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FLEXURAL PERFORMANCE OF CONCRETE BEAMS UNDER CYCLIC LOADING

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Abstract

A large portion of the civil concrete structures get damaged during an earthquake event, hence structures required some substitution and restoration. In the present study, the flexural performance of concrete beams under variation of magnitude on cyclic loading is investigated. ABAQUS finite element (FE) program is used to numerically perform a parametric study for five different depths of beams varying from 250 to 750 mm under cyclic loading. The finite element (FE) beams are modeled using Concrete Damaged Plasticity model (CDP) model. The effect of beam depth on the flexural strength of concrete beam is investigated. The effect of cyclic loading on strength and deformation behavior, yielding, ultimate, failure strengths as well as on displacements are evaluated. The load-deflection curves are obtained for different beams and are compared to static loading.

Keywords: Concrete damage plasticity, Cyclic load, Finite element model, Flexural strength.

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1 INTRODUCTION

A large portion of the civil concrete structures get damaged during an earthquake event, hence structures required some substitution and restoration. A wide range of tests have been conducted to understand the effect of cyclic load on reinforced concrete structural members during the earthquake. The failure of reinforced concrete (RC) beam is a progressive process of micro crack initiation and propagation leading to micro cracks that grow to a stage in which failure occurs. Under the repeated cyclic loading, the mechanical properties of concrete changes, thus strain increases permanently, whereas the modulus of elasticity decreases. In the case of a reinforcing bar, cyclic load causes micro- cracking that initiates a stress concentration at the bar surface. As the cyclic stress continues, the crack propagates, leading to sudden fracture crack that grow to a stage in which failure occurs.

In the present study, the flexural performance of three-dimensional nonlinear RC beams under cyclic and static loading are analyzed using concrete damaged-plasticity (CDP) [10] model available in the software ABAQUS [11].

1.2 Furthermore work has been done on cyclic load

Yonezawa et al., 2020 [1] investigated the effect of cyclic load on welded joints and measured the residual stress at the ultrasonic impact treatment groove using X-ray diffraction method. Ftaikhan et al., 2019 [2] studied the effect of FRP and CFRP bar embedded in RC frame subjected to dynamic loading using ABAQUS and ARCS3D finite element softwares. Tsutsumi et al., 2019 [3] analyzed the cyclic response of steel bridged pier and also evaluate the load-carrying capacity of steel bridge pier. Jamadin et al., 2019 [4] investigated the natural frequencies, mode shapes and damping ratios for bridge reinforced concrete deck slabs under cyclic and static loads. Koltsida et al., 2019 [5] tested brick masonry prisms under compressive cyclic loading at different maximum stress levels until failure and developed three mathematical equations to predict the three characteristic stages of fatigue of brick masonry. Haris and Roszevàk, 2019 [6] analyzed RC frame joint under monotonic increasing quasi-static and cyclic changing loads. Xiao et al., 2018 [7] studied the effect change in loading rate on the dynamic behavior of reinforced concrete beams under cyclic loading. Harba and Abdulridha, 2017 [8] studied the effect of five different cyclic loads on RC hunched beam. Parvez and Foster, 2015 [9] showed that steel-fiber-reinforced concrete under constant amplitude cyclic loading has low smaller deflections and smaller crack widths than that of control specimens and reducing the stress level in the tensile reinforcement.

Based on the observations from the literature review and gaps, the following are the objectives of the present work:

(i) A parametric study of five different depths of rectangular beams (having width 200 mm and length 1500 mm constant) varying from 250 to 750 mm under static and cyclic loading is carried out.

(ii) To study the effect of increasing depth of beam on load-deflection curve of RC beams under cyclic loading and also compared it with static loading.

(iii) To determine plastic strain, principal stress and mid span deflection under cyclic and static loadings.

2 PROPOSED METHODOLOGY

A rectangular RC beam having constant width 200 mm and length 1500 mm. the beam is having varying depths of 250 mm, 350 mm, 500 mm, 600 mm and 750 mm is analysed as given in Table 1. A FE element model of RC beam using C3D8 brick element has been created and analysed in FE software package ABAQUS. The material properties of RC beam are given in Table 2. The nonlinear behavior of concrete is modeled using CDP model [10] can define the compression load behavior and tension load behavior. Figure 1 shows the cyclic loading considered in the present study having load of 2000 N to 3000 N. Figure 2 shows the FE model of RC beam. The steel reinforcement is embedded in to the concrete beam. The mesh size adopted in the present work is 50 mm.

