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$$\bar{f}'_t = \frac{f'_t}{f'_c}, \quad \bar{f}'_{bc} = \frac{f'_{bc}}{f'_c} \quad ()$$

$$b_o = -\rho b_1 - \rho^2 b_2 \quad ()$$

$$b_1 = \left(\bar{\xi}_2 + \frac{1}{3} \right) b_2 + \frac{\sqrt{\frac{6}{5}} - 3 \bar{r}_2}{3 \bar{\xi}_2 - 1} \quad ()$$

$$b_2 = \frac{\bar{r}_2 \left(\rho + \frac{1}{3} \right) - \sqrt{\frac{2}{15}} \left(\rho + \bar{\xi}_2 \right)}{\left(\bar{\xi}_2 + \rho \right) \left(\bar{\xi}_2 - \frac{1}{3} \right) \left(\rho + \frac{1}{3} \right)}$$

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$$f(\sigma) = f(\sigma_m, \tau_m, \theta) = \frac{1}{\bar{r}(\sigma_m, \theta)} \frac{\tau_m}{f'_c} - 1 = 0 \quad ()$$

$$r(\sigma_m, \theta) = \frac{2r_c \left(\frac{2}{r_c} - 2 \right) \cos \theta + r_c (2r_t - r_c) \left[4 \left(\frac{2}{r_c} - 2 \right) \cos^2 \theta + 5r_t^2 - 4r_t r_c \right]^{\frac{1}{2}}}{4 \left(\frac{2}{r_c} - 2 \right) \cos^2 \theta + (r_c - 2r_t)^2} \quad ()$$

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$$f_{cb} = 1.2 f'_c, \quad \bar{r}_1 = 1.45 f'_c, \quad \bar{r}_2 = 1.725 f'_c \quad ()$$

$$\frac{r_t}{\sqrt{5} f'_c} = a_o + a_1 \frac{\sigma_m}{f'_c} + a_2 \left(\frac{\sigma_m}{f'_c} \right)^2 \quad \text{at } \theta = 0 \quad ()$$

$\sqrt{3} f'_c$

$$\frac{rc}{\sqrt{5} f'_c} = b_o + b_1 \frac{\sigma_m}{f'_c} + b_2 \left(\frac{\sigma_m}{f'_c} \right)^2 \quad \text{at } \theta = 60^\circ \quad ()$$

$$\bar{r}(\sigma_m, \theta) = \frac{r(\sigma_m, \theta)}{\sqrt{5} f'_c} \quad ()$$

$\sigma_m, \tau_m, f'_t, f'_c$

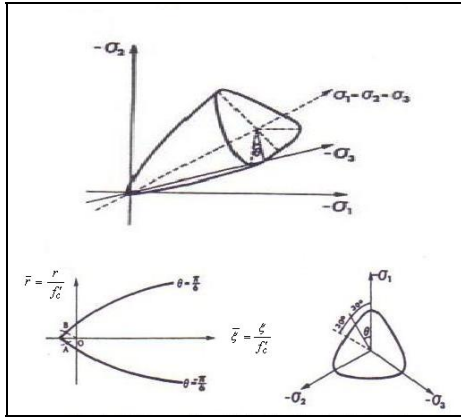
a_i, b_i

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f'_{bc}

$$\left(\frac{\sigma_m}{f'_c}, \frac{\tau_m}{f'_c} \right) = (-\bar{\xi}_1, \bar{r}_1)$$

$$\left(\frac{\sigma_m}{f'_c}, \frac{\tau_m}{f'_c} \right) = (-\bar{\xi}_2, \bar{r}_2)$$



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$$[K_t] = \int_v [B]^T [D_{ep}] [B] dv \quad ()$$

[B]

[Dep]

$$a_o = \frac{2}{3} \bar{f}'_{bc} a_1 - \frac{4}{9} \bar{f}'_{bc}{}^2 a_2 + \sqrt{\frac{2}{15}} f'_{bc} \quad ()$$

$$a_1 = \frac{1}{3} (2 \bar{f}'_{bc} - \bar{f}'_t) a_2 + \left(\frac{6}{5} \right)^{\frac{1}{2}} \frac{\bar{f}'_t - \bar{f}'_{bc}}{2 \bar{f}'_{bc} + \bar{f}'_t} \quad ()$$

