有限元可靠度方法的基本原理与研究进展

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四川，成都

报告提纲

引　言

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  -
    - MCS
    - (RSM)
  - SFEM
    - Taylor Neumann
    - “
      ” (Finite Element Reliability Method, FERM)

一次有限元可靠度方法的基本原理

– **S** **V**

$$\mathbf{S} = \mathbf{S}(\mathbf{V})$$

–

$$g[\mathbf{S}(\mathbf{V}), \mathbf{V}]$$

–

$$p_f = \int_{g[\mathbf{s}(\mathbf{v}),\mathbf{v}]\le 0} f_{\mathbf{V}}(\mathbf{v}) d\mathbf{v}$$

$$\mathbf{Y} = T(\mathbf{V})$$

$$p_f = \int_{G(\mathbf{y})\le 0} \varphi_n(\mathbf{y}) d\mathbf{y}$$

$$G(\mathbf{y}) = g[\mathbf{s}(\mathbf{v}), \mathbf{v}] = g[\mathbf{s}(T^{-1}(\mathbf{y})), \mathbf{y}]$$

一次有限元可靠度方法的基本原理

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$$G(\mathbf{y}) \approx G(\mathbf{y}^*) + \nabla_{\mathbf{y}^*} G^T (\mathbf{y} - \mathbf{y}^*) = \nabla_{\mathbf{y}^*} G^T (\mathbf{y} - \mathbf{y}^*)$$

–

$$p_f \approx p_{f1} = \int_{\beta - \boldsymbol{\alpha}^{*T}\mathbf{y} \le 0} \varphi_n(\mathbf{y}) d\mathbf{y} = \Phi(-\beta)$$

$$\boldsymbol{\alpha}^* = -\nabla_{\mathbf{y}^*} G / \| \nabla_{\mathbf{y}^*} G \| \qquad \beta = \boldsymbol{\alpha}^{*T} \mathbf{y}^*$$

–

$$\mathbf{y}_{i+1} = \left(\frac{G(\mathbf{y}_i)}{\left\| \nabla_{\mathbf{y}_i} G \right\|} + \boldsymbol{\alpha}_i^T \mathbf{y}_i \right) \boldsymbol{\alpha}_i$$

–

$$\nabla_{\mathbf{y}} G = (\mathbf{J}_{\mathbf{y},\mathbf{v}}^{-1})^T \cdot \nabla_{\mathbf{v}} g = (\mathbf{J}_{\mathbf{y},\mathbf{v}}^{-1})^T \cdot [\nabla_{\mathbf{s}} g \cdot \mathbf{J}_{\mathbf{s},\mathbf{v}} + \nabla_{\mathbf{v}} g]$$

线弹性有限元可靠度分析

–

$$\mathbf{R} = \bigcup_e \int_{\Omega_e} \mathbf{B}^T \cdot \boldsymbol{\sigma} d\Omega_e = \bigcup_e \left[\int_{\Omega_e} \mathbf{N}^T \cdot \rho_0 \mathbf{b}_0 d\Omega_e + \int_{\partial\Omega_e} \mathbf{N}^T \cdot \mathbf{t}_0 dS_e \right] = \mathbf{F}$$

$$\mathbf{R} = \mathbf{K}\mathbf{U} = \mathbf{F}$$

–

$$\frac{d\mathbf{R}}{d\mathbf{v}} = \left.\frac{\partial \mathbf{R}}{\partial \mathbf{U}}\right|_{\mathbf{v}} \frac{d\mathbf{U}}{d\mathbf{v}} + \frac{\partial \mathbf{R}}{\partial \mathbf{v}} = \frac{\partial \mathbf{F}}{\partial \mathbf{v}}$$

$$\mathbf{K}\frac{d\mathbf{U}}{d\mathbf{v}} + \frac{\partial \mathbf{R}}{\partial \mathbf{v}} = \frac{\partial \mathbf{F}}{\partial \mathbf{v}}$$

$$\mathbf{J}_{\mathbf{U},\mathbf{v}} = \frac{d\mathbf{U}}{d\mathbf{v}} = \mathbf{K}^{-1}\left(\frac{\partial \mathbf{F}}{\partial \mathbf{v}} - \frac{\partial \mathbf{R}}{\partial \mathbf{v}}\right)$$