Beam Designation	Width (mm)	Depth (mm)	Effective length (mm)	Width/Depth ratio
B-1	200	250	1500	0.8
B-2	200	350	1500	0.57
B-3	200	500	1500	0.4
B-4	200	600	1500	0.33
B-5	200	750	1500	0.27

Table 1: Beam dimensions.

Beam	Concrete mix	f_{ck} (Mpa)	f_{tk} (MPa)	E_c (MPa)	E_s (GPa)	Main Rein-forcement	Stirrups	Effective cover
B-1 to B-5	M60	61.8	4.6	39306 .49	2.1	4#20 mm dia.	10 mm dia. @ 140 mm c/c	20 mm

Table 2: Material properties.

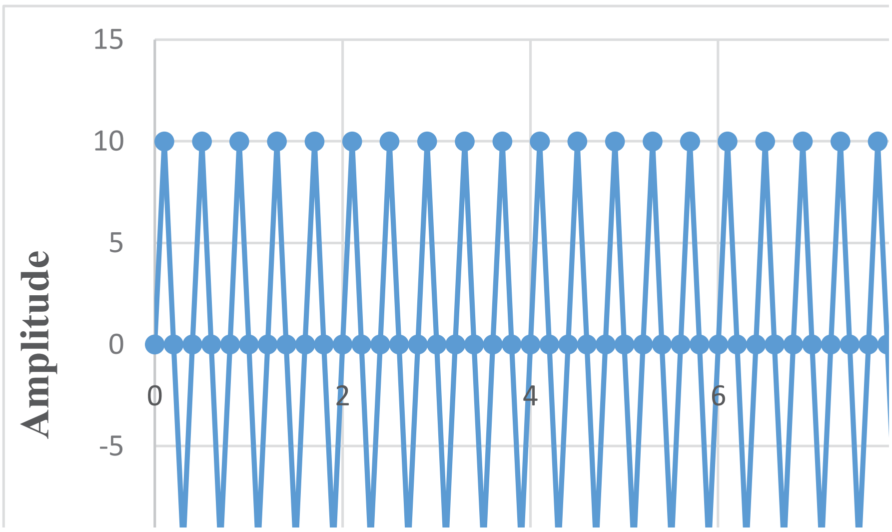


Figure 1: Cyclic loading.

