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NEW CRITERION FOR ESTIMATE OF GROUND VIBRATIONS DURING BLASTING OPERATIONS IN QUARRIES

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ABSTRACT
The paper deals with a new criterion of evaluating the disintegration by blasting operations using cylindrical as well as concentrated charges in quarries and undergrounds. The results of our research show that for seismic safety determination of blasting, the maximum of concentrated charge blasting in one delay stage is not critical, but decisive is the explosion of the total mass of blasting material.

KEYWORDS: blasting operations, seismic safety

1. INTRODUCTION

The contribution deals with a new method evaluating ground vibrations during the disintegration by mass blasts using cylindrical, as well as concentrated charges in quarries, sits, foundation pits and at demolitions. Primarily there are blasts with the bench height as high as tens of meters with the volume of the rock (substances) disintegrated, in order of thousands of tons. Our investigations of the blast damage criterion have recently documented that the sources of the maximum shocks estimated by particle velocity are not the detonations of individual or group of charges of the appropriate detonators´ delays, but it is the rock fall of the disintegrated material on a pad or obstacle. In this way the blast damage generated by this rock fall is substantially higher than the damage induced by explosions of individual charges, however, the corresponding damage limit has not been defined yet. Simultaneously, it is necessary to differentiate between characteristics of the seismic waves generated by the detonation of explosives and fall of the rock material on a pad or an obstacle (Viskup et al., 2005; Purcz, 2006).

2. FIELD EXPERIMENTS

While evaluating the seismic safety of the objects and constructions, in general, it is acknowledged at present and used the way of determining the so called maximum admissible charge per detonator delay Q_t, whose degree of damage is zero, i.e. the function of the protected object will be fully preserved. Simultaneously, the value Q_t coincides with the permissible particle velocity v_p predetermined for the protected object. This case is illustrated in Figure 1, which represents the velocigram v = f (t) of the blast performed in the heading of the Branisko tunnel in Slovakia (Dojčár and Pandula, 1998), where metamorphic and carbonate rocks occurred:
diameter of boreholes d = 41 mm, length of boreholes L_b = 3 m, explosive Danubit 1.28 mm/200 g, totally 94 boreholes for charges, maximum charge per delay 6 kg, total charges Q = 136.4 kg, detonation charges by electric detonators Sada metro from 1° to 36°, with the nominal delay intervals Δt = 23 ms, 250 ms, 500 ms, nominal duration time of detonation t_d = 6 500 ms, the shortest epicentral distance between the blast and site of observation L = 103 m, mass of the rock, approximately T = 350 t (130 m^3), loosened by one blast. Velocigram in Figure 1 unambiguously confirms that the ground vibrations of the blast were induced by the detonation of the explosive charges, while images in Figures 2 and 3 differ substationally from the previous one. Velocigram shown in Figure 2 represents a combined blast, i.e. part of charges is concentrated in a chamber and another part in boreholes in the limestone quarry Gombasek, Slovakia (Dojčár and Pandula, 1993): height of the bench H = 70 m, quarry face of the bench was disintegrated by 2 – row blast, 15 + 15 boreholes, d = 90 mm, α = 80° (borehole inclination), length of boreholes L_b = from 50 to 60 m, charge of boreholes 9 000 kg of the ANFO explosive, timing by millisecond electric detonators DeM - S 14° and 15°, nominal delay intervals Δt = 23 ms, in the toe of the 2nd bench 2 - row chamber blast, mass of charges from 2 000 to 4 700 kg/delay stage, total mass of charge in chambers 20 664 kg, explosives ANFO, TNT, wastes from the production of explosives, priming by detonators DEM-S, from 8° to 13°, total duration time

