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Analysis of Flexural Behavior of RC Members under Blast Loading

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ABSTRACT

In this study, numerical simulation for reinforced concrete members subjected to blast loading is performed based on the moment-curvature relationships of RC sections. A dynamic increase factor with strain rate which is adopted to consider high strain rate effect cannot be directly used in numerical simulation based on the moment-curvature relationship. Therefore, the dynamic increase factor is redefined as a function of the curvature rate in this study and modified monotonic moment-curvature relationship in dynamic state is conducted. In order to evaluate residual response of RC members, unloading and reloading curves in moment-curvature relationship are defined based on the monotonic moment-curvature relationship of RC sections and hysteretic behavior of reinforcing steel. The proposed numerical model is verified by comparison with the experiment and parametric studies are conducted.

1. INTRODUCTION

As explosion accidents increase, interest in securing the safety of structures subjected to blast loading has increased. Accurate explosion analysis of the structure must be preceded in order to secure the safety of structures subjected to explosion. Behavior of structural members under blast loading is different from behavior in static states due to increase in material properties under high strain rate. In order to consider the change of material properties, a dynamic increase factor in terms of strain rate is usually adopted in stress-strain relationship for each material. There are several numerical methods to evaluate behavior of RC members subjected to blast loading such as single degree of freedom model and using 3D solid element with hydro codes. In this paper, numerical simulation for RC member under blast loading based on the moment-curvature relationship of RC section is performed. A dynamic increase factor in terms of curvature rate and modified moment-curvature relationship is constructed for numerical analysis based on the moment-curvature relationship.

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2. MATERIAL PROPERTIES

Stress-strain relationships for concrete and reinforcing steel should be defined to construct moment-curvature relationship. In this paper, Kent & Park model modified by Scott is adopted for the compression region in stress-strain relationship of concrete, which considers confinement effect by transverse steel(Park&Pauley 1975). For tensile region in stress-strain curve of concrete, a bilinear relationship with linear elastic and linear softening is assumed. Menegotto-Pinto model considering Bauschinger effect is used for monotonic and hysteretic stress-strain relationship of reinforcing steel. In order to consider the increase in strength of concrete and steel under high strain rate, dynamic increase factors defined by Malvar(1998) in stress-strain relationship of materials is adopted.

3. MOMENT-CURVATURE RELATIONSHIP

In this paper, monotonic moment-curvature relationship is idealized to trilinear relationship with cracking point, yielding point and failure. A dynamic increase factor is needed to consider the high strain rate effect in moment-curvature relationship. However, dynamic increase factors in terms of strain rate cannot be directly used to moment-curvature relationship. Therefore, a dynamic increase factor in terms of curvature rate is newly constructed in cracking point and yielding point. In this process, neutral axis of strain and neutral axis of strain rate are assumed equal. Effect of bond-slip is also considered to describe behavior of RC members after concrete cracking accurately. Strength of member will be overestimated without consideration of bond-slip. Then, modified monotonic moment-curvature relationship is constructed with considering effect of bond-slip and high strain rate effect as shown in Fig.1.

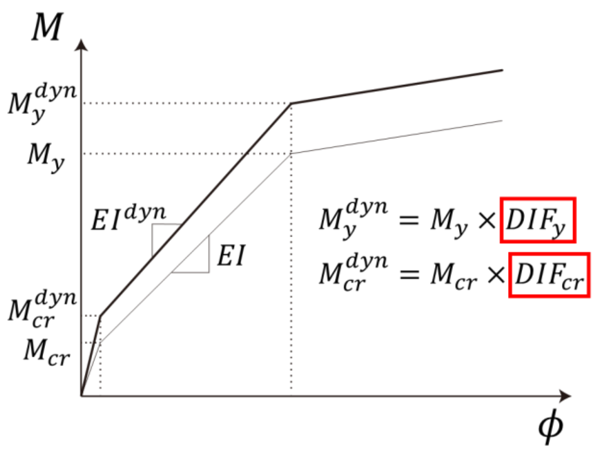

Fig.1 Dynamic moment-curvature relationship of the RC section

In hysteretic moment-curvature, unloading and reloading branch after yielding is governed by hysteretic behavior of reinforcing steel(Kwak&Kim 2001). The coefficient for unloading and reloading branch is redefined as a function of curvature using coefficient in hysteretic curve of reinforcing steel through section analyses.

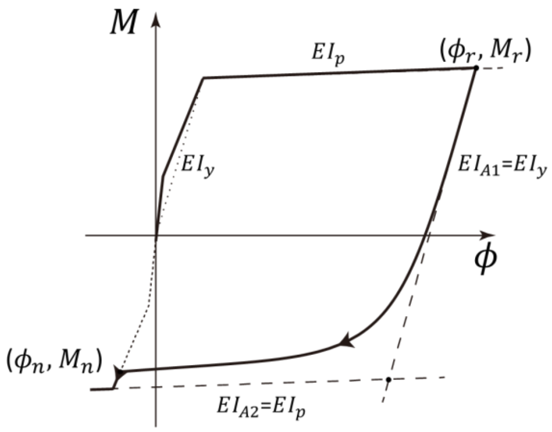

Fig. 2 Unloading branch in hysteretic moment-curvature relationship

4. APPLICATION

RC1 specimen tested by Jacques(2012) et al. is introduced to verify the proposed model. RC1 is simply supported beam with 2,232mm clear span and has 300mm×150mm section. Blast loading is assumed uniformly distributed load because the load is transferred through the shock tube with sufficient distance. Additional mass should be considered due to steel frame device for attachment.

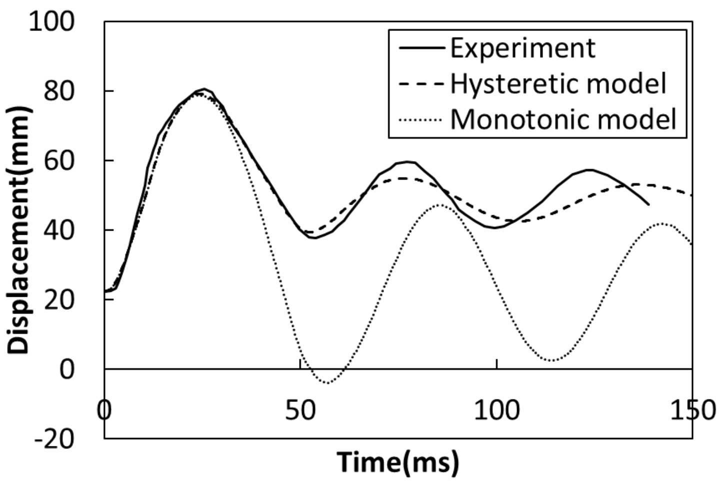

Fig.3 Displacement time history at mid span of RC1

The comparison between numerical results and experiments is shown in Fig. 3 Numerical results from simulation with monotonic moment-curvature relationship and hysteretic moment-curvature relationship show good agreement with experimental results until maximum displacement and corresponding time. However, numerical results from monotonic-curvature relationship has different behavior from experiment after the peak displacement. Numerical result with hysteretic moment-curvature relationship is similar to experiment in both maximum response and residual response.

5. CONCLUSION

Numerical model for RC members under blast loading is introduced base on the moment-curvature relationship. A dynamic increase factor is redefined as a function of curvature rate. Modified monotonic and hysteretic moment-curvature relationship is constructed. Numerical simulation based on the hysteretic moment-curvature relationship describes maximum and residual response of RC members well. The validity of model with hysteretic moment-curvature relationship is verified through RC1 experimental results.

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