$$a_2 = \frac{\sqrt{\frac{6}{5}} \bar{\xi}_1 (\bar{f}'_t - \bar{f}'_{bc}) - \sqrt{\frac{6}{5}} \bar{f}'_t \bar{f}'_{bc} + \eta_1 (2 \bar{f}'_{bc} + \bar{f}'_t)}{\left(2 \bar{f}'_{bc} + \bar{f}'_t \right) \left(\frac{\bar{\xi}_1^2 - 2}{3} \bar{f}'_{bc} \bar{\xi}_1^2 + \frac{1}{3} \bar{f}'_t \bar{\xi}_1 - \frac{2}{9} \bar{f}'_t \bar{f}'_{bc} \right)}$$

$$\rho = \frac{a_1 - \sqrt{a_1^2 - 4 a_o a_2}}{2 a_2} \quad ()$$

$$L = \left\{ \frac{\partial F}{\partial \{\sigma\}} \right\}^T [D] \{\Delta \tilde{\varepsilon}\} \quad ()$$

$$r = \frac{-f(\{\sigma\}_m, k_m)}{\left\{ \frac{\partial f(\{\sigma\}_m, k_m)}{\partial (\sigma)} \right\}^T \{\Delta \sigma^e\}_{m+1}} \quad ()$$

$$m = \text{Min} \left[200 \left[1 - \frac{F(\sigma, y)}{f(y)} \right]_{+1}, 200 \right] \quad ()$$

$$\nabla^2 P = \frac{1}{C^2} \frac{\partial^2 P}{\partial t^2} \quad ()$$

$$\left[\frac{\partial P}{\partial y} + \frac{1}{g} \ddot{P} \right]_{y=\eta} = 0 \quad ()$$

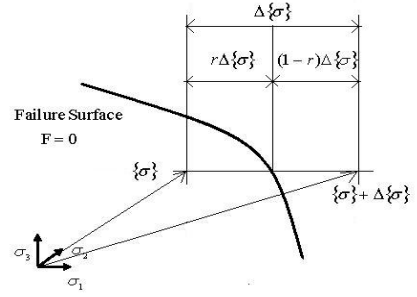
$$\frac{\partial P}{\partial x} = -\frac{\pi}{2h} P - \frac{1}{C} \frac{\partial P}{\partial t} \quad ()$$

$$\frac{\partial P}{\partial n} = -\rho \ddot{v}_{gn} - \frac{1}{\beta C} \frac{\partial P}{\partial t} \quad ()$$

$$\beta = \frac{\rho_b C_b}{\rho C}$$

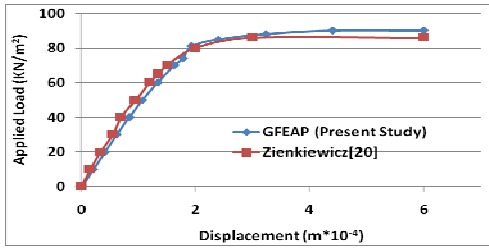
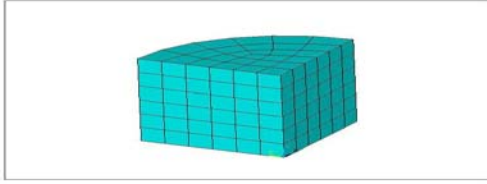
$$\rho \ddot{a}_{ns} = -\frac{\partial P}{\partial n} \quad ()$$

$$\{\delta \sigma\} = -\frac{\left\{ \frac{\partial f}{\partial \sigma} \right\}}{\left\{ \frac{\partial f}{\partial \sigma} \right\}^T \left\{ \frac{\partial f}{\partial \sigma} \right\}} \quad ()$$



90kN/m²

$\beta, C_b, n, \rho, \rho_b, \ddot{v}_g, h$



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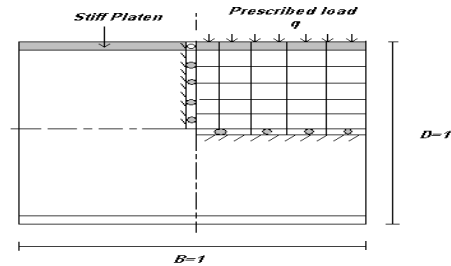
GFEAP

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$f_c = 29 \text{ MPa}, f_t = 3.1 \text{ MPa}, E = 21.7 \text{ GPa}, \nu = 0.2$



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$\phi = \arcsin\left(\frac{f_c - f_t}{f_c + f_t}\right) = 53.79^\circ$ ()