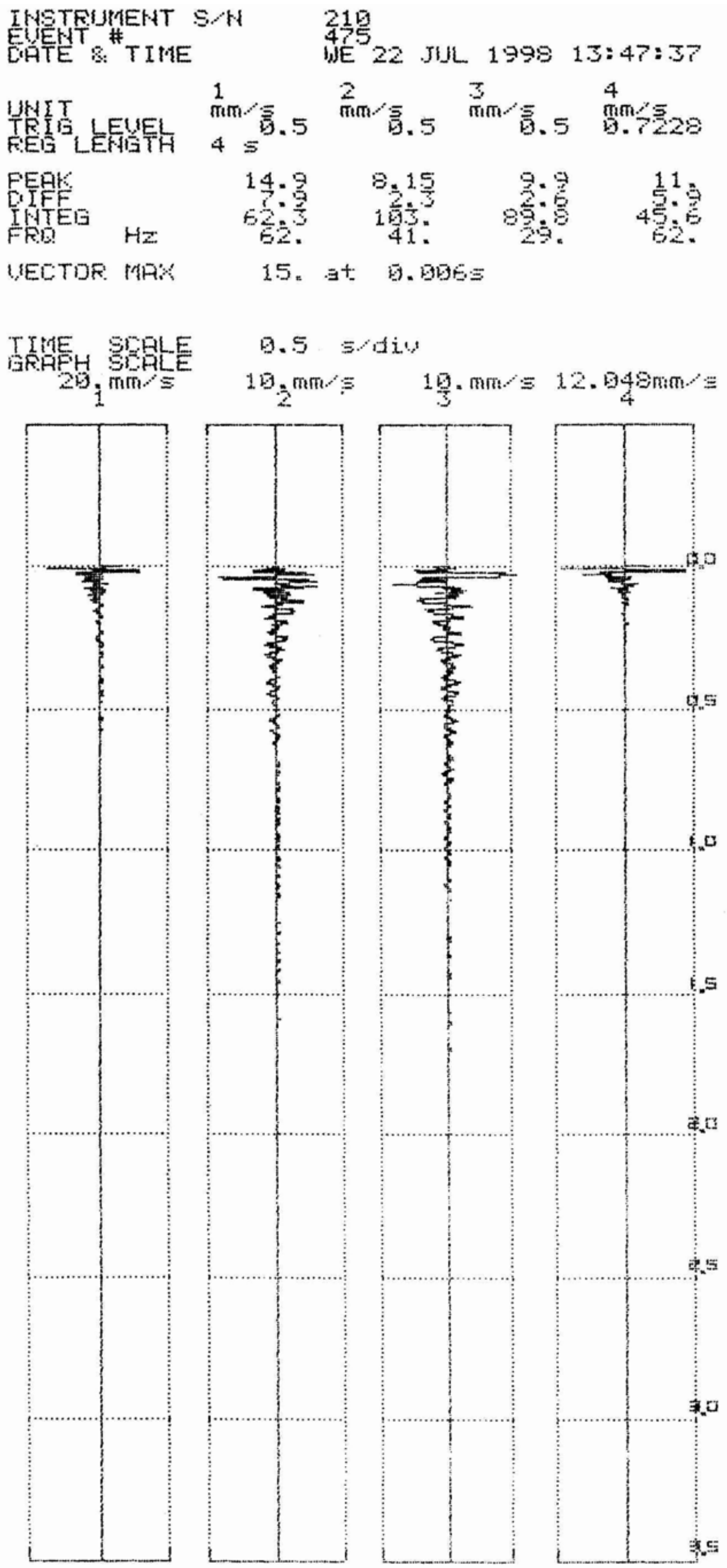


Fig. 1 Velocigrams of the blast carried out at heading of the Branisko tunnel.