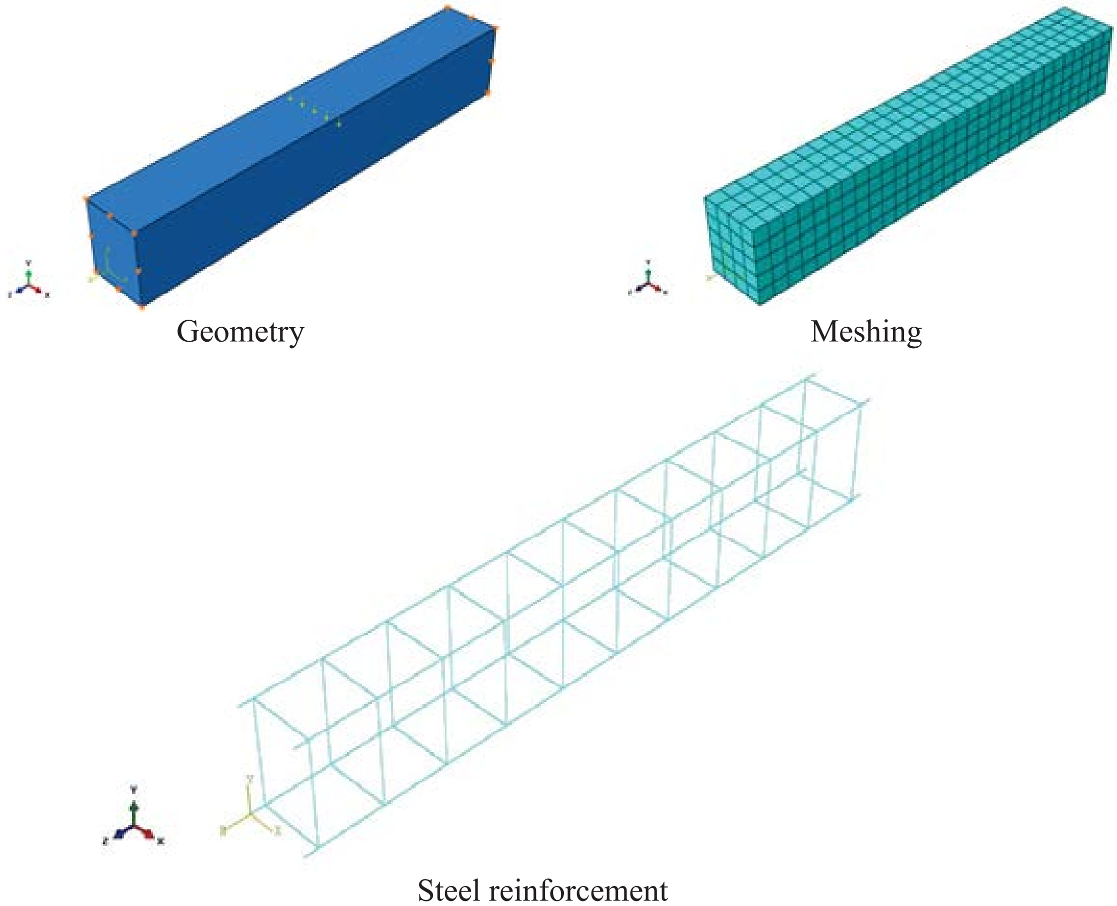


Figure 2: FE model of RC beam.

3 RESULTS AND DISCUSSIONS

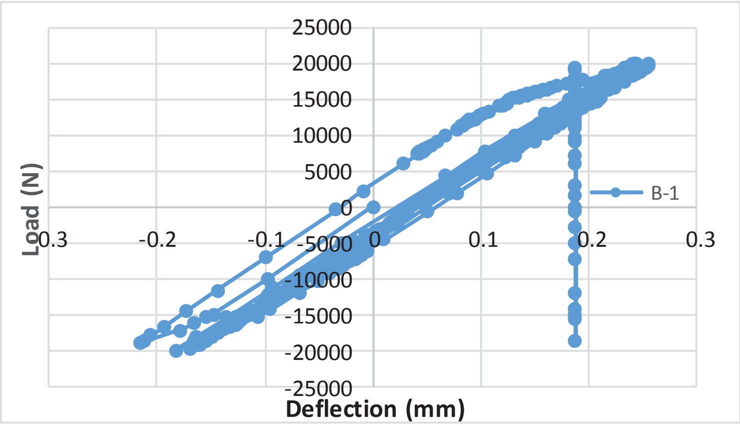
Total five RC beams (B-1 to B-5) has been analyzed. The results prevail to the objectives of the study are presented and discussed in this section. Table 3 gives the initial plastic load and deflection for B-1 to B-5 beams under cyclic loading. Table 4 gives the load and deflection values under static loading of 50000 N. Figure 3 shows the load-deflection curves for B-1 to B-5 RC beams under cyclic loading. It can be observed that as the depth of beam increases the deflection decrease in the beams. Figure 4 shows the load-deflection curve for the RC beams under static loading. It can be observed from the figure that as the depth of beam increases the deflection reduces. It is observed that deflection is less in B-5 beam having a depth of 750 mm.

Beam Designation	Initial Plastic Load (N)	Initial Plastic deflection (mm)
B-1	19987.2	0.26
B-2	24932.6	0.15
B-3	29768.3	0.05
B-4	29586.4	0.03
B-5	25000	0.02

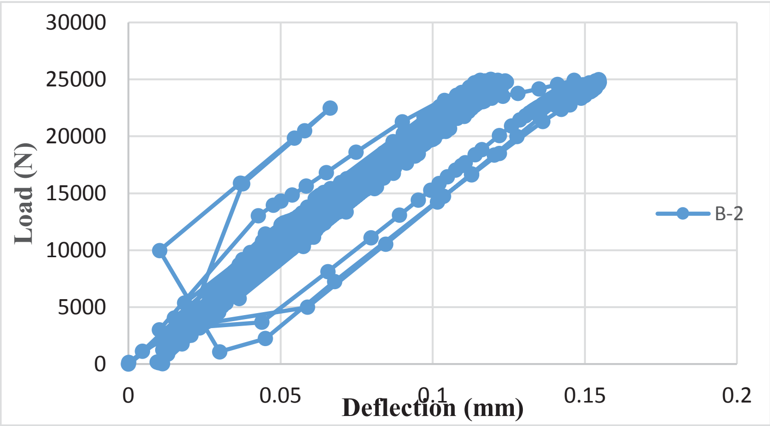
Table 3: Initial plastic load and deflection under cyclic loading.

