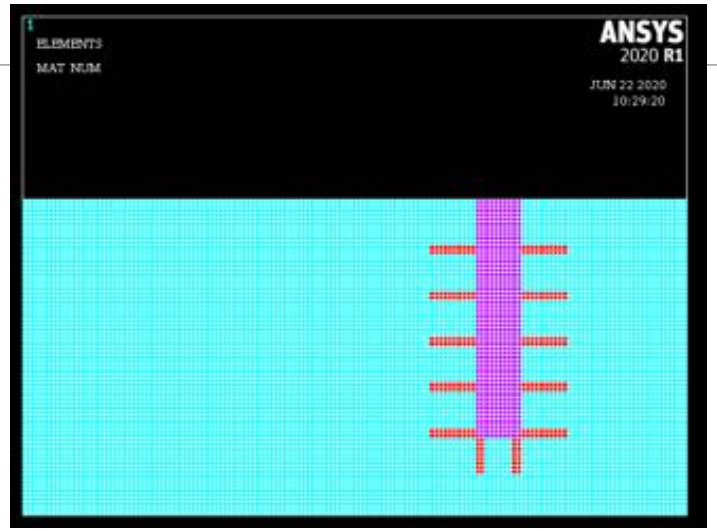


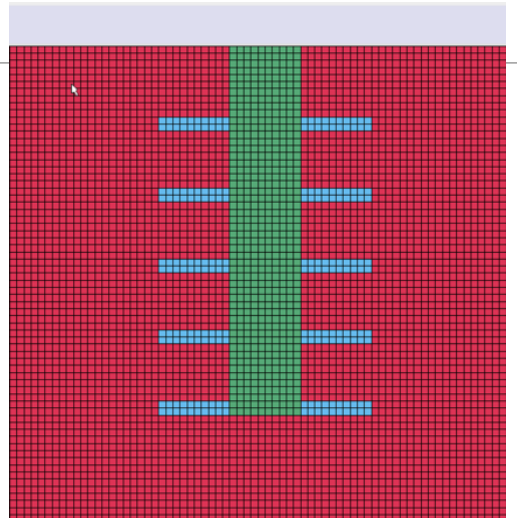
Acceleration

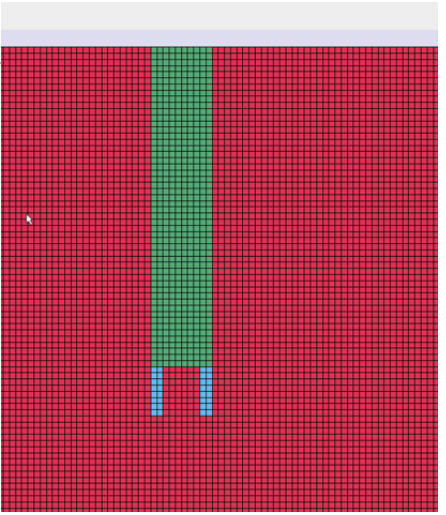
PF=17,5

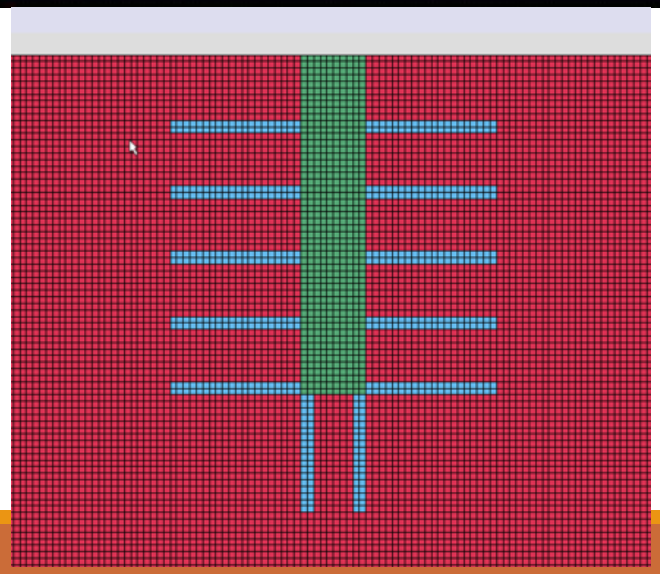
Many different geometries tested

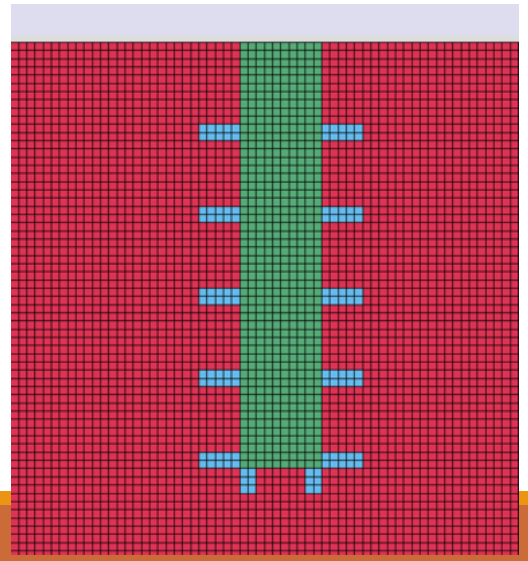


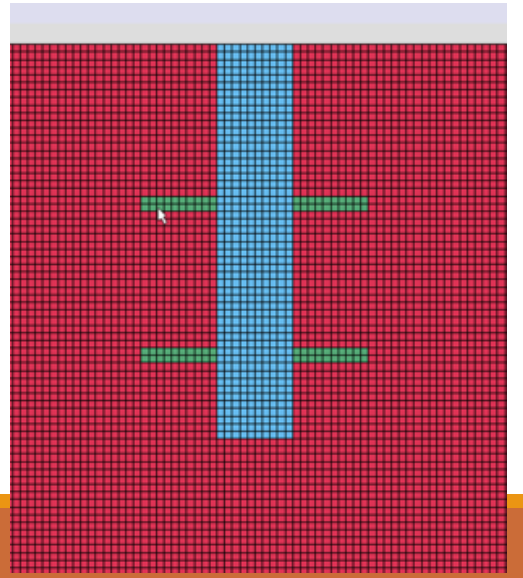


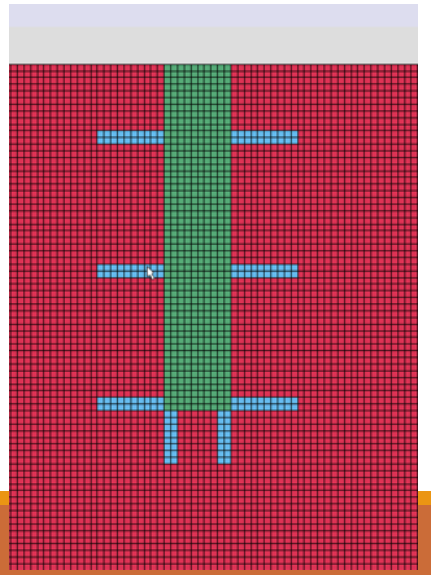