线弹性有限元可靠度分析

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- $\mathbf{V}_p$
- $\mathbf{V}_m$
- $\mathbf{V}_g$

$$\mathbf{R}[\mathbf{X}(\mathbf{V}_g),\mathbf{U}(\mathbf{X}(\mathbf{V}_g),\mathbf{V}_m,\mathbf{V}_p),\mathbf{V}_m]=\mathbf{F}[\mathbf{X}(\mathbf{V}_g),\mathbf{V}_p]$$

–

$$\mathbf{J}_{\mathbf{U},\mathbf{v}_P}=\frac{d\mathbf{U}}{d\mathbf{v}_P}=\mathbf{K}^{-1}\left(\frac{\partial\mathbf{F}}{\partial\mathbf{v}_P}\right)$$

$$\frac{\partial\mathbf{F}}{\partial\mathbf{v}_P}=\bigcup_e\left[\int_{\Omega_e}\mathbf{N}^T\cdot\frac{\partial(\rho_0\mathbf{b}_0)}{\partial\mathbf{v}_P}d\Omega_e+\int_{\partial\Omega_e}\mathbf{N}^T\cdot\frac{\partial\mathbf{t}_0}{\partial\mathbf{v}_P}dS_e\right]$$

线弹性有限元可靠度分析

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$$\mathbf{J}_{\mathbf{U},\mathbf{v}_m} = \frac{d\mathbf{U}}{d\mathbf{v}_m} = \mathbf{K}^{-1}\left(-\frac{\partial \mathbf{R}}{\partial \mathbf{v}_m}\right)$$

$$\frac{\partial \mathbf{R}}{\partial \mathbf{v}_m} = \bigcup_e \int_{\Omega_e} \mathbf{B}^T \cdot \frac{\partial \mathbf{D}}{\partial \mathbf{v}_m} \cdot \mathbf{B} \cdot \mathbf{U}_e d\Omega_e$$

–

$$\mathbf{J}_{\mathbf{U},\mathbf{v}_g} = \frac{d\mathbf{U}}{d\mathbf{v}_g} = \mathbf{K}^{-1}\left(\frac{\partial \mathbf{F}}{\partial \mathbf{X}} - \frac{\partial \mathbf{R}}{\partial \mathbf{X}}\right) \cdot \frac{\partial \mathbf{X}}{\partial \mathbf{v}_g}$$

线弹性有限元可靠度分析

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$$\mathbf{J}_{\boldsymbol{\varepsilon},\mathbf{v}} = \mathbf{B}\mathbf{J}_{\mathbf{U},\mathbf{v}}$$

–

$$\mathbf{J}_{\boldsymbol{\sigma},\mathbf{v}} = \mathbf{D}\mathbf{B}\mathbf{J}_{\mathbf{U},\mathbf{v}} + \mathbf{J}_{\mathbf{D},\mathbf{v}}\mathbf{B}\mathbf{U}$$

–

$$\nabla_{\mathbf{y}} G = (\mathbf{J}_{\mathbf{y},\mathbf{v}}^{-1})^T \cdot \nabla_{\mathbf{v}} g = (\mathbf{J}_{\mathbf{y},\mathbf{v}}^{-1})^T \cdot [\nabla_{\mathbf{s}} g \cdot \mathbf{J}_{\mathbf{s},\mathbf{v}} + \nabla_{\mathbf{v}} g]$$

$$\boldsymbol{\lambda}^T \mathbf{K} = \nabla_{\mathbf{s}} g$$

$$\nabla_{\mathbf{U}} g \cdot \mathbf{J}_{\mathbf{U},\mathbf{v}} = \boldsymbol{\lambda}^T \left(\frac{\partial \mathbf{F}}{\partial \mathbf{v}} - \left.\frac{\partial \mathbf{R}}{\partial \mathbf{U}}\right|_{\mathbf{U}} \right)$$

几何非线性有限元可靠度分析

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$$\mathbf{R} = \bigcup_e \int_{\Omega_e} (\mathbf{B}_L + \mathbf{B}_N)^T \sigma_S d\Omega_e$$

$$\mathbf{F} = \bigcup_e \left[\int_{\Omega_e} \mathbf{N}^T \cdot \rho_0 \mathbf{b}_0 d\Omega_e + \int_{\partial\Omega_e} \mathbf{N}^T \cdot \mathbf{t}_0 dS_e \right]$$

$$\sigma_S = E\varepsilon_G = E(\mathbf{B}_L + \mathbf{B}_N)^T \mathbf{U}$$

$$\mathbf{F} = \mathbf{F}[\mathbf{X}(\mathbf{V}_g), \mathbf{U}(\mathbf{X}(\mathbf{V}_g), \mathbf{V}_m, \mathbf{V}_p), \mathbf{V}_p]$$

