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## Seismic Analysis of Masonry Structures Including Dynamic Soil-Structure Interaction

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### Abstract

Dynamic soil-structure interaction problem during earthquakes is a very important topic in the analysis of the dynamic behaviour of civil engineering structures. A suitable method is the finite and infinite elements coupled model. In this method, the seismic waves propagating from far field (epicenter) are transformed into nodal dynamic loads acting on the common boundary between finite and infinite elements where the reflected waves from foundation surface and structure can be transmitted back into the far field through the finite and infinite elements coupled system. In this paper the method of damage analysis of masonry structures during earthquakes and obtained results are presented. In this investigation the masonry structure is discretised into finite elements. These elements are coupled with infinite elements that are used to model the infinite soil medium. The examples presented indicate the usefulness of the present method in engineering practice.

**Key words:** Analysis, Seismic, Dynamic, Soil, Structure, Interaction, Masonry.

$$[m]\{\ddot{u}\} + [c]\{\dot{u}\} + [k]\{u\} = \{f(t)\} \quad (1)$$

$$\begin{bmatrix} c & m & k \\ \ddot{u} & \dot{u} & u \\ f(t) \end{bmatrix}$$

$\omega_i$

$$\begin{aligned} \{f(t)\} &= \{f_0\}e^{i\omega t}, \quad \{u\} = \{u_0\}e^{i\omega t}, \\ \{\dot{u}\} &= i\omega\{u_0\}e^{i\omega t}, \quad \{\ddot{u}\} = -\omega^2\{u_0\}e^{i\omega t} \end{aligned} \quad (2)$$

$$\begin{aligned} & \{u\} \\ & (1) \quad (2) \end{aligned}$$

$$[\bar{k}]\{u_0\} = \{f_0\} \quad (3)$$

$$[\bar{k}]$$

$$[\bar{k}] = [k] + i\omega[c] - \omega^2[m] \quad (4)$$

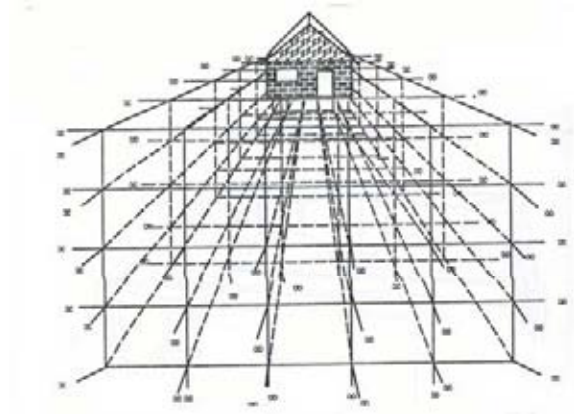
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$\{u_0\}$

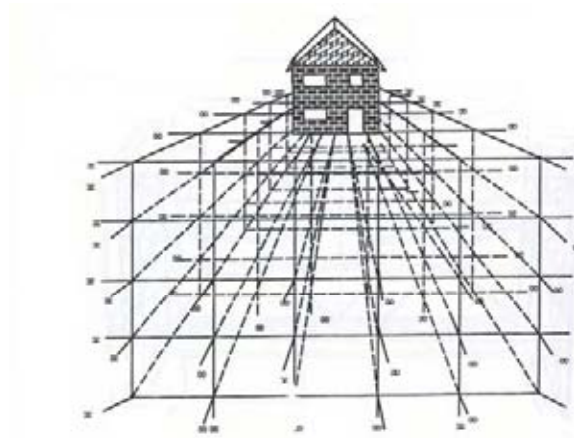
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$$f = f_0 e^{i\omega t}$$



