

LABORATORY MEASUREMENT OF ENERGY DISSIPATION OF THE SEISMIC SOLITON WAVE AT FRACTURE

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Abstract – The simple laboratory model of dissipative fault was built. Two granite cubes were pressed together using a custom made device. When one of the blocks was knocked, the resulting vibration of the other was monitored in the form of local temperature change. The other experiment included the measurement of the friction coefficient for the rock with a smooth as well as a rough surface. In this way we tried to assess energy dissipation of solitary seismic wave crossing the fault.

Keywords: seismic wave, energy dissipation, temperature measurement, friction measurement

1. INTRODUCTION

Macroseismic intensity is an important tool for estimation and evaluation of earthquake effects. It is a function of many parameters which include the magnitude of an earthquake, soil characteristics, quality of the buildings etc. The question of energy dissipation of seismic waves is a significant one because it is possible that it is one of the main factors contributing to macroseismic intensity of the earthquake at a particular place.

It is very well known that with crossing the fault the energy of seismic waves will be transmitted, reflected or dissipated, depending on effects of nonlinear deformation and friction [1-2]. There is no doubt that part of the wave energy is reflected and the other transmitted across the fault. However, the question is whether the dissipated part of seismic energy is significant or not.

The hypothesis of this paper is that energy dissipation at a fault is the dominant attenuator of macroseismic intensity under specific conditions. If true, this assumption could explain the specific shape of isoseismals in certain areas, for example the central part of the External Dinarides (Croatia) where the lines of same intensity level are very elongated in the direction of mountain spreading.

2. THEORETICAL MODEL

Let us consider the inelastic behaviour of the fault. Incident energy of seismic wave, E_i is a sum of reflected, E_r , transmitted, E_t and dissipated energy, E_d (Fig. 1):

$$E_i = E_r + E_t + E_d \quad (1)$$

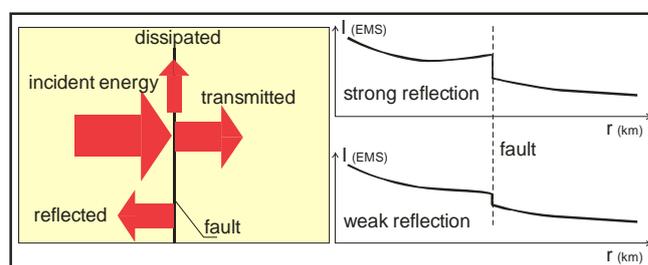


Fig. 1. Diagram of energy and intensity distribution at fault.

Waves on the incident side of the fault are superposition of incident and reflected waves. If the fault reflects a significant part of the energy, the intensity near the fault on the incident side is larger than the intensity at the same distance from the epicenter in the absence of reflection. Such increase is not recorded, but a strong decrease of the intensity perpendicular to the Dinarides can clearly be seen, meaning that the dissipation of energy strongly affects the macroseismic field (Fig. 2).

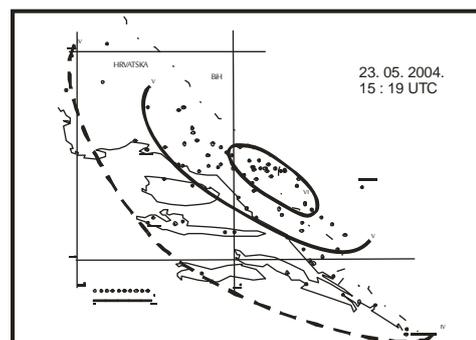


Fig. 2. Example of the typical isoseismal map for an earthquake in Dinarides.

Previous work [3] assumed a welded fracture model [4], showing that the energy dissipation is significant up to pressures of 80 MPa corresponding to a depth of approximately 3000 m. At depths greater than 3 km, the fault behaves almost like a welded fracture. So, our hypothesis could be valid for shallow earthquakes when wave crosses the fault between the surface and depth of 3 km and for intensity points in the range of direct waves, i. e. closer than 90 km.

3. EXPERIMENT

3.1. Temperature measurements

Theory of seismic wave transmission across the fracture predicts that the energy is conserved when the material on both sides of the fracture is the same and the fracture is dry. In case of liquid saturated fracture, theory predicts energy dissipation. We suppose that a dry fracture dissipates a significant part of incoming energy. The concept of a dissipative dry fault was tested using laboratory model (Fig. 3). Two marble blocks were pressed together. One of them was equipped with a differential thermocouple copper – constantan (T – type). Wires were spanned between the centre of the block and the interface separating the blocks (Fig. 4).

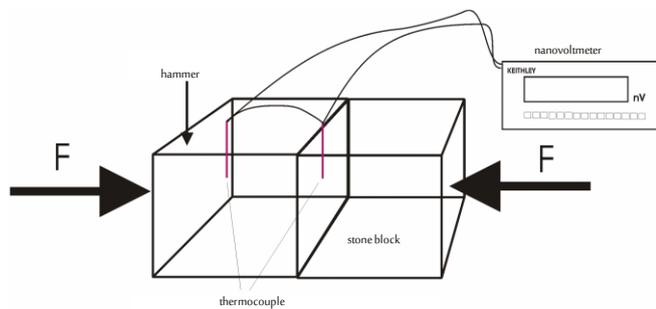


Fig. 3. Schematic illustration of the experiment.

