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Blast Analysis of RC Beam on Moment-Curvautre Relationship

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ABSTRACT

An improved numerical model based on the moment-curvature relationship of a RC section that can simulate the nonlinear behavior of reinforced concrete (RC) beams subjected to blast loadings is introduced. A newly designed dynamic increase factor (DIF) defined with the curvature rate was used in the moment-curvature relationship. The proposed model has an advantage of reducing calculation time, compared with the layered-section approach, in application to large frame structures which have many degrees of freedom. Finally, validity of the proposed model was conducted through the correlation studies between analytical results and experimental studies.

1. INTRODUCTION

RC structures subjected to blast and impact loading show different structure behaviour from static loading conditions. This difference arises from the change of the material properties of concrete and reinforcing steel under short-duration and high amplitude loading accompanying high strain rate condition, and this change is enlarged with an increase of the strain rate (Bischoff and Perry 1991). Therefore, the nonlinearity of concrete and reinforcing steel considering the effect of high strain rate should be taken into account in order to describe the RC structures subjected to blast or impact loading. Since this paper introduces an improved numerical model on the basis of the moment-curvature relation of a RC section, a DIF (Dynamic Increase Factor) should be newly designed because the DIF has been defined for the stress-strain relation of the constituent materials (Cusatis 2011). The proposed model makes it possible leave the number of solution steps out in nonlinear analysis of an entire structure and the verification of the model is conducted by comparing the numerical result with experimental data.

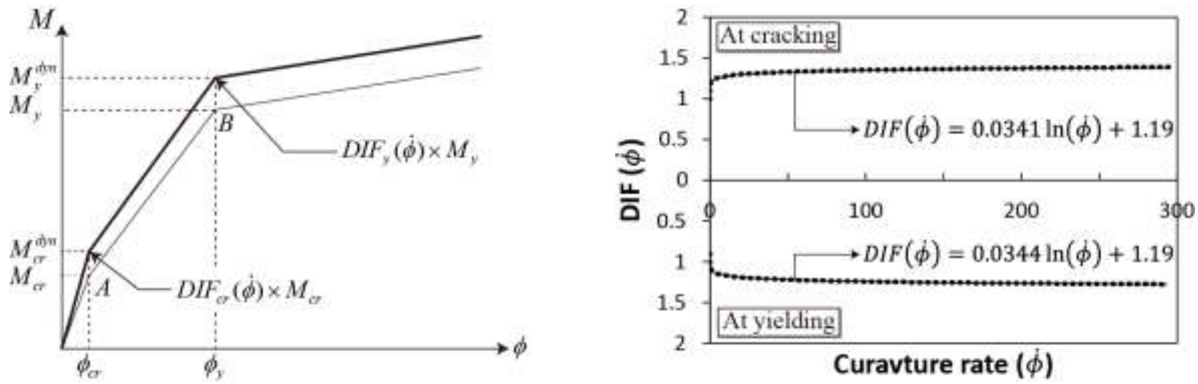
2. PROPOSED FAILURE SURFACE

[1)] Graduate Student
[2)] Professor

To simulate the nonlinear behaviour of RC structures subjected to static or dynamic loading, the numerous mathematical models were proposed. Among them, this paper adopted the monotonic stress-strain relation proposed by Kent and Park and modified by Scott et al.(Scott et al. 1982), in which the stress-strain curve is divided into compression and tensile regions. In addition, this model includes a dynamic increase factor (DIF) to consider the effect of high strain rate. In this paper, simple relations introduced by Saatcioglu et al. (Saatcioglu et al. 2011) are adopted and can be expressed as follows : $DIF = 0.03ln\dot{\varepsilon} + 1.30 \geq 1.0$ for $\dot{\varepsilon} < 30s^{-1}$, and $DIF = 0.55ln\dot{\varepsilon} - 0.47$ for $\dot{\varepsilon} \geq 30s^{-1}$. Furthermore, reinforcing steel is modelled as a linear elastic, linear strain hardening material and the strain-rate effect is also considered by introducing a DIF equation for steel. The same relation proposed by Saatcioglu et al. (Saatcioglu et al. 2011) is adopted and the corresponding equation is represented as follows : $DIF = 0.034ln\dot{\varepsilon} + 1.30 \geq 1.0$.

The moment-curvature relationship of a RC section is introduced and can be idealized to tri-linear relationship including two points (cracking and yielding stages) in this paper for the nonlinear analyses of RC structures. Therefore, a new DIF for the moment-curvature relationship should be proposed because the DIF has been proposed for only the stress-strain relation of each material. DIF expressions in terms of the curvature rate for RC sections are constructed through linear regression. Upon the determination of DIFs for the cracking and yielding curvature, the multiplication of DIFs to the cracking moment and yielding moment, respectively, and then linear connection of cracking and yielding points finally construct the dynamic moment-curvature relationship considering the strain-rate effect.

For the dynamic analysis of RC structures subjected to impact or blast loading, the Newmark method is adopted on the basis of Timoshenko beam theory in this paper. The Newmark method is one of the implicit methods and on the basis of a non-iterative formulation, Newmark coefficients of β =0.25 and γ =0.5 corresponding to the assumption of constant average acceleration are used. More detailed information ca be found elsewhere (Chopra 1995) .



(a) Moment-curvature relationship of RC section

(b) obtained DIFs for B40

Fig. 1 Moment-curvature relationship and Obtained DIFs for B40

3. APPLICATIONS

Beam B40 experimented by Magnussons et al. (Kamali 2012; Magnusson and Hallgren 2003) is employed to verify the accuracy of the proposed nonlinear model. A blast wave was uniformly applied to the simply supported RC beam while passing a sufficient distance through the shock tube and detailed information of the experimental setup and can be found be elsewhere (Magnusson and Hallgren 2003). This beam was modelled with 10 elements along the entire span and Fig. 2 presents a comparison of the experimental result with the numerical result obtained from the propose model. As shown in this figure, the evaluated displacement history with time up to the maximum displacement is almost coincident with that obtained from the experiment. This means that the proposed numerical model can effectively simulate the behaviour of RC beams subjected to blast loadings.

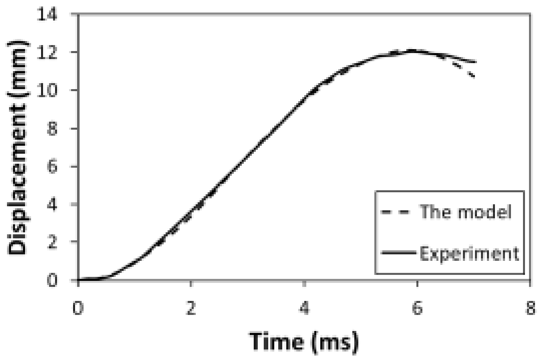


Fig. 2 displacement time history of Beam B40

4. CONCLUSIONS

This paper introduces an algorithm on the basis of the moment-curvature relationship of a RC section which can simulate a blast loading analysis of RC beams. The proposed model can be used effectively to predict the structural response under blast loading.

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