—

$$\mathbf{J}_{\mathbf{U},\mathbf{v}} = \frac{d\mathbf{U}}{d\mathbf{v}} = \mathbf{K}_T^{-1} \left(\frac{\partial \mathbf{F}}{\partial \mathbf{v}} - \frac{\partial \mathbf{R}}{\partial \mathbf{v}} \right)$$

$$\mathbf{K}_T = \frac{\partial \mathbf{R}}{\partial \mathbf{U}} = \bigcup_e \int_{\Omega_e} \left[\frac{\partial \mathbf{B}_N^T}{\partial \mathbf{U}} \sigma_S + (\mathbf{B}_L + \mathbf{B}_N)^T \cdot \frac{\partial \sigma_S}{\partial \mathbf{U}} \right] d\Omega_e$$

几何非线性有限元可靠度分析

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$$\mathbf{K}_T = \mathbf{K}_E + \mathbf{K}_G + \mathbf{K}_U$$

$$\mathbf{K}_E = \bigcup_e \int_{\Omega_e} E\mathbf{B}_L^T \mathbf{B}_L^T d\Omega_e$$

$$\mathbf{K}_G = \bigcup_e \int_{\Omega_e} \frac{\partial \mathbf{B}_N^T}{\partial \mathbf{U}} \sigma_S d\Omega_e$$

$$\mathbf{K}_U = \bigcup_e \int_{\Omega_e} E\left[\mathbf{B}_L^T \mathbf{B}_N^T + \mathbf{B}_N^T \mathbf{B}_L^T + \mathbf{B}_N^T \mathbf{B}_N^T\right] d\Omega_e$$

–

$$\Delta\mathbf{R} = \Delta\mathbf{F} + \Delta\mathbf{S}_P$$

$$\Delta\mathbf{R} = \mathbf{K}_0 \Delta\mathbf{U}$$

$$\Delta\mathbf{F} = \bigcup_e \left[\int_{\Omega_e} \mathbf{N}^T \cdot \rho_0 \Delta\mathbf{b}_0 d\Omega_e + \int_{\partial\Omega_e} \mathbf{N}^T \cdot \Delta\mathbf{t}_0 dS_e \right]$$

$$\Delta\mathbf{S}_p = \mathbf{K}_p \Delta\mathbf{U}$$

$$\mathbf{K}_0 = \bigcup_e \left(\int_{\partial\Omega_e} \mathbf{B}^T \cdot \mathbf{E}_{el} \cdot \mathbf{B} d\Omega_e \right)$$

$$\mathbf{K}_p = \bigcup_e \left(\int_{\partial\Omega_e} \mathbf{B}^T \cdot \mathbf{E}_{pl} \cdot \mathbf{B} d\Omega_e \right)$$

–

$$\mathbf{J}_{\mathbf{U},\mathbf{v}} = \frac{d\Delta\mathbf{U}}{d\mathbf{v}} = \mathbf{K}_T^{-1}\left(\frac{\partial\Delta\mathbf{F}}{\partial\mathbf{v}} + \frac{\partial\Delta\mathbf{S}_p}{\partial\mathbf{v}} - \frac{\partial\mathbf{R}}{\partial\mathbf{v}}\right)$$

$$\mathbf{K}_T = \mathbf{K}_0 - \mathbf{K}_p$$

系统有限元可靠度分析

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$$\mathbf{R} = (\mathbf{K} + \mathbf{K}_R)\mathbf{U} + \mathbf{R}_R = \mathbf{F}$$

