Numerical Evaluation on Impact Behavior of Seismically and Non-Seismically Detailed RC Beams

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***Abstract*—There is an increasing tendency among structural engineers to consider impulsive loads, such as impact and blast loads, in the design of RC members since these loads acting for short time intervals may lead to severe damage to structural elements or even collapse the whole structure. In contrast, the traditional design primarily considers the static loads and the dynamic loads like earthquake and wind effects, disregarding impulsive loads. At this point, it is critical to determine the dynamic response and failure characteristics of existing RC beams designed without special precautions against impact effects since these beams may expose impact load in their service period. The present study intends to reveal the impact resistance and general impact behavior of seismically and non-seismically designed RC beams. For this purpose, an improved finite element code, including the erosion algorithm and considering the strain-rate effects for concrete and steel material, has been established to evaluate the impact response of RC beams, and it has been verified with experimental data provided by a previously published study. Then, using verified finite element code, a parametric study was conducted where the effects of the shear reinforcement ratio, the application point of impact load, and the applied input impact energy on the dynamic responses and damage patterns of the RC beams. Results from numerical analysis were evaluated in detail, and interpretations related to the impact behavior of seismically and non-seismically designed RC beams were made.**

***Keywords*—impact load, Reinforced Concrete (RC), RC beam, seismic design, finite element analysis, LS-DYNA**

I. Introduction

It can be mentioned that there are two main missions for RC beams in structural systems. One of them is transferring the dead and live loads, which act vertically and are transmitted from the slabs, to vertical bearing members such as columns and shear walls. The second one is transferring lateral forces due to the earthquake and wind to vertical members together with slabs [1, 2]. RC beams may also subjected to impulsive dynamic loads such as impact and blast in their service periods. Impulsive loads cause the inertia effect, strain rate effect of materials, and different failure modes in RC structural members in comparison to static load. Furthermore, despite their short acting time, they may cause considerable damage to structural members. Recently, impact loads have also been considered in design on top of static and dynamic loads such as earthquake and wind due to their catastrophic effect. The falling rock, vehicle collisions with transportation structures, aircraft landing on airport runway platforms, ice and/or barge impact to offshore structures, and the collision of masses driven by the landslide and flood to RC structural elements are common impact scenarios generating dynamic loads.

Some studies in the literature handled the RC beams in which failure mode is shear under impact load [3–5]. Saatci and Vecchio [6] revealed differences in moment and shear force distribution in static and impact loading. The study also mentioned that single-degree-of-freedom approaches derived from low-order deformation modes may not capture the response of RC beams prone to shear failure under impact load. The fact that the geometric parameters of a structure have been effective on impact resistance was examined in previous studies [6, 7]. Cotsovos *et al.* [8] emphasized that the response of RC structural members subjected to high loading rates was originally a complicated nonlinear dynamic wave-propagation problem. Since nonlinear wave propagation problems can accurately be evaluated via nonlinear dynamic analysis based on the Finite Element Method (FEM), the shear behavior of RC beams exposed to impact load has been investigated via nonlinear dynamic analysis [9–13]. Drop weigth impact tests has been commonly used for evaluation of impact behavior of RC beams [3, 14–16]. Pham and Hao [18] introduced an analytical approach to derive dynamic shear force and bending moment diagrams under impact loading. Xu and Zeng [19, 20] calculated moment and shear distribution curves under impact loading by regarding the effect of inertia. The impact force profile of the RC beam under impact loading was

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analytically and numerically studied by Li *et al.* [21] and factors affecting the impact force profile have been also investigated by Li *et al.* [22]. The hammer geometry and interlayer effects on the impact response of the RC beams were studied by Li *et al.* [23]. Hao *et al.* [24] examined the effects of the configuration of the test setups and critical factors, such as the position of load cells and restraint conditions, on the impact response of RC beams. The impact behavior of the RC structural members strengthened with FRP sheets was also investigated in the literature [25–32]. The bonding behavior between FRP sheets and concrete was examined in some studies [33, 34]. Furthermore, the concrete structural members designed with Fiber-Reinforced Polymer (FRP) rebars, subjected to impact load, have been studied in the literature [35, 36]. There are also studies focused on the impact behaviors of a concrete beam consisting of additive materials like polypropylene or steel fibers [37–41]. Recent comprehensive studies related to impulsive loads such as impact and blast effects were also taken place in the literature [42–45].

The present study intends to understand the impact behaviour of RC beams in which the design phase has no special precautions against impact load, but it has been detailed by considering the earthquake effect. For that purpose, a detailed finite element code has been established. The present finite element code has considered strain rate effects and included erosion and damage algorithms. The present finite element code has been verified with the experiment of an RC beam, of which results were presented in a previously published study. Based on the verified finite element code, a parametric study has been performed to evaluate the impact behaviour of seismically and non-seismically detailed RC beams. In the parametric study, shear reinforcement spacing, input impact energy transferred to beams, and position of impact load application point were taken as variables. By examining and interpreting numerical results, the effects of chosen variables on the impact behaviour of the RC beams were determined, and to what extent seismic detailing may improve the impact behaviour of RC beams was understood.