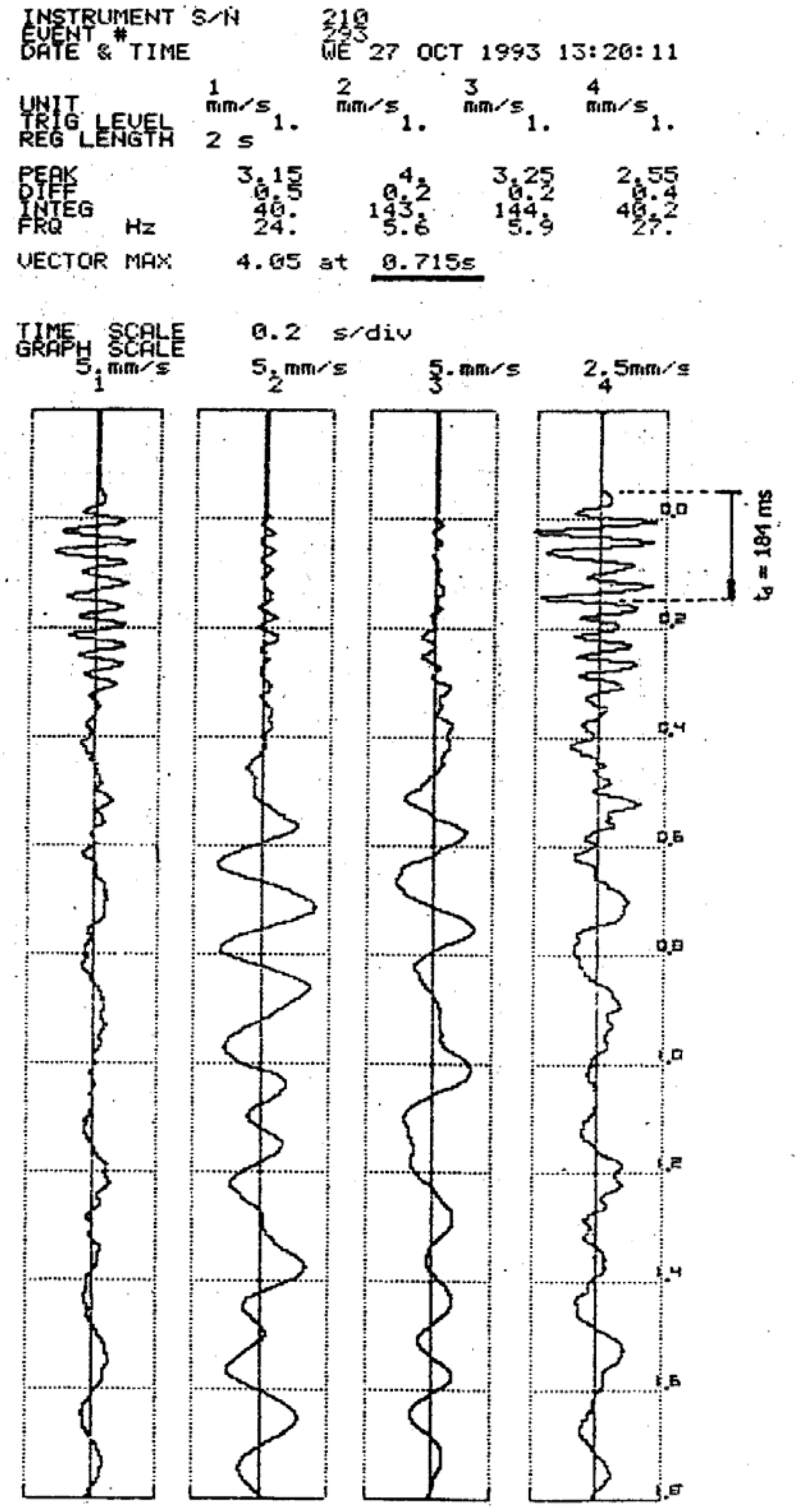


Fig. 2 Velocigrams of the combined blast of concentrated and cylindrical charge of explosives in the Gombasek limestone quarry.