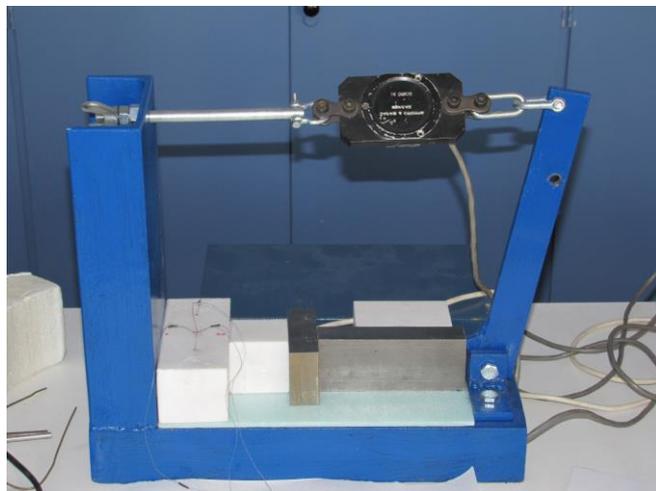


Fig. 4. Custom made mechanical press used in the experiment. Sample and dynamometer can be seen.

When one of the blocks was knocked with a hammer, the temperature difference between the centre of the block and the separating interface jumped up to 0.2 K (Fig. 5). In this way, our hypothesis of noticeable energy dissipation was confirmed.

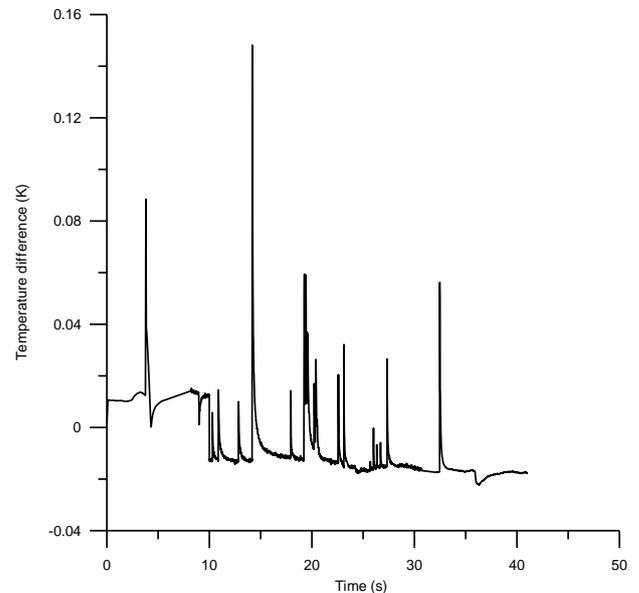


Fig. 5. Temperature difference between stone block and the fracture. Each peak corresponds to one impulse of elastic wave.

3.2. Friction measurements

The contact interface between rocks at the fault can have one of three possible forms, depending on the surface roughness. In order to assess the friction between marble blocks we let one block slide onto the other and measured distance travelled. Three possible cases (sliding of smooth surface of one block on the smooth surface of the other one, smooth surface on rough one and rough on rough) were considered. The coefficients of friction obtained from ten measurements of each of the three cases are given in Table 1.

Table 1. Coefficients of friction (COF) for the three types of interface (TOI) of sliding stone blocks.

TOI	COF
smooth-smooth	0.117
smooth-rough	0.133
rough-rough	0.311

4. CONCLUSION

Energy dissipation occurs each time seismic waves cross a fracture in the rock. Theory predicts that only fractures saturated with fluid dissipate energy, but our experiment indicates that dry fractures dissipate energy as well. In the realistic case of a large number of quasiparallel faults this effect can cause anisotropy of the macroseismic field.

However, even in a case where a lot of energy is dissipated due to friction, the increase of temperature at the fault is extremely small. For example, the amount of 2.252×10^{15} J of energy heats 1 km^3 of sandstone for just 1 K [5].

Total dissipation is a function of frequency, seismic impedance and fracture stiffness. This function can be simplified under certain conditions and be shown as the function of pressure only [3].

Shear waves have the largest influence on macroseismic intensity, especially at resonant frequencies of the buildings ($1 - 13 \text{ Hz}$). Resonant frequency of a 9 m high building is 7 Hz [6] and may be taken as a representative in the Dinaric region.

Dissipation can cause strong attenuation of macroseismic intensity in a narrow area. In the classical approach, an average attenuation coefficient is used for calculating the macroseismic field. If the macroseismic intensity loss and the position of the faults were known, it would be possible to calculate macroseismic field more accurately using gradually decreased attenuation function.

ACKNOWLEDGMENT

Funding from the MZOS project number 035-0352843-2845 is gratefully acknowledged.

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