Beam Designation	Load (N)	Deflection (mm)
B-1	50000	1.42
B-2	50000	0.70
B-3	50000	0.50
B-4	50000	0.47
B-5	50000	0.45

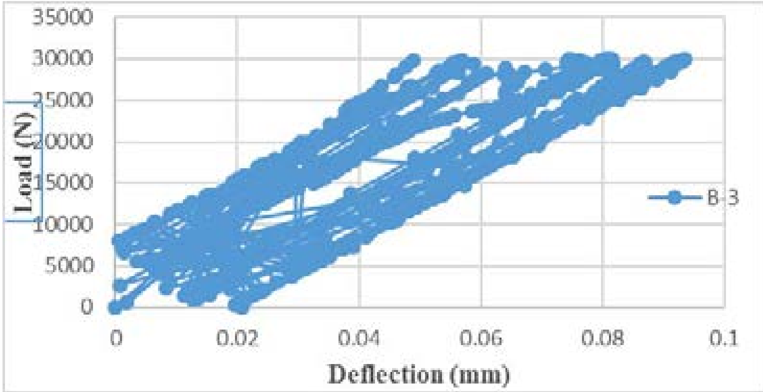
Table 4: Load and deflection under static load.



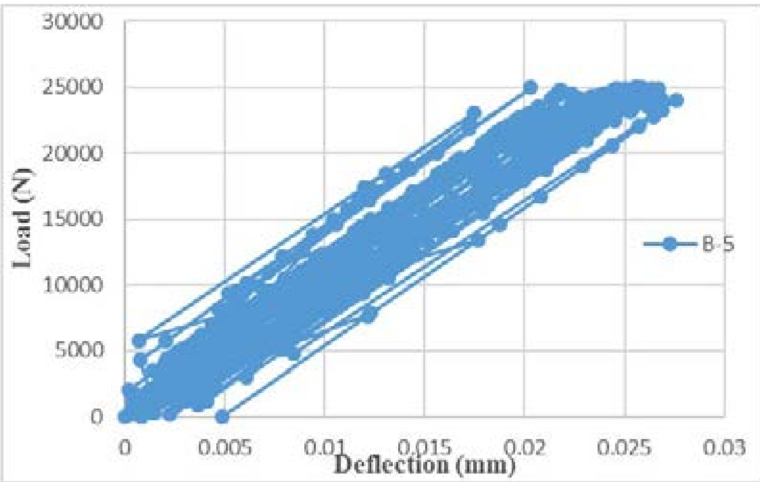
(a) B-1 RC beam



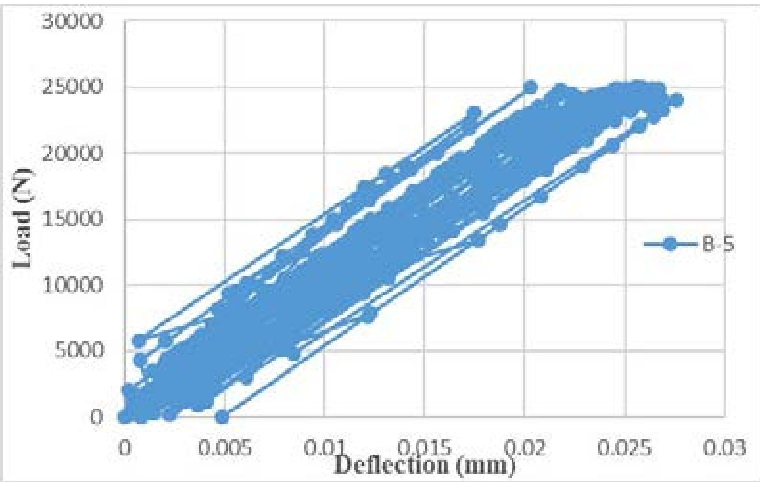
(b) B-2 RC beam



(c) B-3 RC beam



(d) B-4 RC beam



(e) B-5 RC beam

Figure 3: Load-deflection curves RC beams under cyclic loading.