$C = \left(\frac{f_c f_t}{f_c - f_t}\right) \tan \phi = 4.74 \text{ MPa}$ ()

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600N

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1800 N

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$E = 2 \cdot 10^5 \text{ kN/m}^2, \nu = 0.25, C = 10 \text{ kN/m}^2, \phi = 45$

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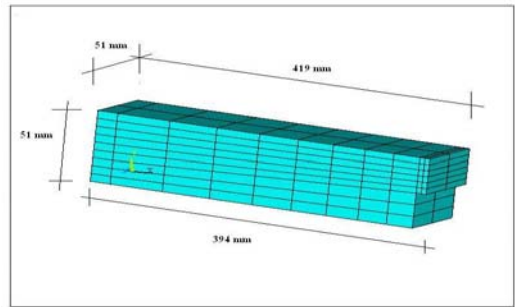
48kN/m²

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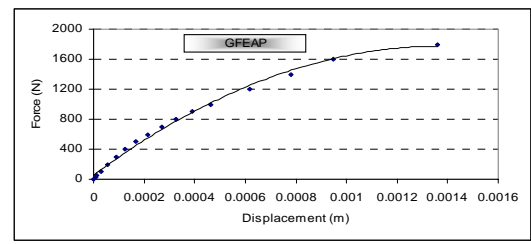
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dN/mm²



dN/mm²

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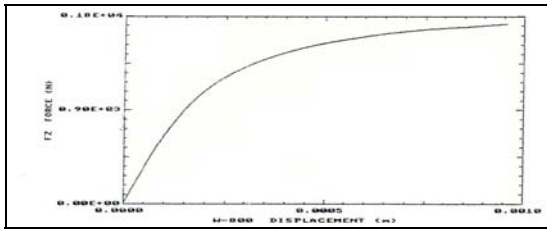
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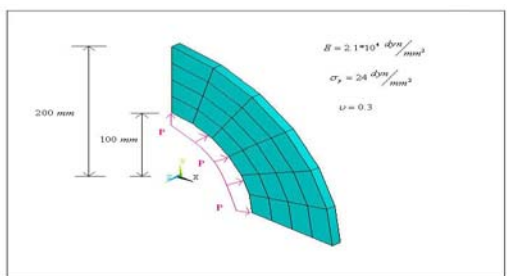
$$K = \frac{6C \cos \phi}{\sqrt{3(3 - \sin \phi)}} = 12.25, \alpha = \frac{2 \sin \phi}{\sqrt{3(3 - \sin \phi)}} = 0.149$$

([])



$$K = \frac{6C \cos \phi}{\sqrt{3(3 + \sin \phi)}} = 9.74, \alpha = \frac{2 \sin \phi}{\sqrt{3(3 + \sin \phi)}} = 0.118$$

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$$K = \frac{3C}{\sqrt{9 + 12 \tan^2 \phi}} = 9.22, \alpha = \frac{\tan \phi}{\sqrt{9 + 12 \tan^2 \phi}} = 0.112$$

