Simulation of High-Cycle Fatigue Problem

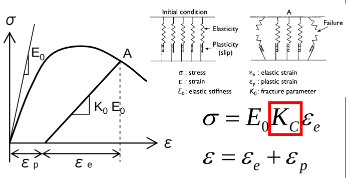
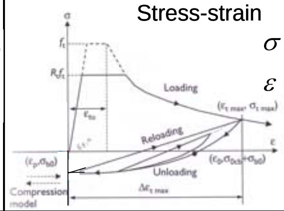
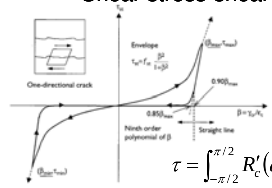
2009.4.6

1. Three dimensional nonlinear FE analysis “COM 3”

The fatigue simulation system used herein is based on the direct path integral scheme, which has been recently incorporated to a finite element package (Maekawa *et al.* 2003). The finite element package includes used here three basic yet essential fundamental constitutive models of concrete, that are; compression, tension and crack- shear models. The evolution of cumulative fatigue damage and time dependency effects is included in the models as shown in Figure. It is then possible to perform a fatigue simulation is conducted by tracing the evolution of microscopic material states at each moment. These three are important to treat the cumulative fatigue damage and time dependency effects.

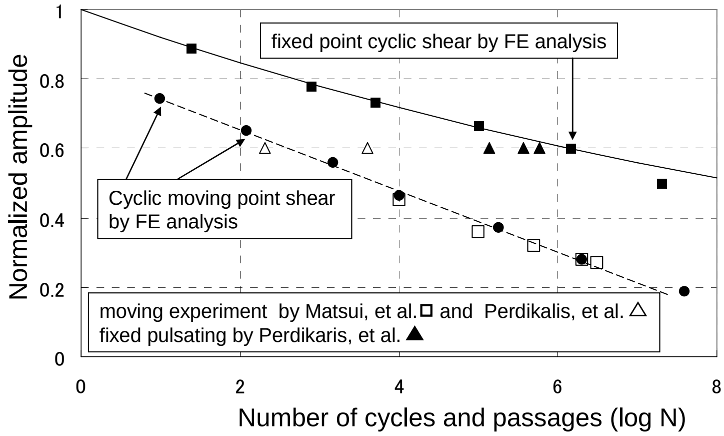
For 3D simulation purpose, Maekawa *et al.* (2003) has extended the in-plane 2D RC models, including time dependent models and creep models , to 3D orthogonal space system by means of the composition method (2003). This composition technique is regarded as a simple extension of the multi-directional non-orthogonal fixed crack approach. This computational framework has already been verified extensively under low-cycle static and dynamic loads. Whatever the complexity of the loading hysteresis, the multi-axial stress-carrying mechanism is formulated as a linear combination of the abovementioned 1D sub-mechanisms, representing the contribution of cracked concrete and reinforcement reinforcing bars. This scheme was originally as proposed by Collins and Vecchio (1982).

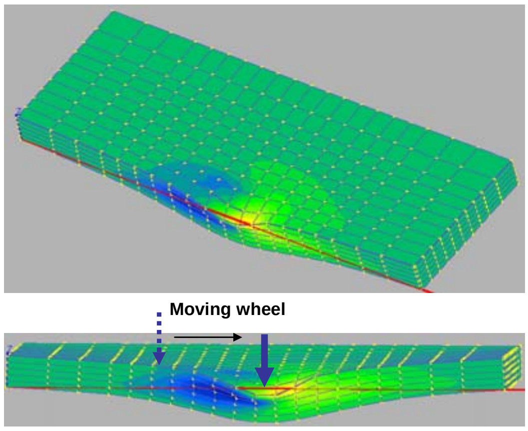
Recently, Ttheis simulation system framework has been enhanced for high cycle fatigue analyses by using with the use of logarithmic integration l method (Maekawa *et al.* 2006a). It was possible then to By using use thise simulation system framework , demonstrated to perform fatigue analysis and to investigate more deeply the fatigue mechanisms of RC slab subjected to wheel type moving load (Maekawa *et al.* 2006b).