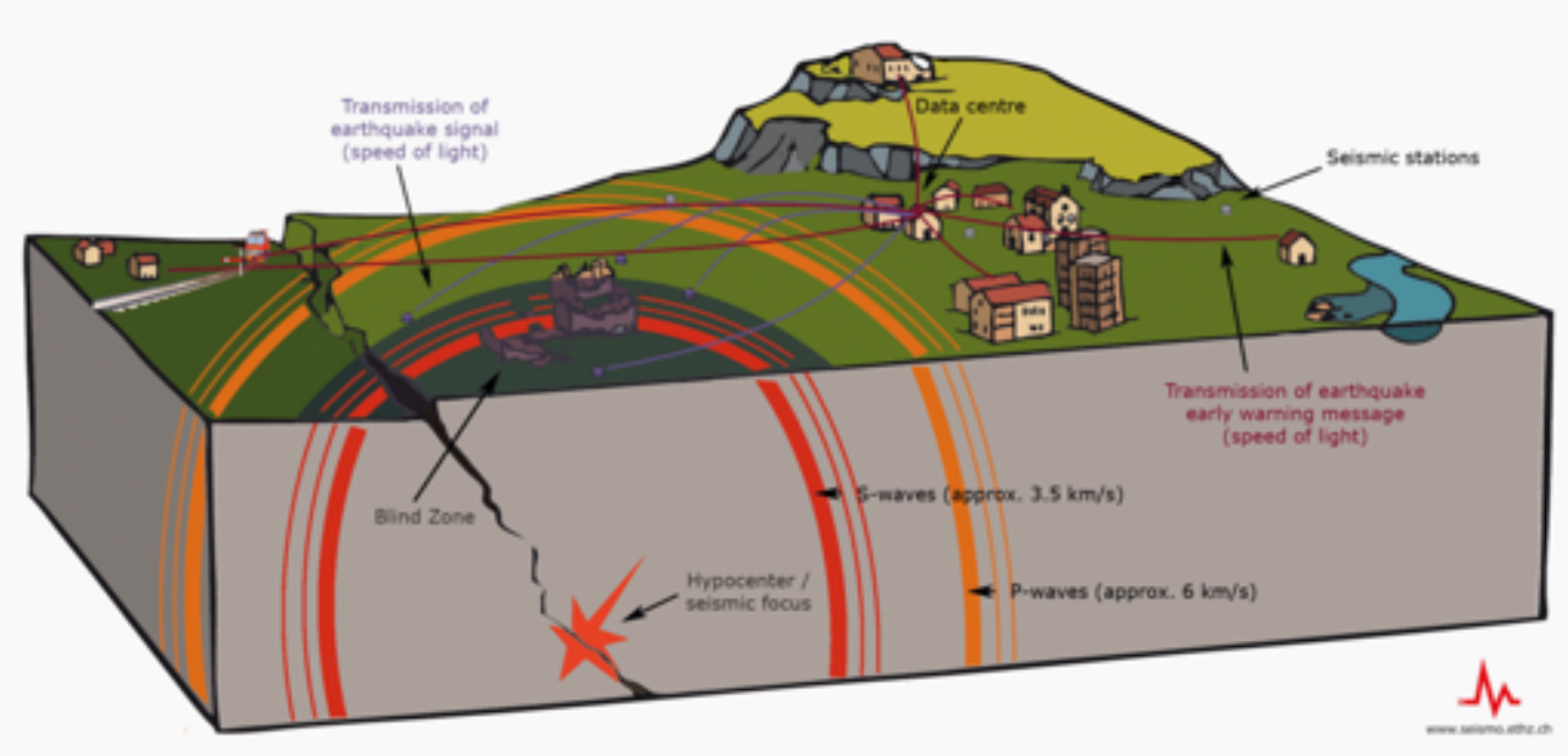




Protection Factors

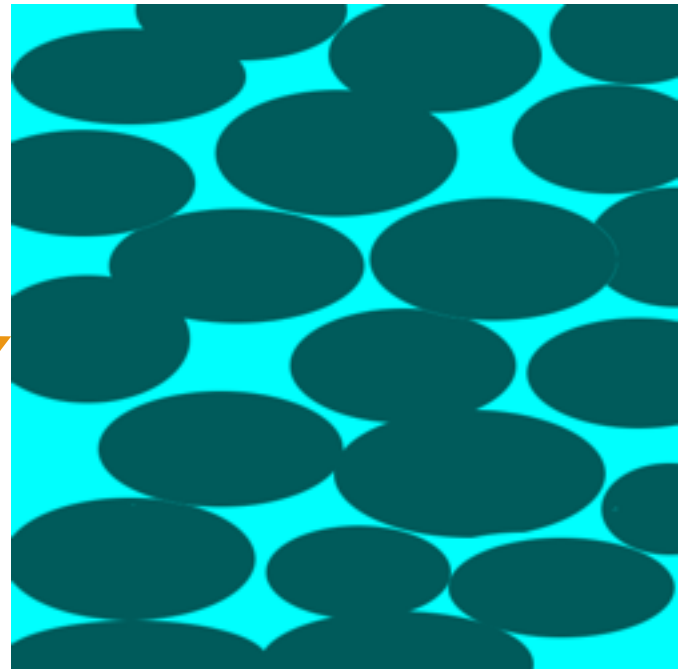
- Diffusors can significantly impact protection factors (in some cases increase protection by a factor of 3)
- It is always better to have diffusors with properties different from the ones of the barrier (i.e. hard barrier-soft diffusors or soft barrier –hard diffusors)
- For longer waves soft barriers with hard diffusors are better, for shorter waves soft barriers with hard diffusors perform better
- Shorter diffusors protect worse, longer diffusors make protection better
- We need at least 3-4 side diffusors
- Lower diffusors are not significantly affecting diffraction
- For some cases protection factor is reaching the value of 35