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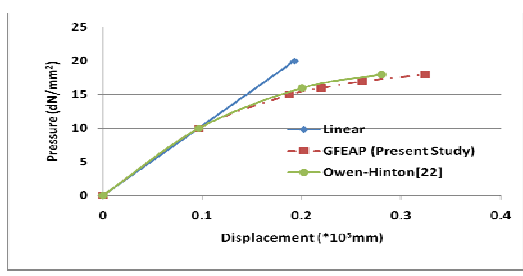
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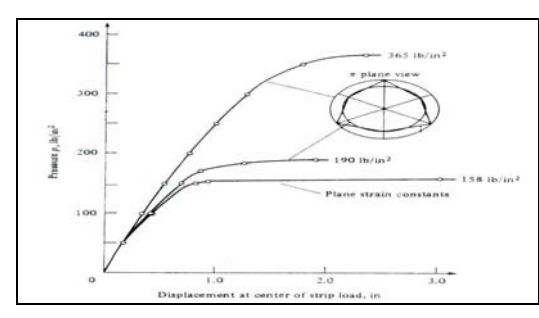
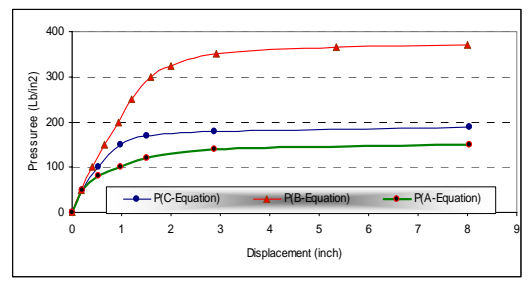
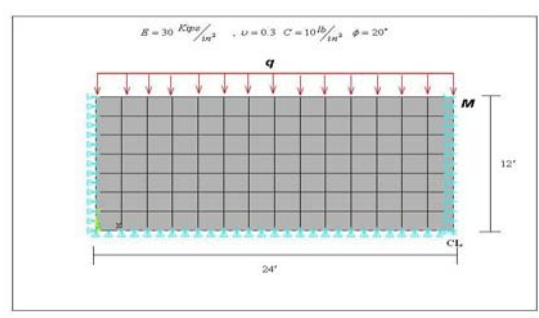
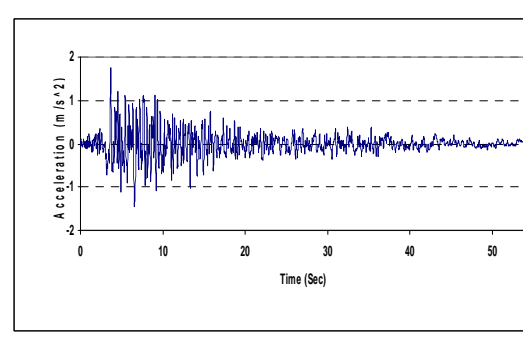
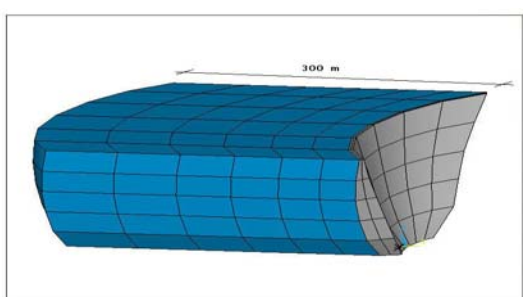


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σ_c / GPa
 ρ / Kg/m³
 σ_t / MPa
 v / m/s

$\alpha = 0.55$
 $\beta = \frac{1+\alpha}{1-\alpha} = 3.44$
 $f_t = 0.324 f_c^{2/3} = 3 \text{ MPa}$

$(-\bar{\xi}_1, \bar{\eta}_1) = (1.73, 1.45)$
 $(-\bar{\xi}_2, \bar{\eta}_2) = (1.73, 1.45)$



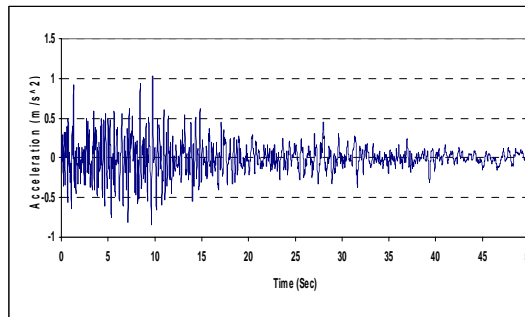
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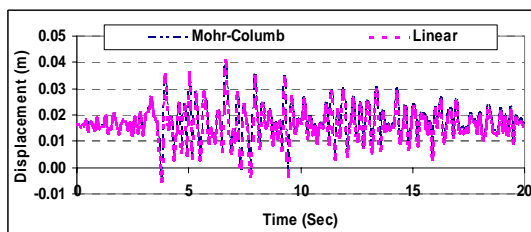
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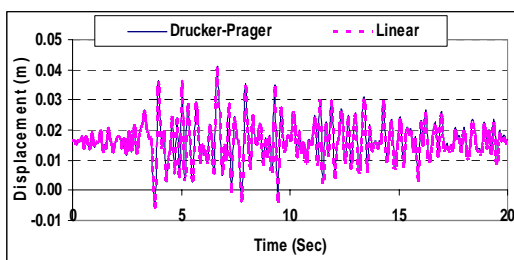


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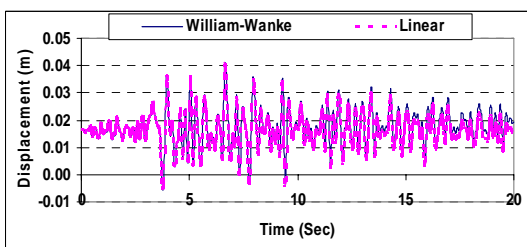
1g 0.5g PGA