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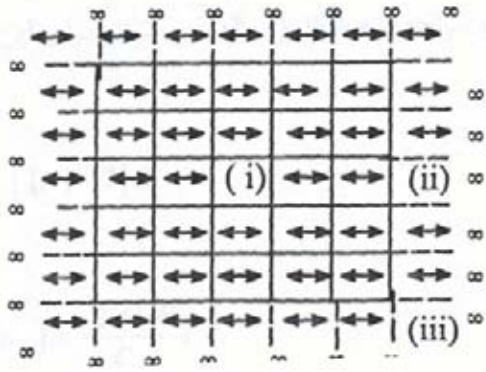
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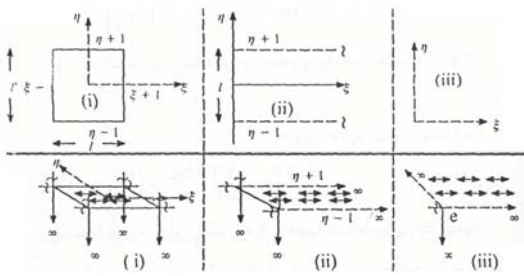
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$$\{P\}^e = P_{sv} \int_0^\infty e^{-(\alpha+i\beta)\xi} d\xi \int_0^\infty e^{-(\alpha+i\beta)\eta} d\eta = P_{sv} \frac{1}{\beta^2} \quad ( )$$

$$A \quad l \quad l \quad l^2 = -1 \quad \beta = \frac{\omega}{C_s}$$

[N]

$$P_{sv} = \frac{-2G.\omega}{C_s} \quad ( )$$

$$G \quad P_{sv} \quad C_s$$

$$\{P\}^e = \int_s [N]^T \{T\} ds \quad ( )$$

$$\{P\}^e \quad \{T\} \quad [N]$$

$$\eta \quad \xi \quad ( ) \quad ( ) \quad i \quad ( )$$

$$iii \quad ii \quad i \quad ( ) \quad ( ) \quad ( )$$

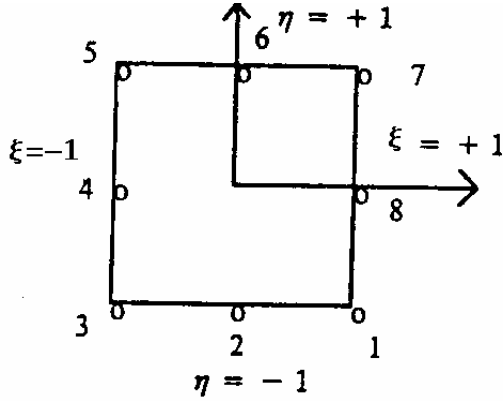
$$\{P\}^e = \int_{-l/2}^{+l/2} \int_{-l/2}^{+l/2} -2.G.\beta.i.[N]^T d\xi d\eta = \begin{Bmatrix} P_1 \\ P_2 \\ P_3 \\ P_4 \end{Bmatrix},$$

$$P_i = \frac{1}{2} G.\beta.A \quad i=1,2,3,4 \quad ( )$$

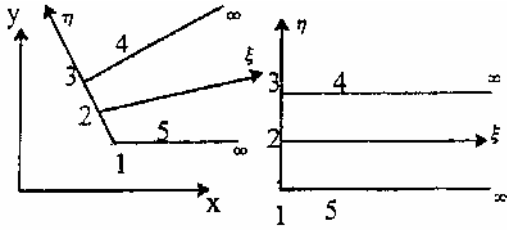
$$\{P\}^e = \int_s [N]^T \{P_{sv}\} ds = P_{sv} \left[ \int_0^\infty e^{-(\alpha+i\beta)\xi} d\xi \right] \times$$

$$\left[ \int_{-l/2}^{+l/2} \begin{Bmatrix} \frac{1}{2}(1-\frac{2\eta}{l}) \\ \frac{1}{2}(1+\frac{2\eta}{l}) \end{Bmatrix} d\eta \right] = \begin{Bmatrix} \frac{P_{sv}}{2} i \\ -\frac{P_{sv}}{\beta} i \\ \frac{P_{sv}}{2} i \\ -\frac{P_{sv}}{\beta} i \end{Bmatrix} \quad ( )$$