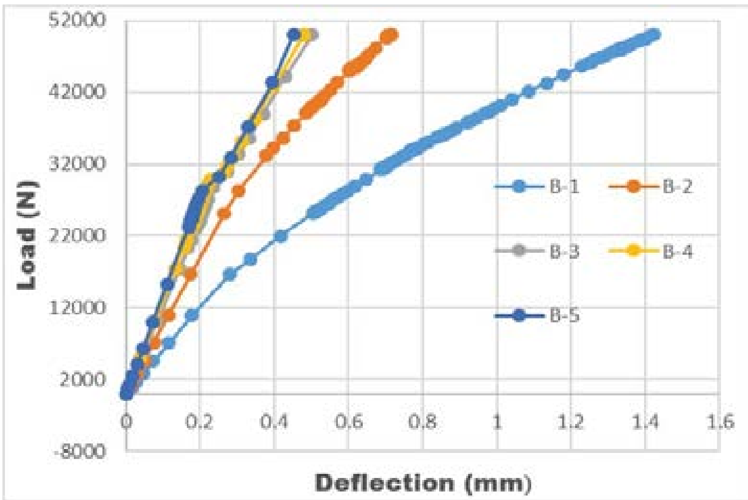
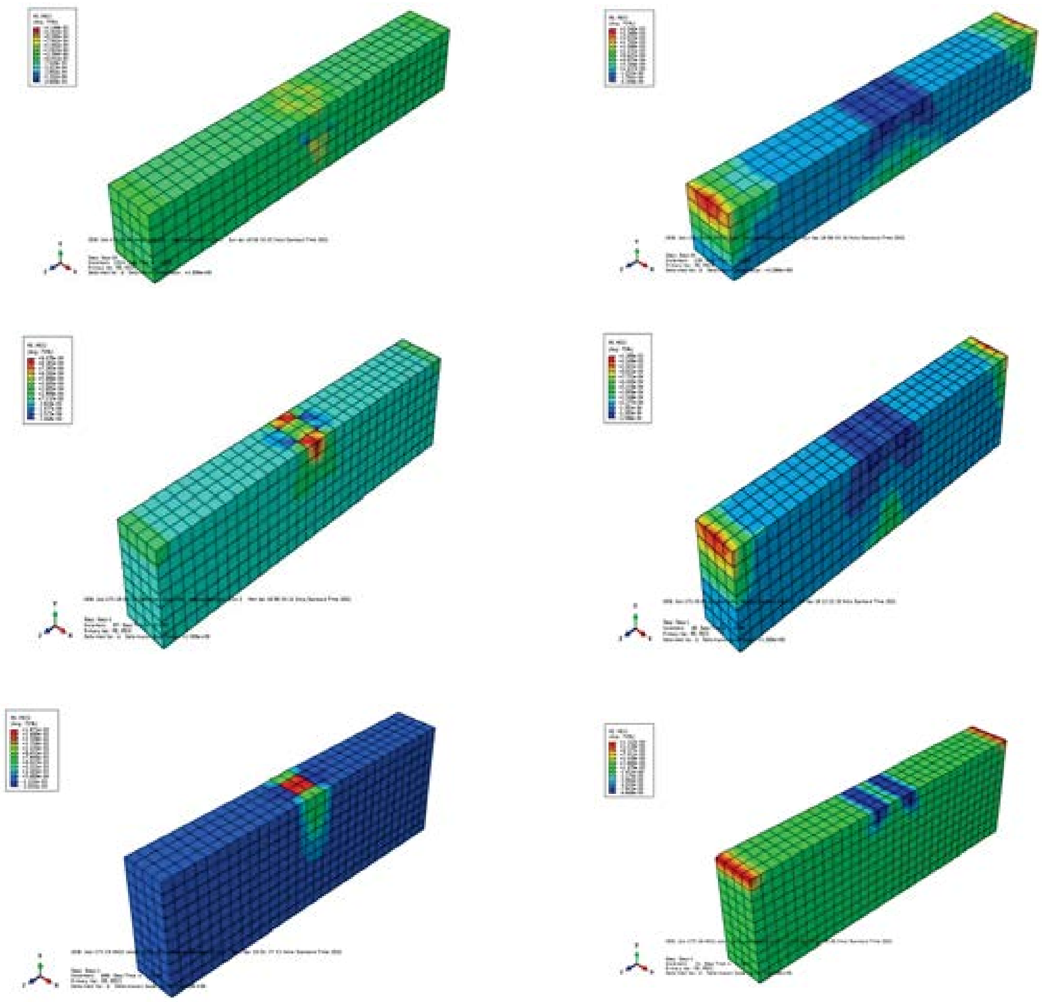


Figure 4: Load-deflection curves RC beams under static loading.