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PGA=0.5g

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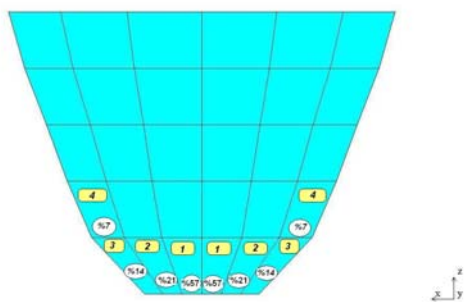


ANSYS

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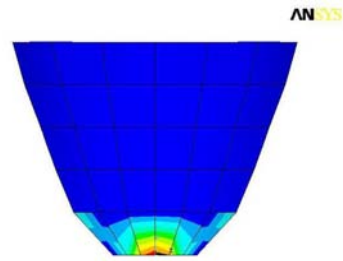
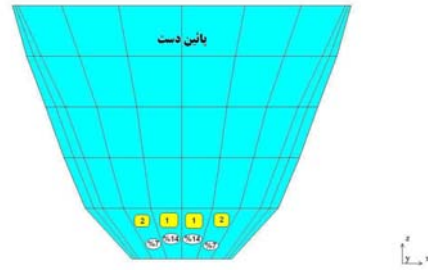
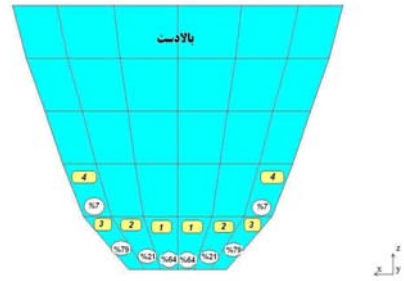
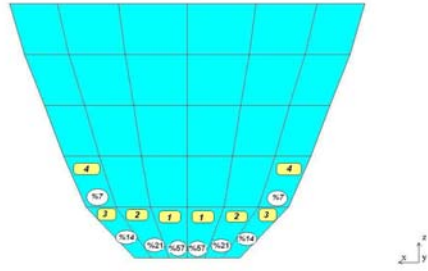
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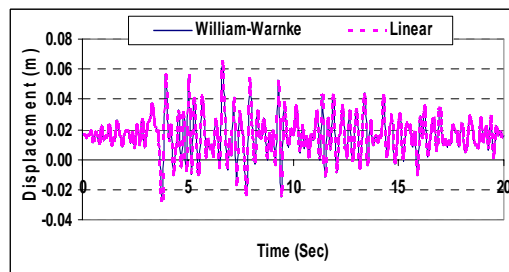
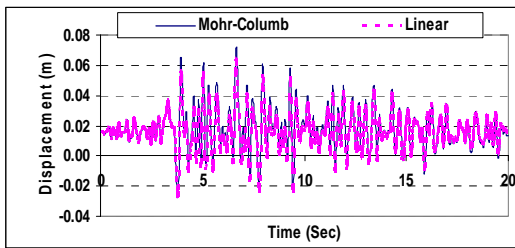
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ANSYS

PGA=1g

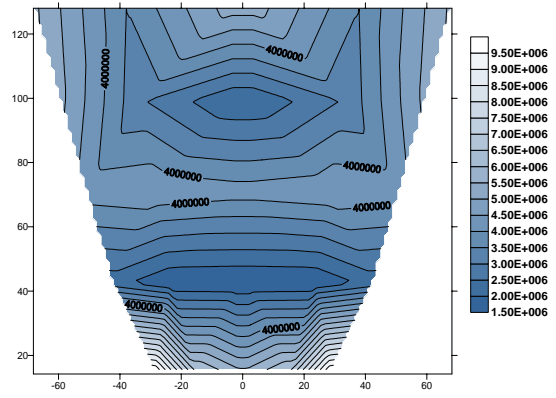
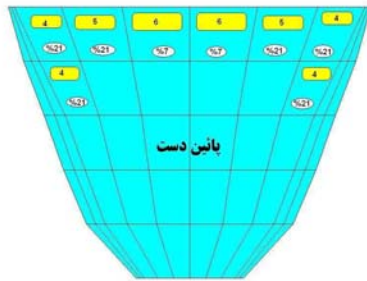
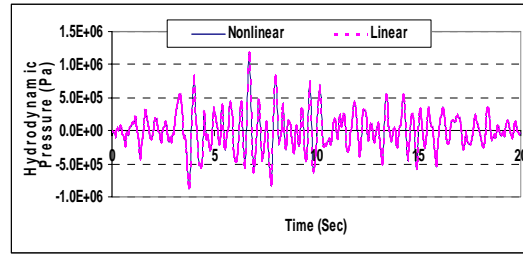
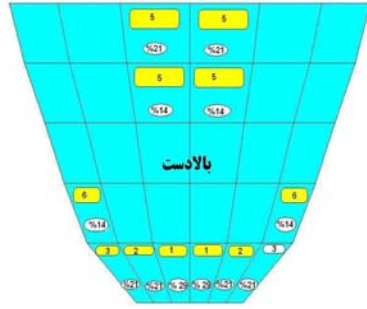


