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Numerical Analysis of RC Structural Members under Blast based on the Moment-Curvature Relation

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ABSTRACT

A numerical model that can evaluate behavior of RC structural members under uniformly distributed blast loading is introduced in this paper. Flexural behavior of RC members is described on the basis of moment-curvature relationship of the RC section and the shear stress-slip relationship from the experiment is adopted to account for direct shear behavior. Since a dynamic increase factor for materials that is the function of strain rate cannot be used directly in the moment-curvature relationship of the RC section, the dynamic increase factor for the RC section is newly defined in terms of the curvature rate. Correlation study between numerical results and experimental results is conducted to verify the validity of the numerical model.

1. INTRODUCTION

In many previous researches on the blast, they focused on the protection performance for the military facilities under blast loading. As a number of blast accidents such as bombing attacks and gas explosions are occurred in ordinary buildings and infrastructures, studies for the ordinary structures subjected to blast loading is actively carried out and the demand for the resistance capacity of structures under blast is increasing. In order to ensure the safety of the structures under explosion, it is necessary to predict the behavior of the structure under the explosion. In this paper, an improved numerical model based on the moment-curvature relationship for the RC section is introduced to evaluate the performance of RC structure under blast loading. Material properties for the concrete and reinforced steel under blast loading with the high strain rate deformation increases when static loading is applied. In general, a dynamic increase factor (DIF) is used to consider the changes of the material properties. Many researchers have proposed various DIF equations that are defined in terms of strain rate (Malvar and Crawford 1998, Saatcioglu et al. 2011)

In this paper, a numerical model for RC structural member using moment-

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curvature relationship of RC sections is introduced. The Timoshenko beam element with 3 DOF at each node is selected. The dynamic increase factor for RC section in terms of curvature rate is constructed. In addition, shear stress-slip relationship from the experiment is adopted to describe direct shear behavior. The model is verified by results from experiment and hydro codes.

2. Numerical model

2.1 Material properties

In this paper, the stress-strain relationship for concrete proposed by Kent &Park and modified by Scott et al.(1982) is adopted to explain the nonlinear behavior of the concrete. The concrete in tensile region is assumed linear elastic and linear strain softening. The material model for reinforcing steel with linear elastic and linear strain hardening zone in both tensile and compressive region is used. Dynamic increase factor equations for stress-strain relationships of concrete and steel proposed by Saatcioglu(2011) are adopted

2.2 Moment-curvature relationship

Moment-curvature relationship for RC section can be assumed to tri-linear relation with cracking point and yielding point. Since a dynamic increase factor for materials that is the function of strain rate cannot be used directly in the moment-curvature relationship of the RC section, the dynamic increase factor for the RC section is newly defined in terms of the curvature rate. Moment-curvature relationship can be modified as Fig 1. Axial force effect to moment-curvature relationship is also considered.

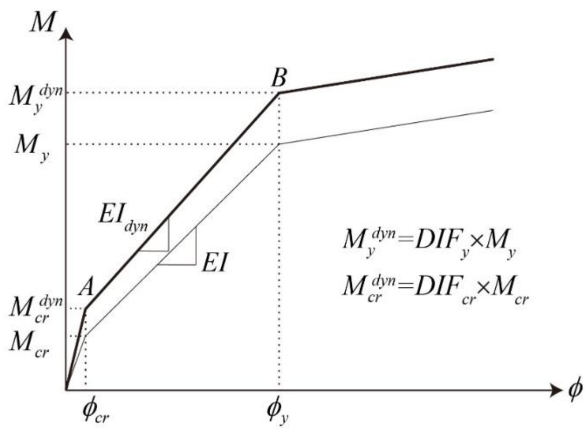

Fig 1. Moment-curvature relationship considering dynamic increase factor

2.3 Direct shear behavior

Direct shear failure can be occurred under loading with high pressure and short duration. Many researchers have conducted experiments for direct shear stress-slip relation. Among them, direct shear stress-slip relation suggested by Krauthammer and Astarlioglu(2017) is adopted to describe direct shear failure.