B-1

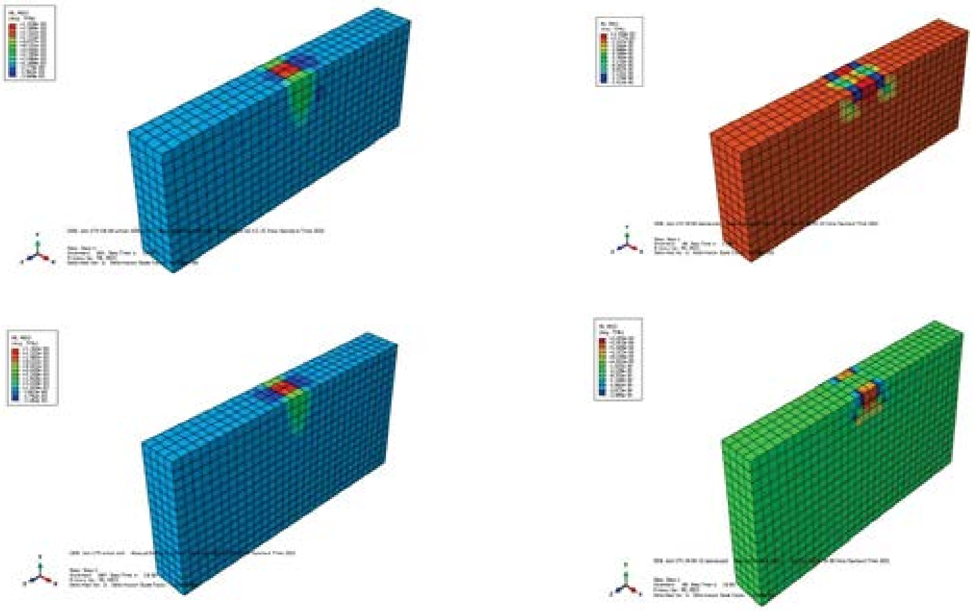
B-2

B-3



B-4

B-5



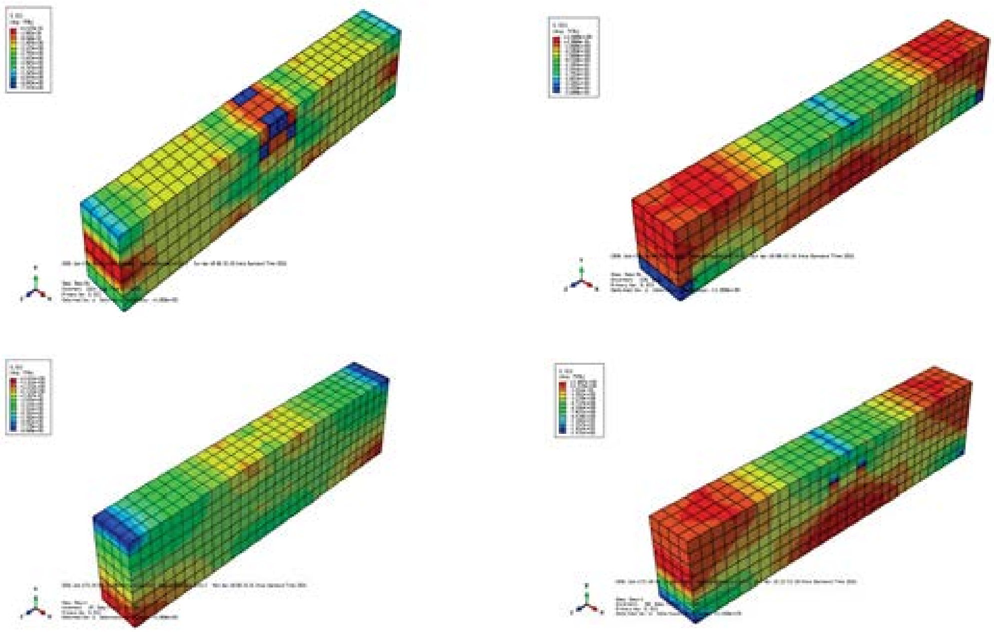
Cyclic loading

Static loading

Figure 5: Plastic strain for RC beams under cyclic and static loading.