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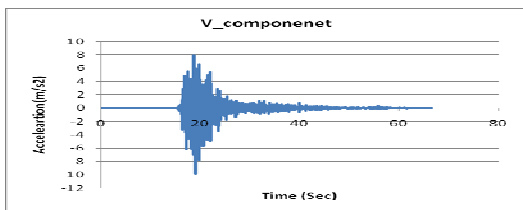
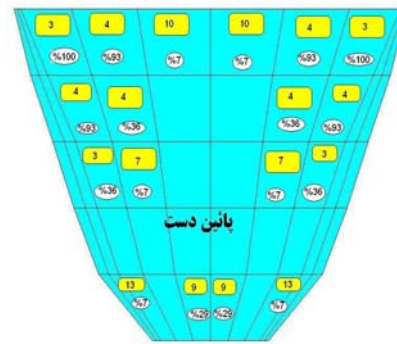
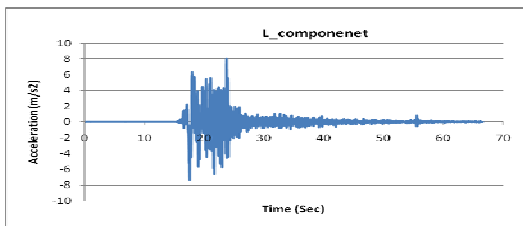
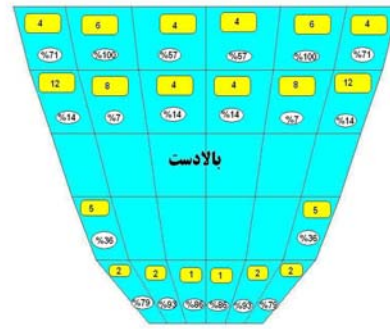


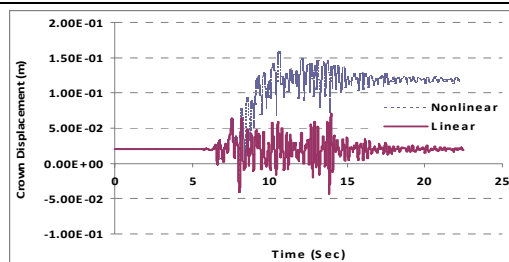
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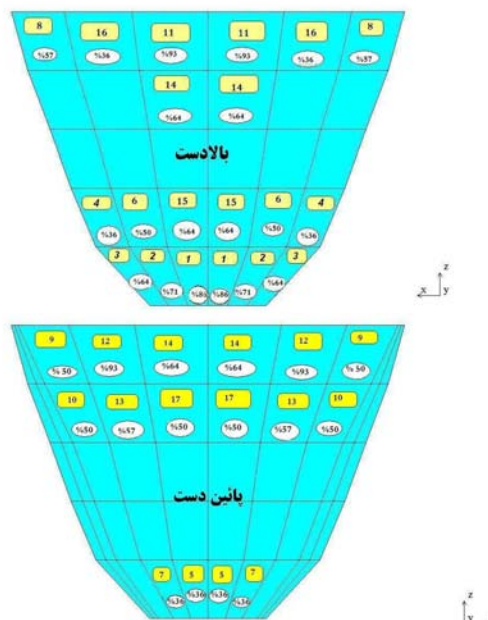
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- 1 - Objective Stress
 - 2 - Staggered Method
 - 3 - Fixed Smeared Crack Model
 - 4 - Added Mass
 - 5 - Damage Mechanics
 - 6 - Associative flow rule
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