
RELIABILITY OF DEMOLITION BY CONTROLLED IMPLOSIONS

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ABSTRACT

The achievement of demolition works on structures, by authorized personnel, using explosives, implies a combination of risks that exist on any construction site with the specific risks of work with explosives. These specific risks are generated mainly by the effects of explosions and partial or total misfires. The requirements and the feasibility to demolition of construction, requires on behalf of companies carrying out demolition with explosives to identify and assess the risks to which workers may be exposed during the destruction of the building elements and also to achieve the initiation schemes for explosions at the best price/efficiency ratio.

Keywords: probability; efficiency; explosives; destructions; structures

REZUMAT

La realizarea lucrărilor de demolare a structurilor cu ajutorul explozivilor de către personalul autorizat, se combină riscurile care există pe orice șantier de construcții cu cele specifice lucrului cu materii explozive. Riscurile specifice sunt generate în principal de efectele exploziilor de demolare și de rateurile parțiale sau totale. Cerințele și fezabilitatea demolării construcțiilor, impun firmelor care execută lucrări de demolări cu materii explozive, să identifice și să evalueze riscurile la care pot fi expuși lucrătorii pe durata efectuării distrugerilor elementelor de construcții precum și să realizeze rețele de inițiere a exploziilor cu cel mai bun raport cost/eficiență.

Cuvinte cheie: probabilitate; eficiență; explozivi; distrugeri; structuri

1. INTRODUCTION

In order to evaluate the reliability of schemes needed to initiate the explosions for the demolishing of structures, the paper presents a concept and comparisons. In this respect, the approach takes into account the calculation of the reliability of nonlinear connection schemes for detonators used to initiate explosions schemes. These are dependent on the variants of branch arrangement schemes from the point of view of firing and on the operational safety means of the priming (initiation) of explosives. Some indicators of reliability express quantitatively the reliability of network components demolition, as follows: the probability of the proper functioning (the reliability system), the failure probability function (the failure system), the intensity or misfire rate (risk factor) and the reliability of the efficient initiation of detonators. This calculation

concept for the reliability of schemes used to initiate the demolition explosions is valid for any type of initiation technology and depends on the probability of the scheme components to have misfires. The concept of calculation is based on the probability of the means of initiation of having misfire [5].

2. CALCULATION OF THE RELIABILITY OF EXPLOSION INITIATION SCHEMES

As known, the factories producing means of initiation (detonators) take into account the probability of misfire for a few pieces in a thousand. It follows that, for the probability of misfire at one thousand pieces of detonators, the risk factor of detonators can be calculated. In the calculations, we took into account that each detonator initiates the explosive charge associated with each pole / floor and that the branches of demolition schemes are identical.

The priming system of explosive charges can be electric, pyrotechnic or other.

A) First calculation example

It is required to calculate the reliability of detonators efficiency initiation in case of controlled implosion, for a reinforced concrete frame structure, as shown below (Fig. 1):

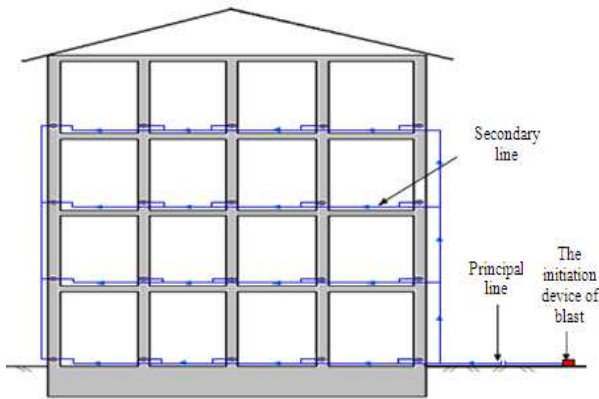


Fig. 1. Scheme of controlled demolition by structure implosion of structure. Variant I

It is considered that the means of initiation of the explosions are detonators at millisecond, that are guaranteed by the manufacturer to have not more than one misfire per 1000 detonators.