–

$$\frac{d\mathbf{R}}{d\mathbf{v}} = \left.\frac{\partial \mathbf{R}}{\partial \mathbf{U}}\right|_{\mathbf{v}} \frac{d\mathbf{U}}{d\mathbf{v}} + \left.\frac{\partial \mathbf{R}}{\partial \mathbf{v}}\right|_{\mathbf{U}} + \frac{d\mathbf{R}_R}{d\mathbf{v}} = (\mathbf{K} + \mathbf{K}_R)\frac{d\mathbf{U}}{d\mathbf{v}} + \left.\frac{\partial \mathbf{R}}{\partial \mathbf{v}}\right|_{\mathbf{U}} + \frac{d\mathbf{R}_R}{d\mathbf{v}} = \frac{d\mathbf{F}}{d\mathbf{v}}$$

$$\mathbf{J}_{\mathbf{U},\mathbf{v}} = \frac{d\Delta\mathbf{U}}{d\mathbf{v}} = (\mathbf{K} + \mathbf{K}_R)^{-1}\left(\frac{d\mathbf{F}}{d\mathbf{v}} - \left.\frac{\partial \mathbf{R}}{\partial \mathbf{v}}\right|_{\mathbf{U}} - \frac{d\mathbf{R}_R}{d\mathbf{v}}\right)$$

–

$$\mathbf{M}(\theta)\ddot{\mathbf{U}}(t,\theta)+\mathbf{C}(\theta)\dot{\mathbf{U}}(t,\theta)+\mathbf{R}[\mathbf{U}(t,\theta),\theta]=\mathbf{F}(t,\theta)$$

– **Newmark—β**

$$\ddot{\mathbf{U}}_{n+1}=\left(1-\frac{1}{2\beta}\right)\ddot{\mathbf{U}}_{n}-\frac{1}{\beta(\Delta t)}\dot{\mathbf{U}}_{n}+\frac{1}{\beta(\Delta t)^{2}}(\mathbf{U}_{n+1}-\mathbf{U}_{n})$$

$$\dot{\mathbf{U}}_{n+1}=\Delta t\left(1-\frac{\alpha}{2\beta}\right)\ddot{\mathbf{U}}_{n}+\left(1-\frac{\alpha}{\beta}\right)\dot{\mathbf{U}}_{n}+\frac{\alpha}{\beta(\Delta t)}(\mathbf{U}_{n+1}-\mathbf{U}_{n})$$

–

$$\boldsymbol{\Psi}(\mathbf{U}_{n+1}) = \tilde{\mathbf{F}}_{n+1} - \left[\frac{1}{\beta(\Delta t)^2}\mathbf{M}\mathbf{U}_{n+1} + \frac{\alpha}{\beta(\Delta t)}\mathbf{C}\mathbf{U}_{n+1} + \mathbf{R}(\mathbf{U}_{n+1}) \right] = \mathbf{0}$$

$$\tilde{\mathbf{F}}_{n+1} = \mathbf{F}_{n+1} + \mathbf{M}\left[\frac{1}{\beta(\Delta t)^2}\mathbf{U}_n + \frac{1}{\beta(\Delta t)}\mathbf{C}\dot{\mathbf{U}}_n - \left(1 - \frac{1}{2\beta}\right)\ddot{\mathbf{U}}_n \right]$$
$$+ \mathbf{C}\left[\frac{\alpha}{\beta(\Delta t)^2}\mathbf{U}_n + \left(1 - \frac{\alpha}{\beta}\right)\dot{\mathbf{U}}_n - (\Delta t)\left(1 - \frac{\alpha}{2\beta}\right)\ddot{\mathbf{U}}_n \right]$$

$$\mathbf{R}(\mathbf{U}_{n+1}) = \bigcup_e \left(\int_{\partial\Omega_e} \mathbf{B}^T \cdot \boldsymbol{\sigma}(\boldsymbol{\varepsilon}_{n+1})\, d\Omega_e \right)$$

时变有限元可靠度分析

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$$(\mathbf{K}_T^{\text{dyn}})_{n+1}^i \Delta \mathbf{U}_{n+1}^i = \mathbf{\Psi}(\mathbf{U}_{n+1}^i) \quad i = 0,1,2,\cdots$$

$$\mathbf{\Psi}_{n+1}^i = \tilde{\mathbf{F}}_{n+1} - \left[\frac{1}{\beta(\Delta t)^2} \mathbf{M}\mathbf{U}_{n+1}^i + \frac{\alpha}{\beta(\Delta t)} \mathbf{C}\mathbf{U}_{n+1}^i + \mathbf{R}(\mathbf{U}_{n+1}^i) \right]$$