$$u = \sum_{i=1}^3 N_i u_i, \quad v = \sum_{i=1}^3 N_i v_i \quad ( )$$



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$$N_i \quad (i=1,2,3)$$

$$N_1 = P(\xi) \xi \frac{\eta(\eta-1)}{2}, \quad N_2 = -P(\xi) (\eta-1)(\eta+1)$$

$$N_3 = P(\xi) \frac{\eta(\eta+1)}{2} \quad ( )$$

$$P(\xi) \quad ( ) ( ) \quad \xi$$

$$P(\xi) = e^{-\alpha\xi} e^{i\beta\xi} \quad ( )$$

$$e^{-\alpha\xi}$$

$$e^{-i\beta\xi}$$

$$N_1 = \frac{1}{4} \eta \xi (\eta-1) (\xi+1), \quad N_2 = \frac{1}{2} \eta (\eta-1) (1-\xi^2)$$

$$N_3 = \frac{1}{4} \xi \eta (\eta-1) (\xi-1)$$

$$N_4 = \frac{1}{2} \xi (\xi-1) (\xi+1) (1-\eta^2)$$

$$N_5 = \frac{1}{4} \xi (\eta+1) (\xi-1), \quad N_6 = \frac{1}{4} \xi \eta (\xi+1) (\eta+1)$$

$$N_7 = \frac{1}{4} \xi \eta (\xi+1) (\eta+1), \quad N_8 = \frac{1}{8} \xi (\xi+1) (1-\eta^2)$$

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(\xi, \eta)

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$$x = \sum_{i=1}^5 M_i x_i, \quad y = \sum_{i=1}^5 M_i y_i \quad ( )$$

$$M_i \quad (i=1,2,3,4,5)$$

$$M_1 = \frac{1}{2} (\xi-1) (\eta-1), \quad M_2 = 0$$

$$M_3 = -\frac{1}{2} (\xi-1) (\eta+1)$$

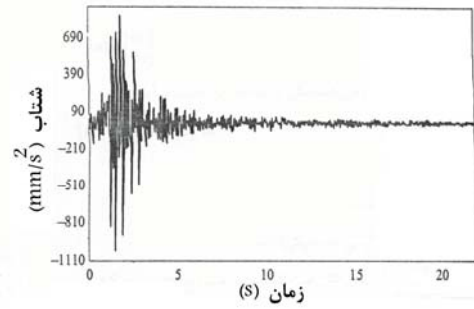
$$M_4 = -\frac{1}{2} \xi (\eta+1), \quad M_5 = -\frac{1}{2} \xi (\eta-1) \quad ( )$$

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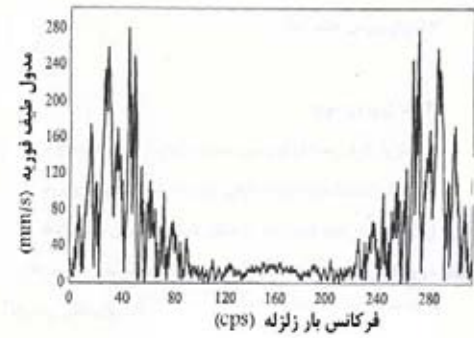
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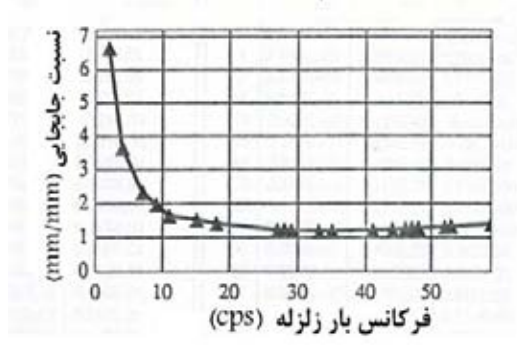


