The 2021 World Congress on
Advances in Structural Engineering and Mechanics (ASEM21)
GECE, Seoul, Korea, August 23-26, 2021

Blast Analysis of RC Frames using Moment-Curvature Relationship

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ABSTRACT

In this paper, Moment-Curvature approach for a numerical analysis of RC frames under blast loading is introduced. Hysteretic behavior of RC members is considered to describe the post peak behavior of structures and interaction between the beam and column. In order to consider the change of material properties under high strain rate, a dynamic increase factor in terms of the curvature rate is constructed. In order to verify the proposed numerical model, the numerical results were compared with the experimental results in a member level. In addition, numerical analyses with LS-DYNA and the proposed model for a simple RC frame was performed to confirm the accuracy and computational efficiency of the model.

1. INTRODUCTION

Many researchers have conducted numerical and experimental studies for the evaluation of the behavior of RC structures under blast loading. Among many numerical approaches, numerical studies based on the single degree of freedom (SDOF) model or using commercialized hydro-codes with 3D solid element such as LS-DYNA have been popularly employed (Zhang et al., 2020). However, the former shows relatively inaccurate results caused by many assumptions, and the latter requires user's skills for application of material models and failure criteria and high computational cost. Therefore, the moment-curvature approach is introduced to describe the peak and post-peak behavior of RC structures subjected to blast loading, which shows relatively accurate results and less computational cost.

2. NUMERICAL MODEL

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Since the blast analysis is conducted based on the moment-curvature relationship, moment-curvature relationship should be defined first before blast analysis. Monotonic and hysteretic moment-curvature relationship was constructed to describe peak and post-peak behavior of structures, and dynamic increase factor was built to consider high strain rate effect in this paper.

2.1 Moment-curvature relationship

In this study, monotonic moment-curvature relationship is simplified to trilinear relationship with 2 representative points which means concrete cracking and rebar yielding. Monotonic moment-curvature relationship is uniquely constructed as Fig. 1 through section analysis based on the layered section method. Axial force effect and bond-slip effect also considered. Since hysteretic behavior of RC sections after yielding is governed by hysteretic behavior of reinforcing steel, hysteretic moment-curvature relationship is constructed based on the hysteretic stress-strain relationship of steel. Unloading/reloading branches in moment-curvature relationship after yielding consists of two asymptotes and is represented by Eq. (1).

$$M^* = p \cdot \phi^* + \frac{(1-p)\cdot\phi^*}{\left(1+\phi^{*G}\right)^{1/G}} \tag{1}$$

In construction of moment-curvature relationship, modified Kent & Park model with unloading-reloading equations by Karsan and Jearsa is adopted for the compressive concrete and linear elastic and linear strain softening behavior is assumed for the tensile concrete. For steel, a linear elastic and linear strain hardening relation together with the definition of the unloading and reloading behavior by the nonlinear model of Menegotto and Pinto is employed. (Park&Paulay, 1975).

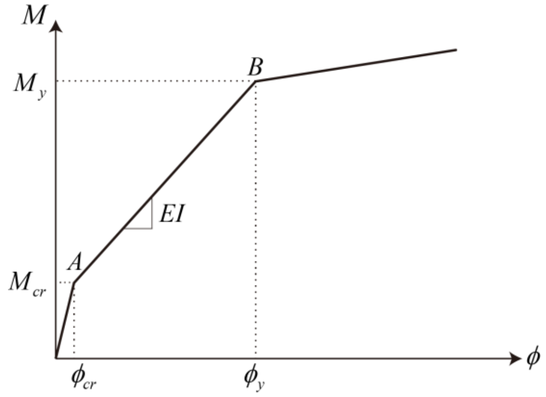

Fig. 1 Typical moment-curvature relationship

2.2 Dynamic increase factor

A dynamic increase factor(DIF) is popularly used to consider the high strain rate effect, it is newly built as a function of the curvature rate to be directly applicable to the moment-curvature relationship. A DIF equation for the section is constructed through regression of cracking moments and yielding moments from iterative section analysis including Malvar's DIF equations for material models. (Taerwe & Matthys, 2013).

3. NUMERICAL APPLICATION

To verify the validity of the proposed model, a comparative study with the experimental results by Liu was performed. More details for experimental setup and information of specimen can be found elsewhere. (Liu et al., 2019). In addition, numerical analyses of a simple 2-bay frame structure were performed with LS-DYNA and the proposed model, respectively, and the results were compared to verify accuracy and computational efficiency of the proposed model.

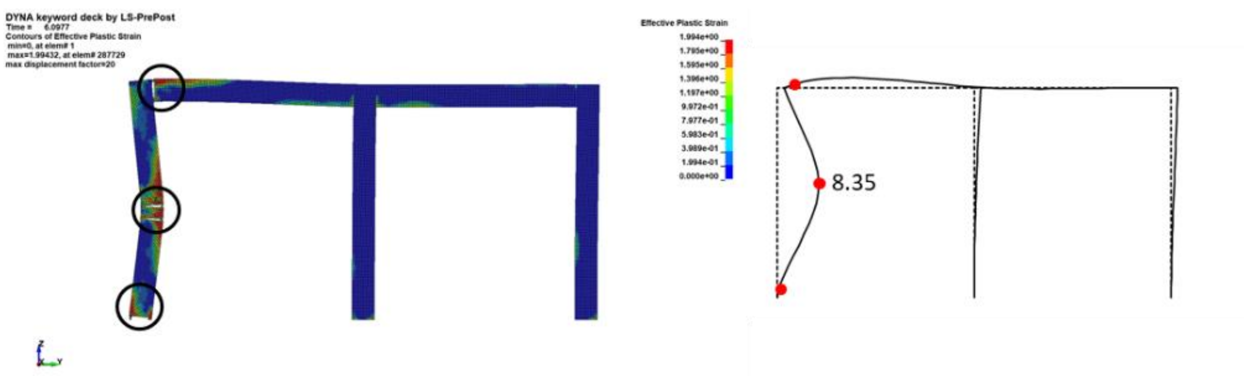

Fig.2 Numerical results of a simple RC frame under blast loading with LS-DYNA and the proposed method

4. CONCLUSIONS

Blast analysis method based on the moment-curvature relationship was introduced. The validation of the proposed model was consolidated through comparison with the experimental results in member level In addition, in order to confirm the applicability to the RC frame, comparative studies between using LS-DYNA and proposed model were performed. Proposed model showed similar results from LS-DYNA in location of damage and occurrence time with less computational cost.

Acknowledgement

This work is financially supported by Korea Ministry of Land, Infrastructure and Transport(MOLIT) as 「Innovative Talent Education Program for Smart City」" and supported by a grant (21SCIP-B146646-04) from Construction Technology Research Project funded by the Ministry of Land, Infrastructure and Transport of Korea government.

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