II. The Experiment Used for Verification of Numerical Analysis

The comprehensive experimental program conducted by Yan *et al.* [46], where the conventional Reinforced Concrete (RC) and precast concrete beams exposed to impact loading are examined, has been used for verification of the presented finite element code. In the experimental program, the RC beam, named B1a in the experimental program, had the dimensions of 200x400x3300 mm, and the clear span was 2900 mm. The concrete compressive strength after 28 days from the cast was determined as 36.7 MPa. The RC beam was designed using 2Φ16 HRB400 steel rebars placed at tensile and compressive parts of the beam. These reinforcements are hot-rolled China standard deformed steel rebars, and their yield and ultimate strength are 478.7 MPa and 602.2 MPa, respectively. The diameter of HRB400 shear reinforcement was 6 mm and was placed at a spacing of 150 mm. The yield and ultimate strength of shear reinforcement were 414.5 MPa and 478.7 MPa, respectively. Fig. 1 depicts the dimensions and rebar arrangement of the RC beam.

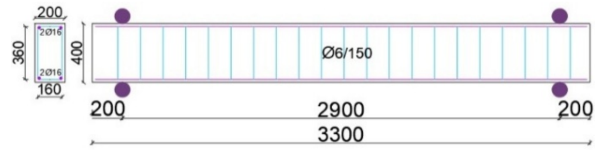

Fig. 1. The dimensions and rebar arrangement of the RC beam.

The impact tests of the RC beam were performed using a high-energy drop hammer test machine. The flat hammer, whose diameter was 200 mm, has been used as a drop-weight. The mass of hammer was 253 kg. The RC beam was pin-supported at both ends, and uplift plates were placed at the two supports to prevent the beam from breaking away from the support during the impact loading. The uplift plates were connected to the base pins by tie bars, and they did not affect the rotation of the beam. The input impact energy was transferred to the RC beam by dropping the hammer from the height of 2.4 m, which corresponded to 5,951 kJ. The impact force was measured via the load cell in the hammer, while mid-span deflection was obtained by the displacement meter mounted in the mid-span at the bottom of the beam. Fig. 2 shows the test setup in the reference study used for impact loading.

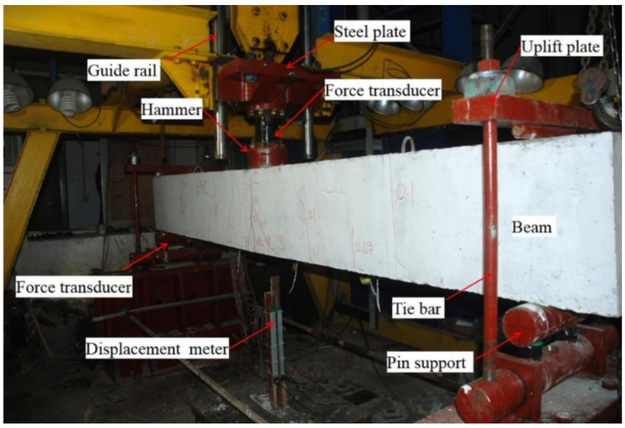

Fig. 2. The test setup used for impact loading in the reference study.

III. The Details of the Presented Finite Element Model

The Finite Element Models (FEM) of the RC beam in experimental program carried out by Yan *et al.* [46] and RC beams existing in numerical analysis part of present study was generated in LS-DYNA software [47]. The LS-DYNA software, which can conduct non-linear dynamic analysis, has a broad spectrum of concrete material models for dynamic loading and contains advanced contact algorithms for simulating the interaction of collided parts in the impact analysis [48].

The generated FEM consists of the RC beam, steel rebar, support and hammer parts. While an 8-node hexahedron solid element was used for modeling RC beam, support and hammer, the steel rebars were modeled with a Hughes-Liu beam element. Full bond between concrete and rebar was defined with the CONSTRAINED_LARGRANGE_IN_SOLID keyword existing in the software. After mesh convergence trials, concrete element sizes were defined as 20x20x33 mm for the RC beam used for verification, while it was defined as 25×25×25 mm for RC beams used for parametric analysis. The element sizes of reinforcement, support and hammer for the RC beam used for verification were 33 mm, 5 mm, and 7 mm, respectively. These sizes were 20 mm, 5 mm and 12.5 mm for RC beams used for parametric analysis. The defined element sizes have yielded accurate results; further refinement on mesh size has almost no effect on outcomes, although it increases solution time. It should be emphasized that when the RC beam mesh sizes in the parametric analysis were decided, it was also considered the fact that mesh sizes were compatible with their actual geometric dimensions. Impact load was applied by defining the velocity at the moment of collision to the hammer. The friction occurring in the drop of steel weight has been neglected.