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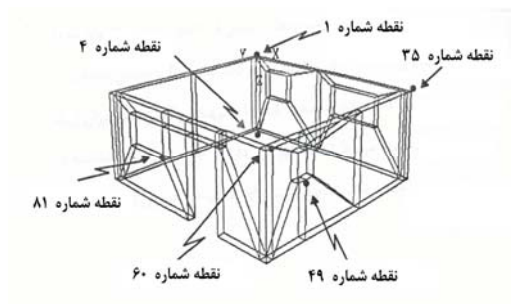
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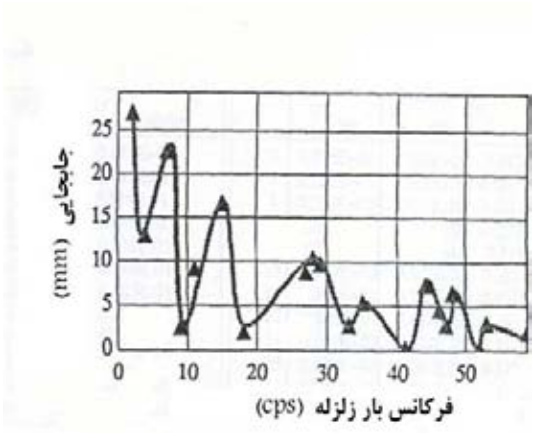
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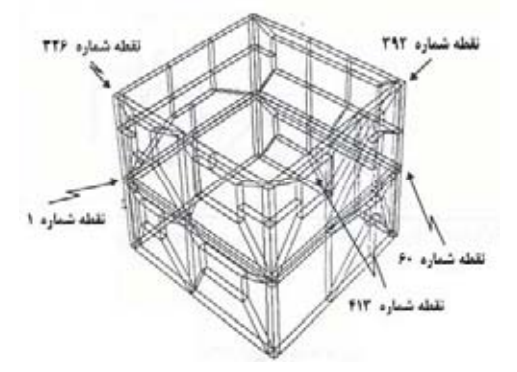
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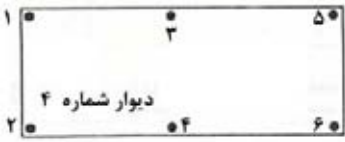
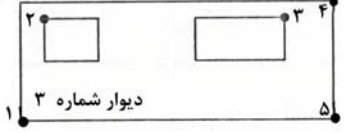
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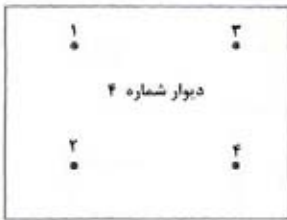
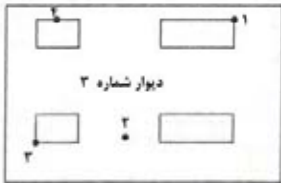
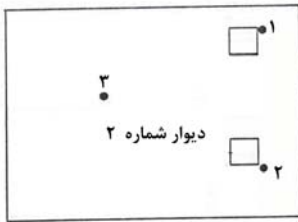