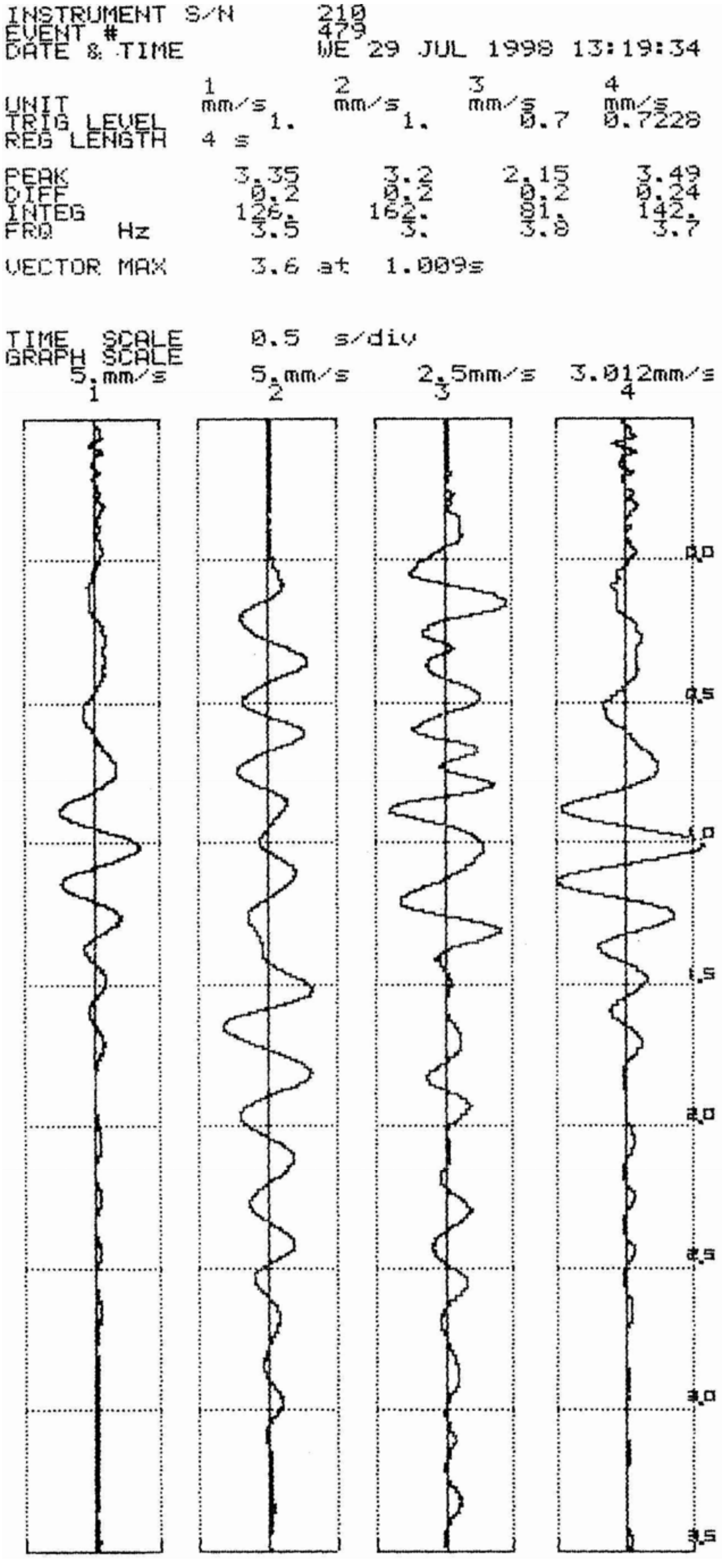
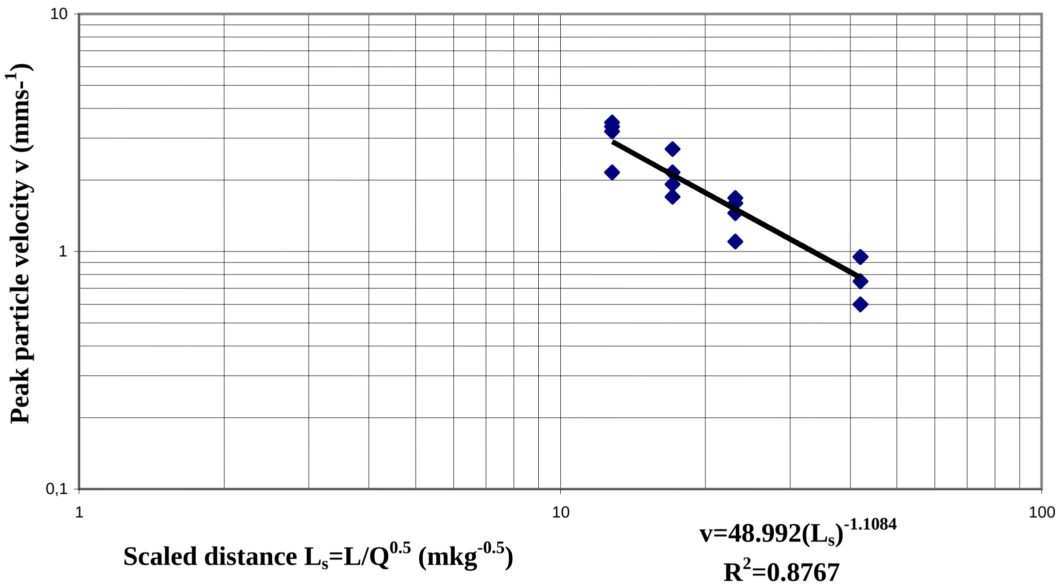