B-1

B-2



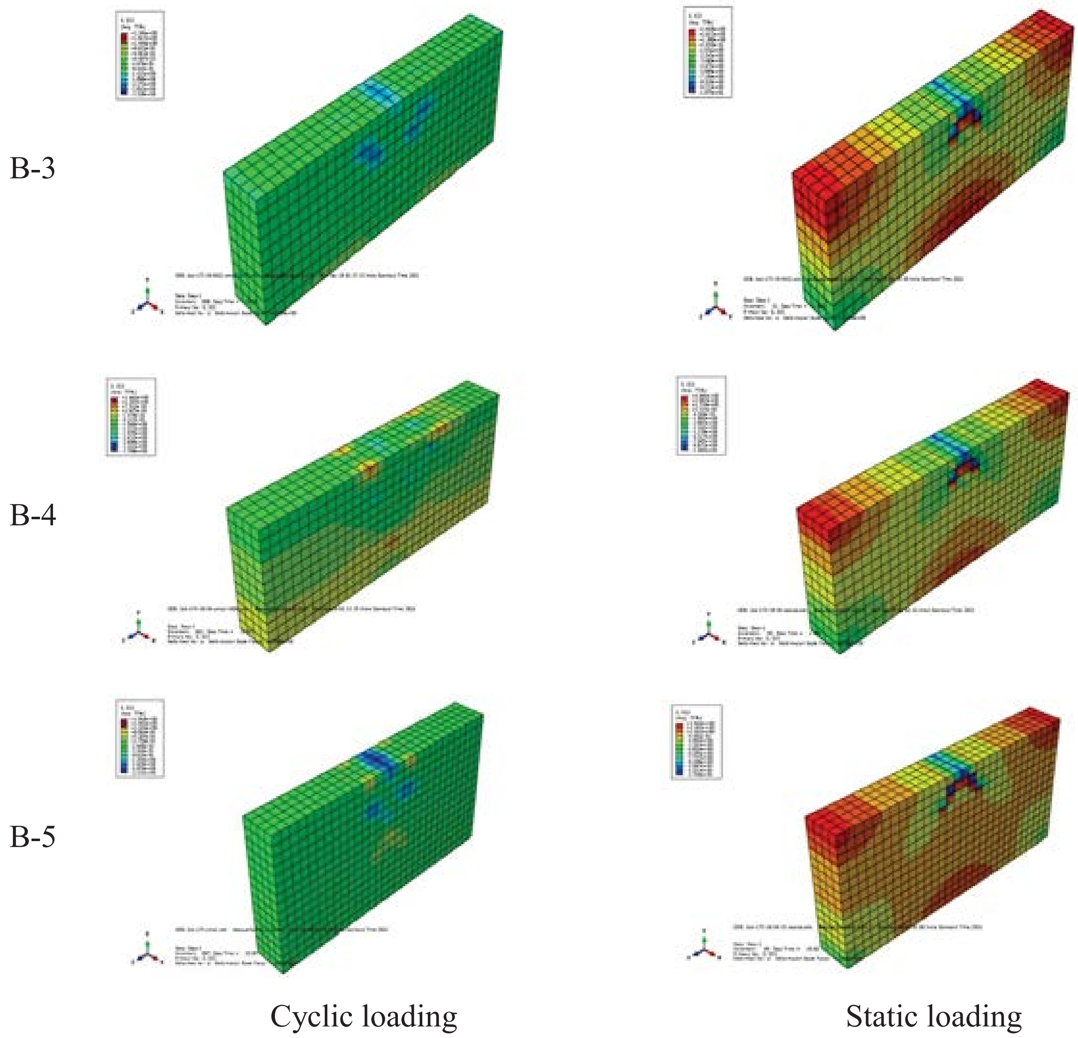
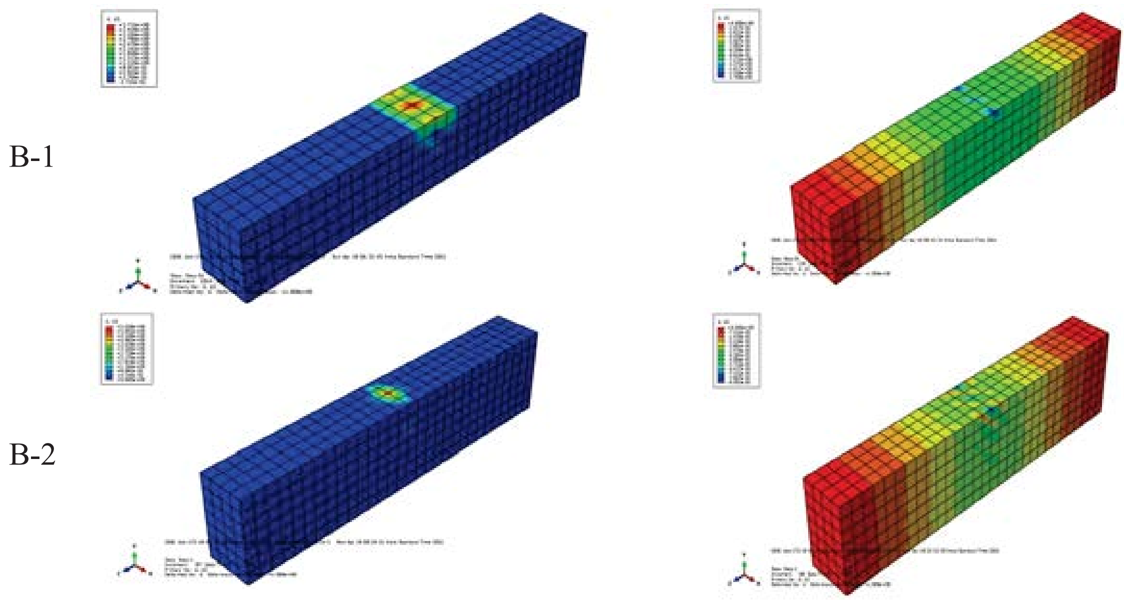


Figure 6: Principal stress for RC beams under cyclic and static loading.