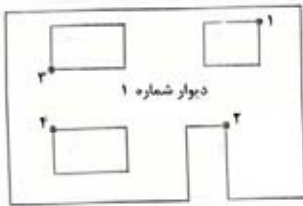
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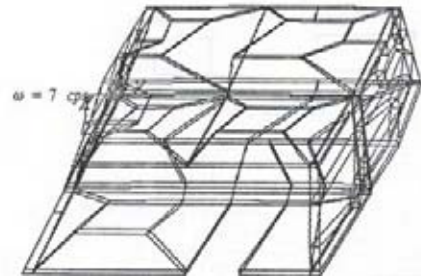
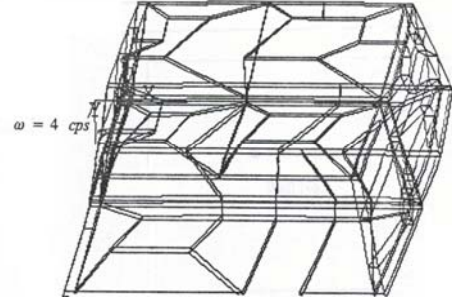
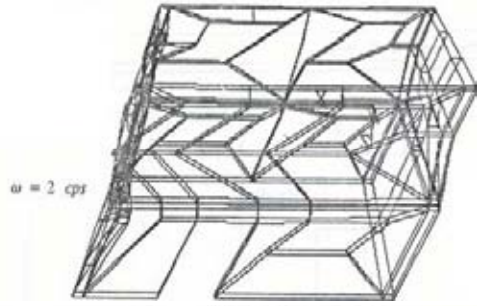
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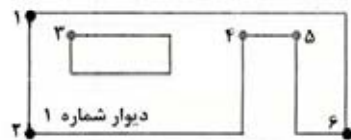
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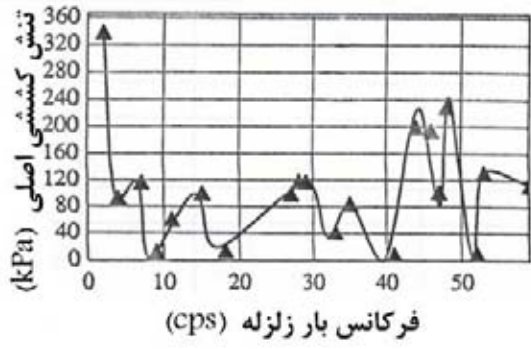
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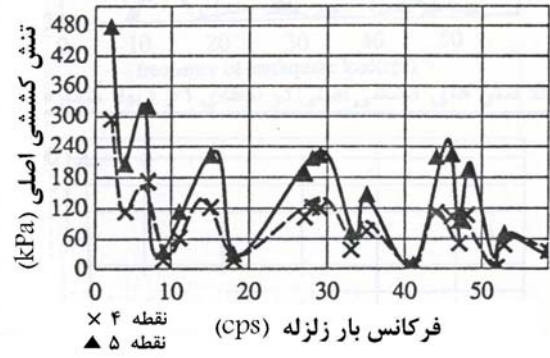
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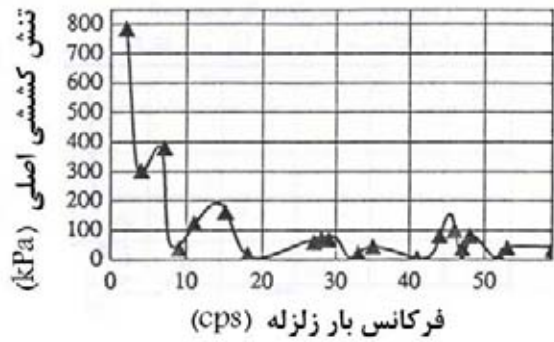