The solution of the connection scheme of detonators (6) is as shown in Fig. 2:

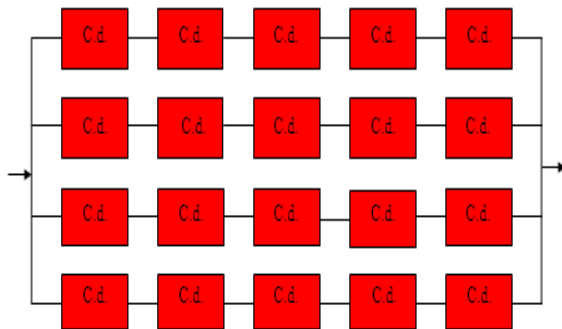


Fig. 2. Scheme of detonator connections for variant I

The calculation of the reliability of initiation schemes for the detonators is as follows:

$$\eta_I = \int_0^{\infty} F_I(\eta) d\eta \quad (1)$$

where η_I is the reliability efficiency of

initiation for the first scheme, F_I is the reliability of first scheme and n is the number of millisecond detonators (1).

$$F_I + D_I = 1 \quad (2)$$

$$D_I = D_r^4 \quad (3)$$

$$D_r = 1 - F_r \quad (4)$$

$$F_r = F_0^5 \quad (5)$$

$$F_0 = e^{-\lambda n} \quad (6)$$

where D_I is the opposite reliability of demolition schemes for variant I, D_r is the opposite reliability of the ramifications of demolition schemes, F_r is the reliability of the ramifications of initiations schemes, F_0 is the individual reliability of milliseconds detonators corresponding to each column / level, λ is the risk factor of detonators.

Considering the factory probability of misfire in operation a few pieces in a group of a thousand detonators, results that for the misfire probability to one detonator per one thousand pieces, the risk factor is

$$\lambda = \frac{1}{999} (\text{initiations})^{-1} \quad (7)$$

and the reliability of efficiency initiation of the detonator unit is

$$\eta = 999 \text{ initiations} \quad (8)$$

It results that [2,4]:

$$1 - F_I = (1 - F_r)^4 = C_4^0 - C_4^1 F_r^1 + C_4^2 F_r^2 - C_4^3 F_r^3 + C_4^4 F_r^4 \quad (9)$$

$$1 - F_I = 1 - 4F_r + 6F_r^2 - 4F_r^3 + F_r^4 \quad (10)$$

$$F_I = 4F_r - 6F_r^2 + 4F_r^3 - F_r^4 \quad (11)$$

$$F_I = 4F_0^5 - 6F_0^{10} + 4F_0^{15} - F_0^{20} \quad (12)$$

$$\begin{aligned} \eta_I &= \int_0^{\infty} F_I(n) dn = \\ &= \int_0^{\infty} (4F_0^5 - 6F_0^{10} + 4F_0^{20} - F_0^{20}) dn \end{aligned} \quad (13)$$

$$\eta_I = \frac{4}{5\lambda} - \frac{6}{10\lambda} + \frac{4}{15\lambda} - \frac{1}{20\lambda} = \frac{5}{12\lambda} \quad (14)$$

The reliability efficiency initiation for the first scheme of detonator connections has the value:

$$\eta_I = \frac{5}{12\lambda} = \frac{5}{12} \times 999 \cong 416 \text{ initiations} \quad (15)$$

B) Second calculation example

It is required to calculate the reliability of detonators efficiency initiation in case of controlled implosion, for a reinforced concrete frame structure, as shown below (Fig. 3):

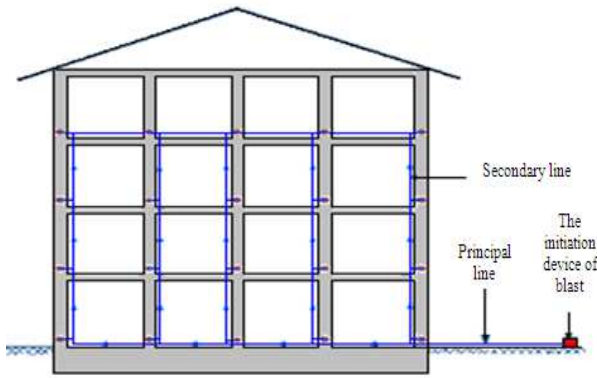


Fig. 3. Scheme of controlled demolition by structure implosion. Variant II

It is considered that the means of initiation of the explosions are detonators at millisecond, that are guaranteed by the manufacturer to have not more than one misfire per 1000 detonators.

The solution of the detonator connection scheme of (6) is as shown in Figure 4.