Phononic Crystals – protection from surface/bulk waves

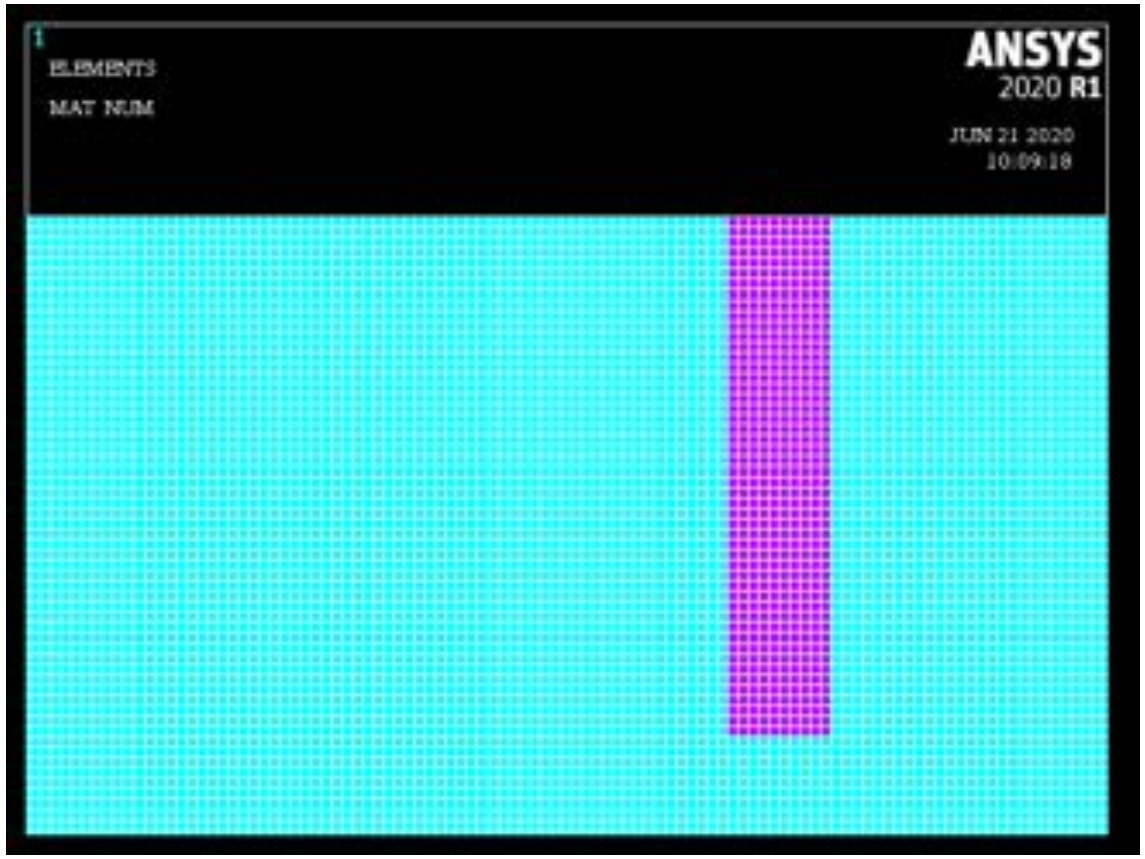


Phononic Crystals – protection from surface/bulk waves

Lentil – shaped stiff particles in soft matrix

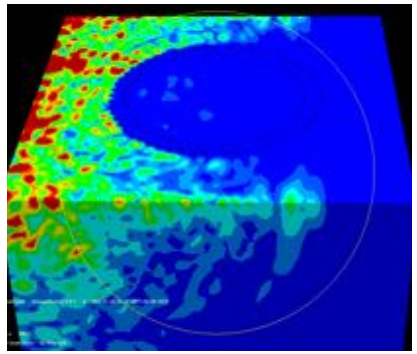


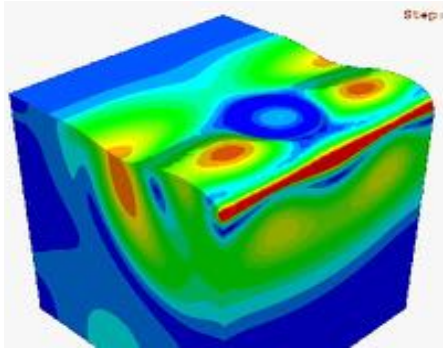
Utilizing Phononic Crystals (granular metamaterials)as filling for vertical seismic barriers

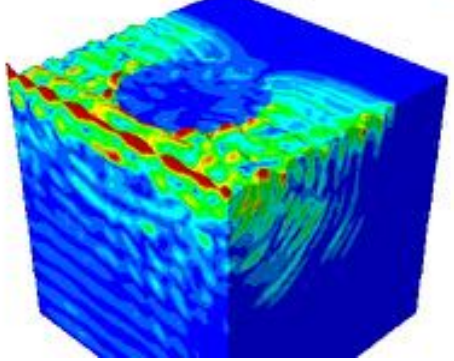


Protection Factors can increase by the factor of 5-7 and the "shadow zone" dimensions can be increased 3-5 times

Conclusions







- Seismic barriers can be successfully utilized to protect enclosed areas from different types of oncoming waves of seismic origin. It is possible to reduce the induced displacements and accelerations on the surface by an order of magnitude.
- Numerical simulations can be employed to predict optimal configuration of protecting structures in order to assure the desired reduction of intensity of oncoming waves likely to be exited in the protected area.
- Protective and functional properties of seismic barriers often make them a better choice competing against more traditional protective techniques.
- In most cases construction of seismic barriers securing desired protection level is associated with lower cost as comparing to more traditional protective techniques.

Thank you for attention!