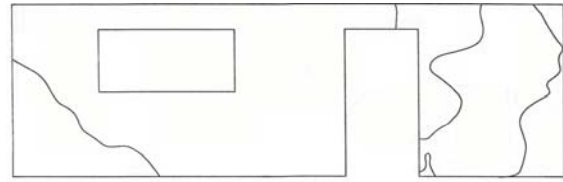
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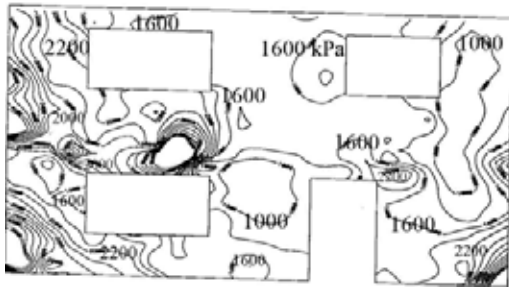
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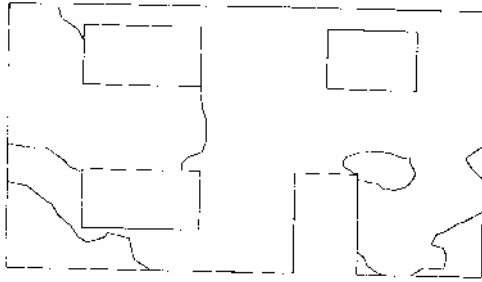
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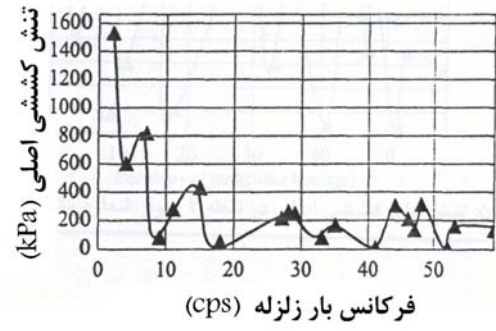
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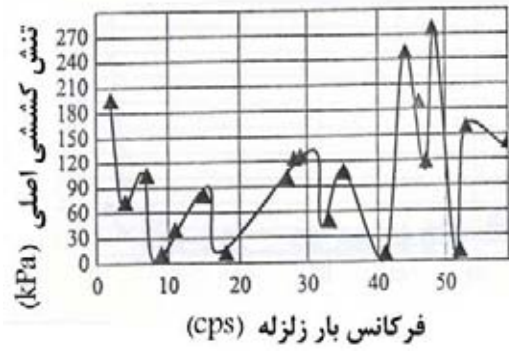
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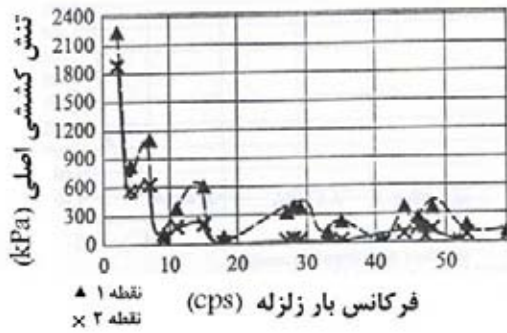
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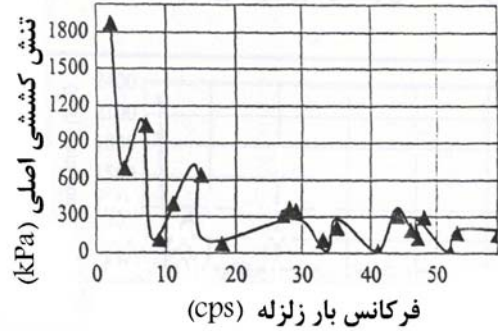
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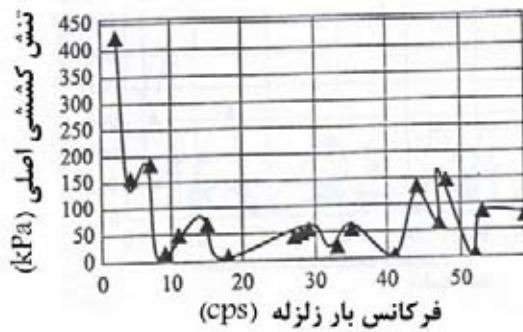