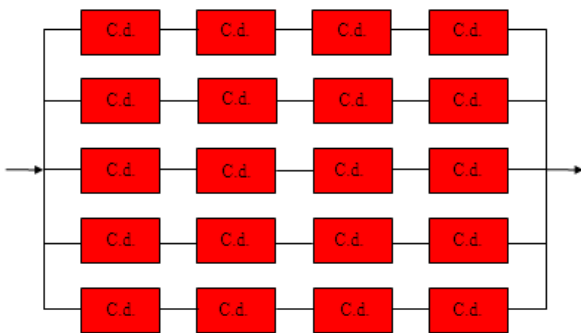


Fig. 4. Scheme of detonator connections for variant II

The calculation of the reliability of efficiency initiation for the second scheme of detonator connections is as follows:

$$\eta_{II} = \int_0^{\infty} F_{II}(\eta) d\eta \quad (16)$$

where η_{II} is the reliability of efficiency initiation of detonators for the second scheme; F_{II} is the reliability of the second scheme; n is the number of millisecond detonators (1).

$$F_{II} + D_{II} = 1 \quad (17)$$

$$D_{II} = D_r^5 \quad (18)$$

$$D_r = 1 - F_r \quad (19)$$

$$F_r = F_0^4 \quad (20)$$

$$F_0 = e^{-\lambda n} \quad (21)$$

where D_{II} is the opposite reliability of demolition schemes for variant II, D_r is the opposite reliability of the ramifications of demolition schemes, F_r is the reliability of the ramifications of the initiations scheme, F_0 is the individual reliability of milliseconds detonators corresponding to each column / level, λ is the risk factor of detonators.

The risk factor for one detonator is

$$\lambda = \frac{1}{999} (\text{initiations})^{-1} \quad (22)$$

It results that [2, 4]:

$$\begin{aligned} 1 - F_{II} &= (1 - F_r)^5 \\ &= C_5^0 - C_5^1 F_r^1 + C_5^2 F_r^2 - C_5^3 F_r^3 + \\ &\quad + C_5^4 F_r^4 - C_5^5 F_r^5 \end{aligned} \quad (23)$$

$$\begin{aligned} 1 - F_{II} &= 1 - 5F_r + \\ &\quad + 10F_r^2 - 10F_r^3 + 5F_r^4 - F_r^5 \end{aligned} \quad (24)$$

$$F_{II} = 5F_0^4 - 10F_0^8 + 10F_0^{12} - 5F_0^{16} + F_0^{20} \quad (25)$$

$$\begin{aligned} \eta_{II} &= \int_0^{\infty} F_{II}(n) d\eta = \\ &= \int_0^{\infty} (5F_0^4 - 10F_0^8 + 10F_0^{12} - 5F_0^{16} + F_0^{20}) d\eta \end{aligned} \quad (26)$$

$$\eta_{II} = \frac{5}{4\lambda} - \frac{10}{8\lambda} + \frac{10}{12\lambda} - \frac{5}{16\lambda} + \frac{1}{20\lambda} = \frac{137}{240\lambda} \quad (27)$$

The reliability of efficiency initiation for the second scheme of detonator connections is:

$$\eta_{II} = \frac{137}{240\lambda} \cong 570 \text{ initiations} \quad (28)$$

3. CALCULATION OF DETONATORS PRICE

Considering that the average purchase price of a millisecond detonator is about 10 Romanian Lei (RON), it results that the cost of detonators, in both variants of calculation, is:

$$C_I = C_{II} = n \times 10 = 200 \text{ RON} \quad (29)$$

4. CALCULATION OF THE PRICE / RELIABILITY RATIO OF THE INITIATION SCHEMES

The calculation of the price/reliability efficiency ratio of the detonators initiation schemes, in the two alternatives of calculation, is as follows:

$$\frac{C_I}{\eta_I} = \frac{200}{416,25} = 0,40 \frac{\text{RON}}{\text{initiation}} \quad (30)$$

$$\frac{C_{II}}{\eta_{II}} = \frac{200}{570,26} = 0,35 \frac{\text{RON}}{\text{initiation}} \quad (31)$$

5. CONCLUSIONS

The first version of the explosion initiation scheme for controlled demolition by implosion, has four lines in parallel and five lines in series and the second, has five lines in parallel and four lines in series. The reliability efficiency of the second initiation schemes is by 37% higher than that of the first scheme (6):

$$\frac{\eta_{II} - \eta_I}{\eta_I} \times 100 = 37\% \quad (32)$$

In both cases, the reliability efficiency of connection initiation schemes of detonators is much smaller than the reliability efficiency of initiation of one detonator:

$$\eta_I < \eta_{II} \ll \eta \quad (33)$$

The detonators cost is the same in both variants of the initiation calculation schemes. The price/reliability ratio efficiency of the initiation schemes of the detonators, in the second calculation case, is by 37% lower (better) than in the first.

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