Fig. 3 Velocigrams 2- to 3- row blast of cylindrical charges of explosives in the Včeláre limestone quarry.

a)



b)

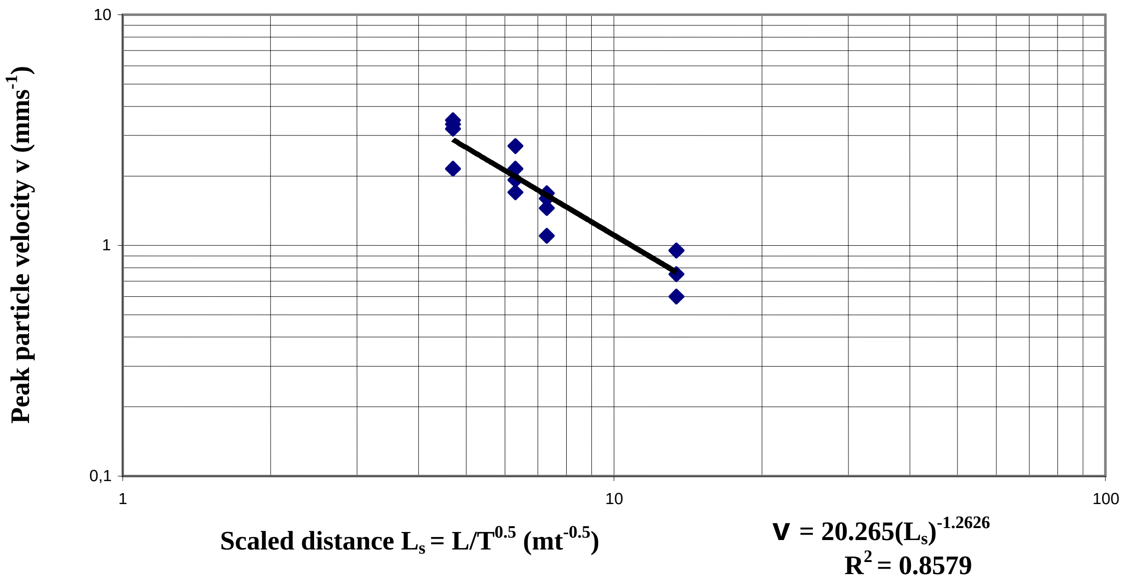


Fig. 4 Peak particle velocity in any direction versus scaled distance for all recorded data (attenuation law of seismic wawes) in the Včeláre limestone quarry, determined by the new approach using the total mass of explosives per one blast Q, as the main criterion (a), and using the total mass (volume) of the rock being disintegrated by one blast T, (i.e. by the charge Q), as an auxiliary criterion (b).