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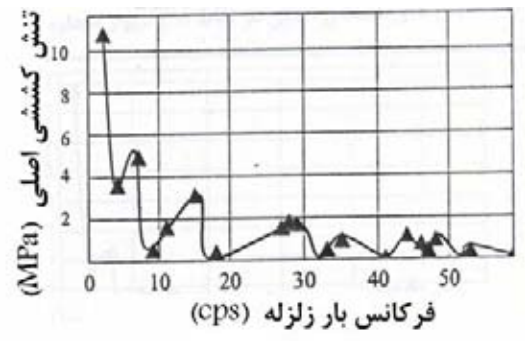


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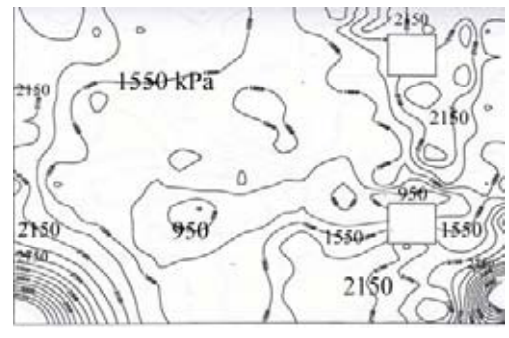
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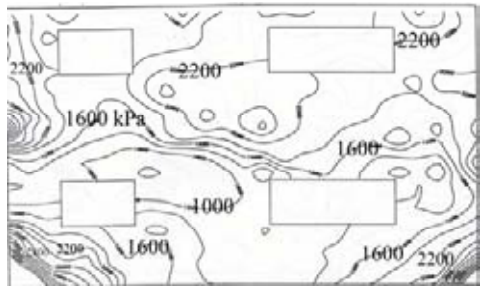


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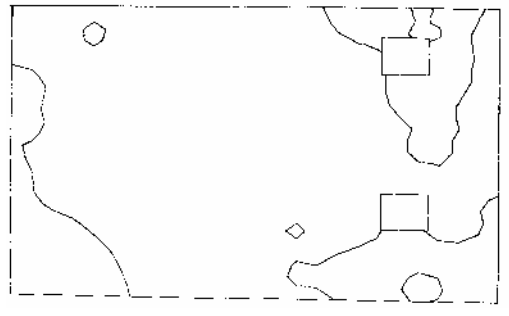