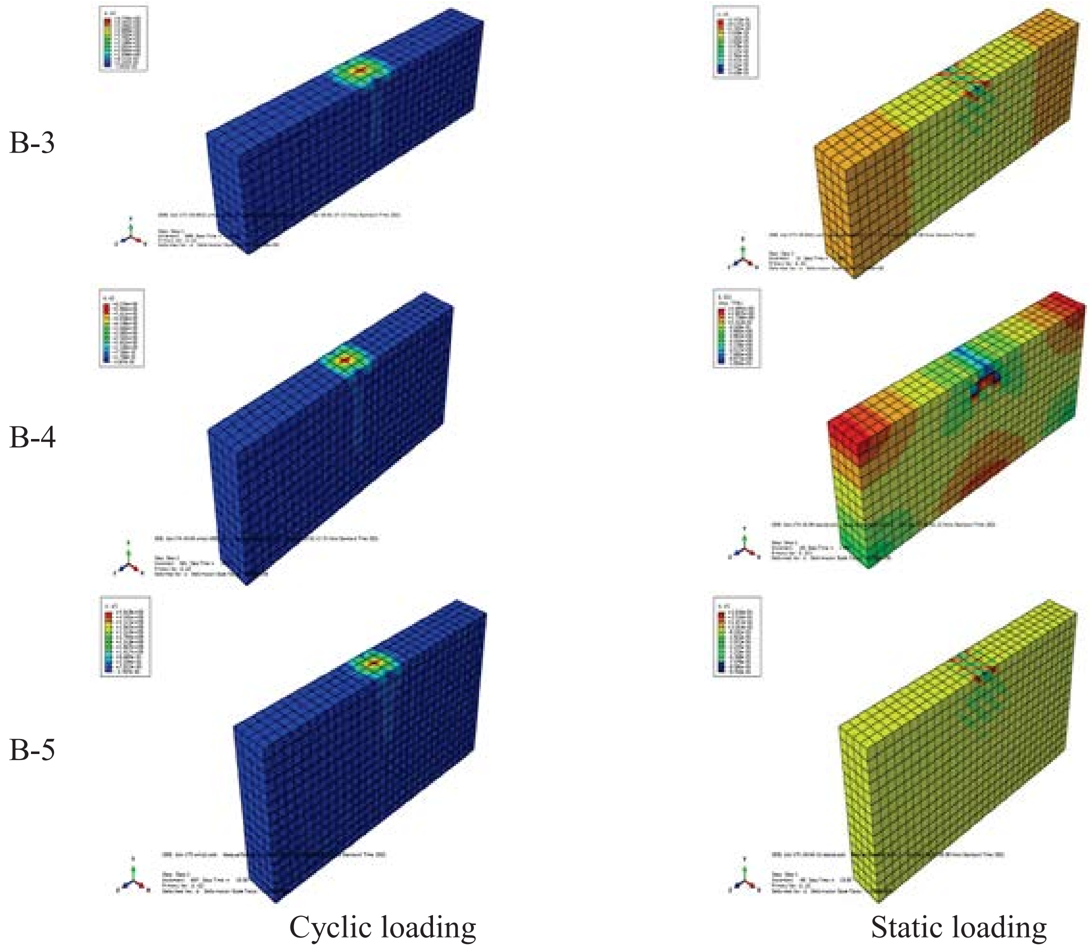


Figure 7: Mid span deflection for RC beams under cyclic and static loading.

Figures 5, 6 and 7 shows the plastic strain, principal stress and mid span deflection for RC beams under cyclic and static loading, respectively. The plastic strain, principal stress and deflection are observed less in the case of B-5 RC beam having a depth of 750 mm for cyclic load and static load.

4 CONCLUSIONS

In the present study, the flexural performance of three-dimensional nonlinear RC beams under cyclic and static loading are analyzed using concrete damaged-plasticity (CDP) model. A parametric study of five different depths of rectangular beams (having width 200 mm and length 1500 mm constant) varying from 250 to 750 mm under static and cyclic loading is carried out. The effect of increasing depth of beam on load-deflection curve of RC beams under cyclic loading and also compared it with static loading are studied. The plastic strain, principal stress and mid span deflection under cyclic and static loadings are investigated. On the basis of FE analysis of RC beams the following conclusions are drawn:

(i) By increasing the depth of beam that is width to depth ratio the load carrying capacity of beam increases for both cyclic and static loadings.
(ii) In cyclic loading it is observed that as the load amplitude is high the damage observed is more as compared to static loading.

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