of the charge detonation t_d = 8 x 23 ms = 184 ms, total mass = 29 664 kg, epicentral distance L = 1 186 m. Velocigram in Figure 3 shows the components of the particle velocity (3 - v_x, 2 - v_y, 1 - v_{z1} and 4 - v_{z2}), from 2- to 3- row blast in boreholes in the limestone quarry VSŽ Včeláre, Slovakia: H = 18 m, α = 60°, d = 115 mm, L_b = 21 m, totally 58 boreholes, explosive ANFO DCH-S, Q = 10 846.4 kg, priming by millisecond electric detonators DeM-S 0° to 8°, total duration time of charges detonation t_d = 8 x 23 ms = 184 ms, L = 1 312 m, total mass of charge in chambers 20 664 kg, explosives ANFO, TNT wastes from the production of explosives, mass limestone disintegrated T = 78 082 t (Dojčár and Pandula, 1998).

The measured values of the particle velocity v in Figure 2 and Figure 3 unambiguously have already confirmed the fact mentioned above that the decisive particle velocities of vibrations are generated by the rock fall. It was, in principle, documented that the waveforms of vibrations generated either by the detonations of the charges of explosives or by rock fall differ each other. During the field experiments a special seismograph Swede UVS 1504 Nitro Consult was used.

Six blasts were fired in the VSŽ Včeláre quarries, where cylindrical charges were used. These experiments were aimed at evaluation of seismic safety and/or seismic load of objects and constructions using the new criterion instead of the former estimate by means of the maximum charge per delay stage Q_t. The results of data interpretation displayed in Figure 4 proved that for the millisecond delay blasting, especially for short-delay firing as a suitable substitution of the Q_t two parameters can serve, namely:

a) total mass the explosives per one blast Q
b) total mass (volume) of the rock disintegrated (being disintegrated) by blast T, i.e. by the charge Q, as an auxiliary parameter. Figure 4 shows the attenuation law of seismic waves (peak particle velocity versus scaled distance for all recorded data) (Dojčár and Pandula, 1998) for the quarry VSŽ Včeláre, where the Q_t value was replaced by the Q and T values in the following equations:

$$v = f(L_s) = f\left(\frac{L}{Q^{0..5}}\right), \quad \text{or} \quad v = f(L_s) = f\left(\frac{L}{T^{0.5}}\right) \ (\text{mm.s}^{-1}),$$

where: v is particle velocity generated by the blast (mm.s^{-1}),
L_s is the scaled distance ($\text{m.kg}^{-0.5}$),
L is the shortest epicentral distance between the blast and dwelling (m),
Q is the total mass (volume) of explosives per one blast (kg),
T is the total mass (volume) of the rock being disintegrated by one blast, i.e. by the charge Q (t).

3. CONCLUSION

The determination of the attenuation law of the seismic waves by this new blast damage criterion, besides the given replacement of the Q_t by Q or T, will not require any other adjustments, and therefore, it can be applied equally with any other law of attenuation. The validity of this method was also proved in other quarries, e.g. by several blasts in the Vechec andesite quarry (Dojčár and Pandula, 1998). However, many questions remain still open and they will not be analysed here, nevertheless, the aim of field experiments was to introduce the principle of the new method.

Finally, it can be stressed that the attenuation law for finding the higher seismic safety, at present is not usually determined for the mean particle velocity v_m, but for the limit – maximum peak particle velocity v_{mp}, as it is shown in Figure 4.

ACKNOWLEDGEMENT

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