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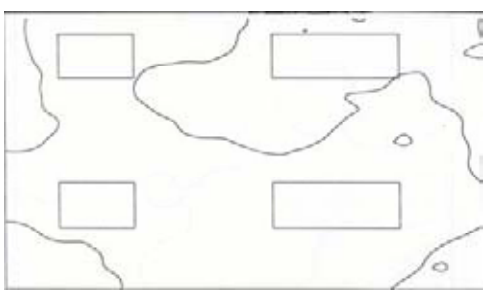
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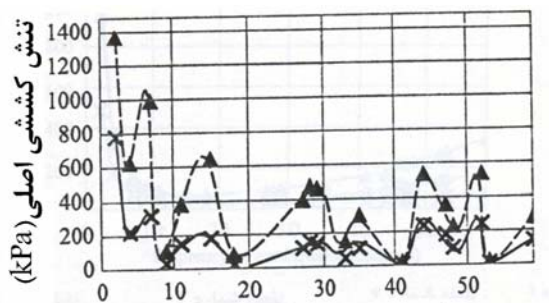
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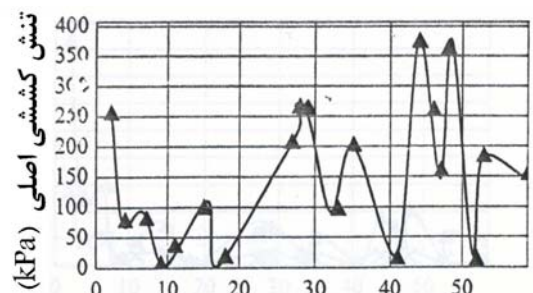
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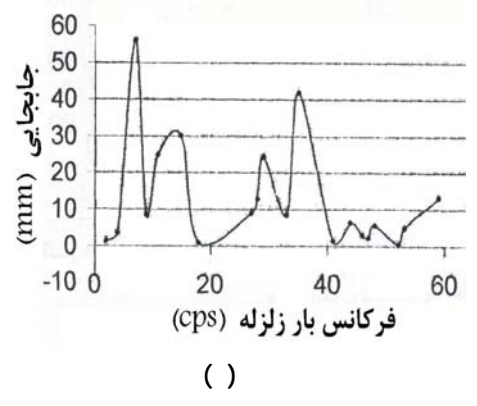
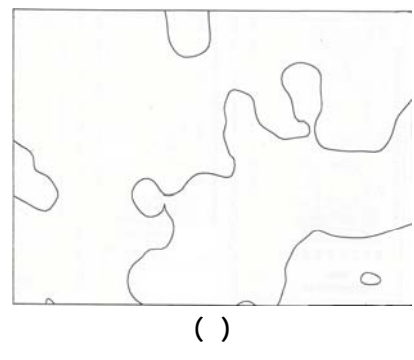
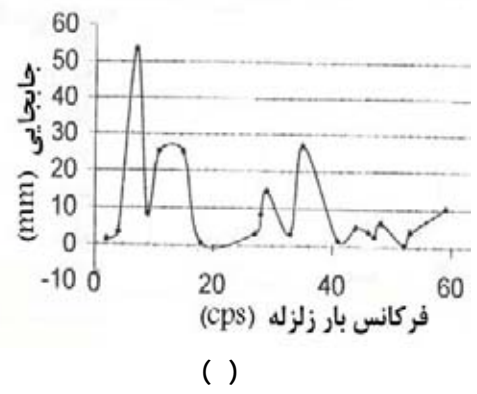
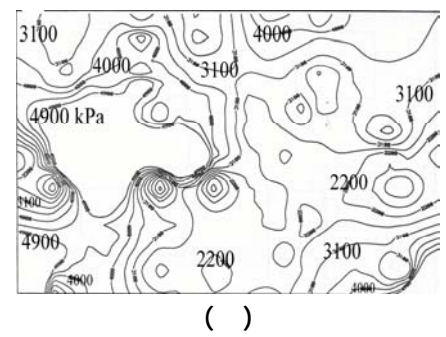
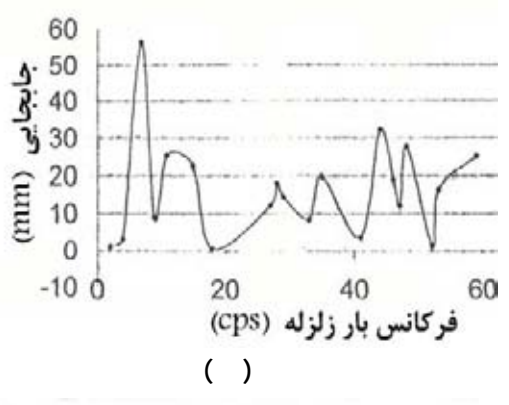


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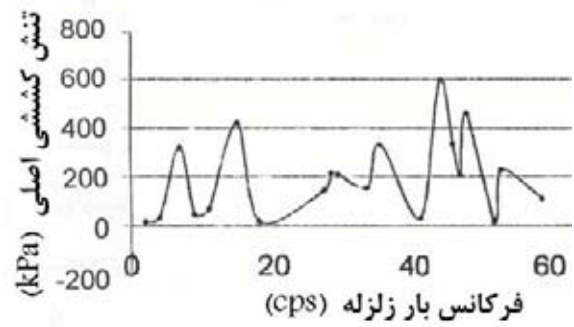
$$T = 2\pi\sqrt{\frac{m}{k}} \quad ( )$$



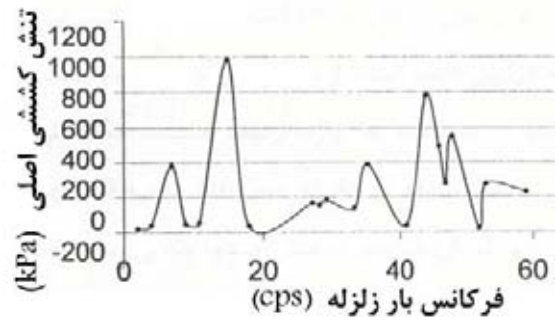
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