3. Application

The experimental results conducted by Jacques et al.(2015) are investigated to verify proposed model. RC1-2 was a simply supported beam with clear span length of 2,232. The numerical results by LS-DYNA and by proposed model are as shown in Fig 2. The numerical results by LS-DYNA and by proposed model provide good agreement with the experiment for both the maximum displacement and corresponding time.

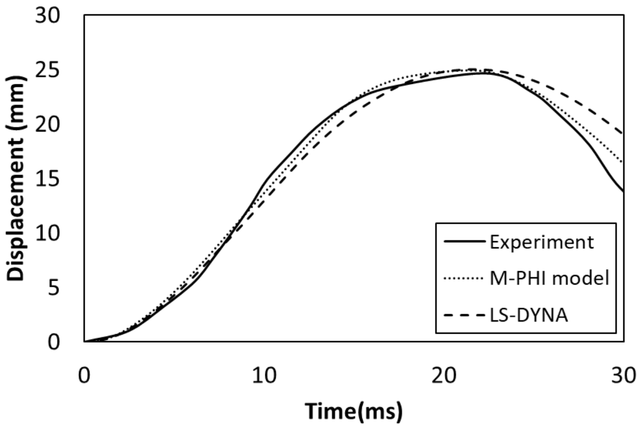

Fig. 2 Displacement history for RC1-2 at mid span

Analysis of the structure member for RC frame is also conducted for application to general reinforced structures. The configuration of target frame structures with the same section as RC1-2 is as shown in Fig 3. History of maximum displacement at the column subjected blast loading from proposed model is very similar to history from hydro codes.

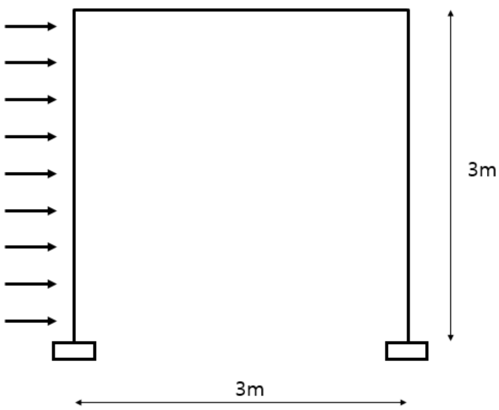

Fig.3 Target frame structures

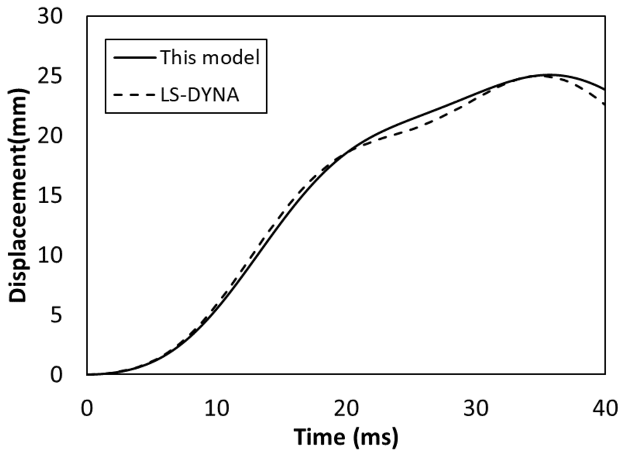

Fig. 4 Displacement history for the member

Since the hysterical moment-curvature relationship is not taken into consideration, behavior of the RC members after maximum response is not coincidence with experimental result.

4. CONCLUSIONS

The nonlinear numerical model is introduced to evaluate the response of RC structural members under blast loading. The proposed model can predict behavior of RC member until maximum response. Hysteric moment-curvature relation of loading and unloading should be considered in the further studies.

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