	Compression model	Tension model	Crack shear model
Core Constitu tive low	Stress-strain  $\sigma = E_0 K_C \varepsilon_e$ $\varepsilon = \varepsilon_e + \varepsilon_p$	Stress-strain  $\sigma = E_0 K_T \varepsilon_e$ $\varepsilon = \varepsilon_e + \varepsilon_p$	Shear stress-shear strain  $\tau = \int_{-\pi/2}^{\pi/2} R_c'(\omega,\delta,\theta)\sin\theta d\theta$
Enhanced model for High cycle fatigue	Fracture parameter Kc considers time dependent plasticity & fracturing and cyclic fatigue damage $dK_C = \left(\frac{\partial K_C}{\partial t}\right)dt + \left(\frac{\partial K_C}{\partial \varepsilon_e}\right)d\varepsilon_e$ time dependent cyclic fatigue $\left(\frac{\partial K_c}{\partial \varepsilon_e}\right) = \lambda \sim when F_k = 0$ $\left(\frac{\partial K_c}{\partial \varepsilon_e}\right) = -\left(\frac{\partial F_k}{\partial \varepsilon_e}\right)\left(\frac{\partial F_k}{\partial K}\right) + \lambda \sim when F_k = 0$ $\lambda = K^3 \cdot (1-K^4) \cdot g \cdot R$ El-Kachif and Maekawa 2004	Fracture parameter K_T considers time dependent fracturing and cyclic fatigue damage $dK_T = Fdt + Gd\varepsilon_e + Hd\varepsilon_e$ Time dependent fracturing Cyclic fatigue damage Maekawa et al. 2003, Hisasue 2005	Accumulated path function X reduce shear associated with cyclic fatigue damage $\tau = X \cdot \tau_0(\delta,\omega)$ function original model $X = 1 - \frac{1}{10}\log_{10}\left\{1 + \int \lvert d(\delta/\omega)\rvert\right\} \geq 0.1$ Contact density model by Li & Maekawa 1989 Modification of accumulated path function by Gebreyouhannes 2006
Physical meaning	Decrease of stiffness and plasticity accumulation by continuous fracturing of concrete	Decrease of tension stiffness by bond fatigue	Decrease of shear transfer normal to crack by continuous deterioration of rough crack surface

2. Examples ; Slabs subjected to high-cycle moving load

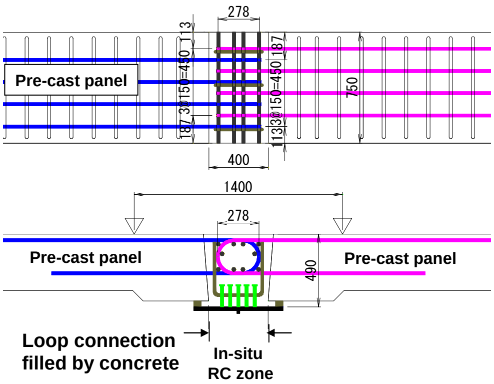
(1) Simulation for RC slab ～ verified by past experiments

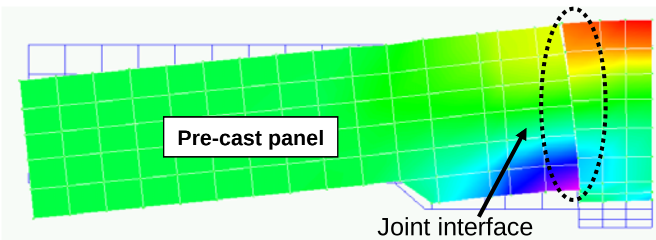




Three-Dimensional Fatigue Simulation of RC Slabs under Traveling Wheel-Type Loads , Maekawa, K., Gebreyouhannes, E., Mishima, T. and An, X., Journal of Advanced Concrete Technology, 4(3) 445-457, 2006.

(2) Simulation for pre-cast PC slab with joint elements ～ runway for Tokyo International airport at Haneda

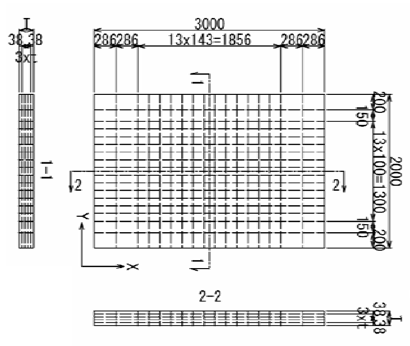




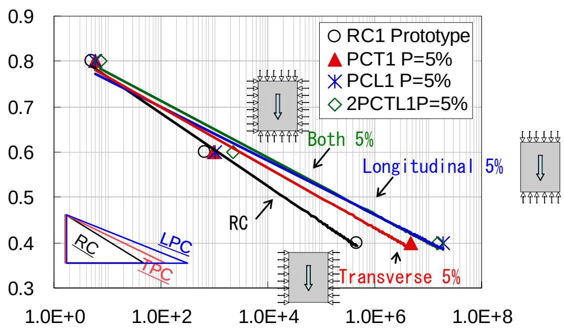
Finite elements and magnified mode of deformation

Path-Dependent High Cycle Fatigue Modeling of Joint Interfaces in Structural Concrete , Maekawa, K., Fukuura, N. and Soltani, M., Journal of Advanced Concrete Technology, Vol.6, No.1, 227-242, February 2008.

(3) Analysis of Influence factors～such as thickness, pre-stressing and rebar-arrangement of slab



■ S-N diagram



Present achievement and future possibility of fatigue life simulation technology for RC bridge deck slab, Fujiyama, C., Gebreyouhannes, E. and Maekawa, K., Society for Social Management Systems, internet journal serial No. SMS08-117.

[References]

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7) Maekawa, K., Fukuura, N. and Soltani, M., Path-Dependent High Cycle Fatigue Modeling of Joint Interfaces in Structural Concrete, *Journal of Advanced Concrete Technology*, 6(1), pp.227-242, 2008.
8) Soltania,M., and Maekawa, K, Path-dependent mechanical model for deformed reinforcing bars at RC interface under coupled cyclic shear and pullout tension. Engineering Structures, 30, pp.1079-1091, 2008.

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