–

$$(\mathbf{K}_T^{\text{dyn}})_{n+1}^i = \left[\frac{1}{\beta(\nabla t)^2} \mathbf{M} + \frac{1}{\beta(\nabla t)} \mathbf{C} + (\mathbf{K}_T^{\text{stat}})_{n+1}^i \right]$$

$$(\mathbf{K}_T^{\text{stat}})_{n+1}^i = \bigcup_e \left(\int_{\partial\Omega_e} \mathbf{B}^T \cdot \mathbf{D}_T \cdot \mathbf{B} d\Omega_e \right)$$

时变有限元可靠度分析

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$$\frac{d\mathbf{U}_{n+1}}{d\theta}=\left[(\mathbf{K}_T^{\mathrm{dyn}})_{n+1}^{i}\right]^{-1}\left[\frac{\partial\tilde{\mathbf{F}}_{n+1}}{\partial\theta}-\left.\frac{\partial\mathbf{R}(\mathbf{U}_{n+1}(\theta),\theta)}{\partial\theta}\right|_{\mathbf{U}_{n+1}}-\left(\frac{1}{\beta(\Delta t)^2}\frac{\partial\mathbf{M}}{\partial\theta}+\frac{\alpha}{\beta(\Delta t)}\frac{\partial\mathbf{C}}{\partial\theta}\right)\mathbf{U}_{n+1}\right]$$

$$\begin{aligned}\frac{\partial\tilde{\mathbf{F}}_{n+1}}{\partial\theta}=&\frac{\partial\mathbf{F}_{n+1}}{\partial\theta}+\frac{\partial\mathbf{M}}{\partial\theta}\left[\frac{1}{\beta(\Delta t)^2}\mathbf{U}_n+\frac{1}{\beta(\Delta t)}\dot{\mathbf{U}}_n-\left(1-\frac{1}{2\beta}\right)\ddot{\mathbf{U}}_n\right]\\&+\mathbf{M}\left[\frac{1}{\beta(\Delta t)^2}\frac{\partial\mathbf{U}_n}{\partial\theta}+\frac{1}{\beta(\Delta t)}\frac{\partial\dot{\mathbf{U}}_n}{\partial\theta}-\left(1-\frac{1}{2\beta}\right)\frac{\partial\ddot{\mathbf{U}}_n}{\partial\theta}\right]\\&+\frac{\partial\mathbf{C}}{\partial\theta}\left[\frac{\alpha}{\beta(\Delta t)}\mathbf{U}_n-\left(1-\frac{\alpha}{\beta}\right)\dot{\mathbf{U}}_n-(\Delta t)\left(1-\frac{\alpha}{2\beta}\right)\ddot{\mathbf{U}}_n\right]\\&+\mathbf{C}\left[\frac{\alpha}{\beta(\Delta t)}\frac{\partial\mathbf{U}_n}{\partial\theta}-\left(1-\frac{\alpha}{\beta}\right)\frac{\partial\dot{\mathbf{U}}_n}{\partial\theta}-(\Delta t)\left(1-\frac{\alpha}{2\beta}\right)\frac{\partial\ddot{\mathbf{U}}_n}{\partial\theta}\right]\end{aligned}$$

$$\left.\frac{\partial\mathbf{R}(\mathbf{U}_{n+1}(\theta),\theta)}{\partial\theta}\right|_{\mathbf{U}_{n+1}}=\bigcup_e\left(\int_{\partial\Omega_e}\mathbf{B}^T\cdot\left.\frac{\partial\boldsymbol{\sigma}}{\partial\theta}\right|_{\boldsymbol{\varepsilon}_{n+1}}d\Omega_e\right)$$

— FORM

$$w(\mathbf{v},t)=r(\mathbf{v},t)-s(\mathbf{v},t)$$ —

$$\tilde{g}(\mathbf{v})=\min_{t\in[a,b]} w(\mathbf{v},t)$$ —

$$g(\mathbf{v})=\min_{n\in\mathfrak{N}} w_n(\mathbf{v})$$ —

$$w_n(\mathbf{v})=w(\mathbf{v},t_n)$$

$$\mathfrak{N}=\{0,1,\cdots,N\}$$

$$g(\mathbf{v})=w_{\hat{n}}(\mathbf{v})$$ —

$\hat{n}$ —

– FORM

$$\mathbf{d}_k = -f(\mathbf{v}_k) + \frac{(\nabla f(\mathbf{v}_k), \nabla w_{\hat{n}_k}(\mathbf{v}_k))}{\left\| \nabla w_{\hat{n}_k}(\mathbf{v}_k) \right\|^2} \nabla w_{\hat{n}_k}(\mathbf{v}_k)$$

–

$$f(t) = \mu(t) + \sum_{i=1}^{n} y_i b_i(t) = \mu(t) + \mathbf{b}(t)^T \mathbf{y}$$

-
- Karhunen-Loeve
-
-

–

$$z(\mathbf{x}) = \mu(\mathbf{x}) + \mathbf{b}(\mathbf{x})^T \mathbf{y}$$

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• **Karhunen-Loeve**

空变有限元可靠度分析

$$p_{\mathfrak{D}}(\mathbf{x},t) = P[\mathbf{s}(\mathbf{y},\mathbf{x},t) \in \mathfrak{D}(\mathbf{x},t)]$$

$$p_{\mathfrak{D}} = P[\mathbf{s}(\mathbf{y},\mathbf{x},t) \in \mathfrak{D}(\mathbf{x},t) \mid \mathbf{x} \in \Omega, t \in T]$$

$$p_{\mathfrak{D}}(t) = P[\mathbf{s}(\mathbf{y},\mathbf{x},t) \in \mathfrak{D}(\mathbf{x}) \mid \mathbf{x} \in \Omega]$$

$$p_{\mathfrak{D}}(t) > P\left[\bigcup_i \left\{\mathbf{s}(\mathbf{y},\mathbf{x}_i,t) \in \mathfrak{D}(\mathbf{x}_i) \mid \right\}\right]$$

–　FORM

$$p_{\mathfrak{D}}(t) = P\left[\mathbf{s}(\mathbf{y},\mathbf{x},t) \in \mathfrak{D}(\mathbf{x}) \mid \mathbf{x} \in \Omega\right]$$

$$= P\left[\{\mathbf{s}(\mathbf{y},\mathbf{x}_0,t) \in \mathfrak{D}(\mathbf{x}_0)\} \bigcup \{0 < N_{\mathfrak{D}}(\Omega)\}\right]$$

$$\leq p_{\mathfrak{D}}(\mathbf{x}_0,t) + P[0 < N_{\mathfrak{D}}(\Omega)]$$

$$p_{\mathfrak{D}}(\mathbf{x},t) + \int_{\Omega} v_{\mathfrak{D}}(\mathbf{x},t)d\mathbf{x}$$

–

$$v_{\mathfrak{D}}(x,t) = \lim_{\delta x \to 0} \frac{P[\{\mathbf{s}(\mathbf{y},x,t) \notin \mathfrak{D}(x)\} \bigcap \{\mathbf{s}(\mathbf{y},x+\delta x,t) \notin \mathfrak{D}(x+\delta x)\}]}{\delta x}$$

有限元可靠度软件

– STRUREL

“ ” RCP

- COMREL
- SYSREL
- STATREL
- Permas-RA

– Slang

ISM

– NESSUS

NASA

有限元可靠度软件

- ISPUD　COSSAN

(IFM)

G.I. Schuëller

- COMPASS

Martec

- ProSINTAP

Failure Assessment Diagram, FDA　MCS

FORM

有限元可靠度软件

– CALREL-FEAP

Der

Kiureghian

20 80

– SYSREL-FEAP

Frangopol

2000

有限元可靠度软件

- FERUM

  Der

  Kiureghian Haukaas Song 2000

  Matlab

- OpenSees-Reliability

  Der

  Kiureghian Haukaas

  (PEER)

  OpenSees

有限元可靠度软件

– **FERAP**

(**2005)**

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Unified Modeling Language, UML

FERAP(Finite Element Reliability Program

FORM

有限元可靠度方法的工程应用

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- (A. Der Kiureghian & Ke)
- (A. Haldar & S. Mahadevan)
- (D. Frangopol)
-
  - FORM .
  - FORM .
  - . .
  - . .

有限元可靠度方法的工程应用

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- ➢
  - D. Frangoplol & K. Imai
- ➢
- ➢

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- ➢
  - 1996, 1997, 1999, 2001, 2004

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- ➢
  - 2001

结　论

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结 论

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谢谢！

Thank you for your attention！