The concrete material in numerical analysis was modeled utilizing MAT_072R3, which is a material model that considered strain-rate effect, plasticity, and shear failure damage. Thanks to yielding accurate results, it has been commonly used for impact and blast simulation. In MAT72 model, the stress tensor is defined as the sum of hydrostatic and deviatoric stress. The hydrostatic stress changes with concrete volume, and the deviatoric stress rules the shape deformation. Three shear failure surfaces are utilized to build the intact, yield and residual strength curves of concrete material. The deviatoric stress behaves as elastic during the initial loading and reloading phase until the stress reaches the initial yield surface. The deviatoric stress then rises until the maximum strength surface is reached. The response can be perfectly plastic or softened to the residual strength surface beyond this stage. A damage scalar is used to account for concrete damage, which ranges from 0 to 1.0 for concrete material experiencing strain hardening, and from 1.0 to 2.0 for the material softening stage. For the definition of concrete material, the only required parameter is unconfined cylinder concrete compressive strength. Based on compressive strength, other parameters have been calculated by software. Besides, the software allows the user to modify the generated parameters. The MAT_072R3 material model was used with the MAT_ADD_EROSION function in LS-DYNA to remove damaged concrete, which no longer contributes to the bearing capacity of beams. The algorithm prevents excessive distortion and deformation, which causes computational overflow by removing elements whose tensile strength exceeds the defined erosion tensile strength or the principal erosion strain [46]. The maximum principal strain was defined for the erosion criterion, and its value was taken as 0.15 by means of trial error to achieve accurate results. In the numerical analysis, concrete material density was defined as 2400 kg/m^3. Steel reinforcements were modeled as elastic-plastic material without hardening via MAT_PIECEWISE_LINEAR_PLASTICITY (MAT_24) material card in LS-DYNA. Elastic modulus, yield strength, Poisson's ratio and the density were defined in this material card. Elastic modulus, Poisson's ratio and density were defined as 200000 MPa, 0.3, and 7850 kg/m^3, respectively. Hammer and supports were modeled as rigid material.

Impulsive loading enhances steel and concrete materials' tensile and compression strength. This phenomenon is known as a strain-rate effect; its consideration in impact analysis is compulsory for the proper evaluation of dynamic responses [48]. This effect is commonly implemented in the material model by using a Dynamic Increase Factor (DIF), which refers to a ratio of dynamic strength to static strength. Several equations were presented to define DIFs of steel and concrete materials in the literature [49–54]. For the DIFs of the concrete compressive and tensile strength, the equations proposed by Hao and Hao [54] were used. For a strain rate of $\dot{\varepsilon}_d$, the compressive and tensile DIFs of the concrete material can be expressed as follows:

$$CDIF = \frac{f_{cd}}{f_{cs}} = \begin{cases} 0.0419\,(log\dot{\varepsilon}_d) + 1.2165 & for(\dot{\varepsilon}_d \le 30s^{-1}) \\ 0.8988(log\dot{\varepsilon}_d)^2 - 2.8255(log\dot{\varepsilon}_d) + 3.4707 & for(\dot{\varepsilon}_d > 30s^{-1}) \end{cases} \quad (1)$$

$$TDIF = \frac{f_{td}}{f_{ts}} = \begin{cases} 0.26(log\dot{\varepsilon}_d) + 2.06 & for\ (\dot{\varepsilon}_d \le 1s^{-1}) \\ 2(log\dot{\varepsilon}_d) + 2.06 & for\ (1s^{-1} < \dot{\varepsilon} \le 2s^{-1}) \\ 1.44331(log\dot{\varepsilon}_d) + 2.2276 & for\ (2s^{-1} < \dot{\varepsilon}_d \le 150s^{-1}) \end{cases} \quad (2)$$

where CDIF and TDIF refer to compressive and tensile DIFs for the concrete, respectively. The static and dynamic compressive strengths have been swown with f_{cs} and f_{cd}, respectively. The f_{ts} and f_{td} denote static and dynamic tensile strengths. Besides, tensile and compressive DIFs at strain rate $\dot{\varepsilon}$, which belongs to strain material can be writtes as:

$$\text{DIF} = \left(\frac{\dot{\varepsilon}}{10^{-4}}\right)^{\alpha} \quad (3)$$

where α coefficient can be calculated via steel yield strength f_y as follows:

$$\alpha = 0.074 - \frac{0.04 f_y}{414}. \quad (4)$$

In the numerical analysis, rigid supports were constrained against rotation and translation through rigid material card existing in LS-DYNA. However, the RC beams can rotate between cylinder these supports like in the reference test. the test setup in the reference study used for impact loading. Furthermore, the contact between steel impactor and the RC beam were defined by AUTOMATIC_SURFACE_TO_SURFACE keyword which based on penalty approach. The contact stiffness scale factors (SFS/SFM) for master and slave elements were taken as 0.2. Fig. 3 shows the finite element model of the RC beam used for verification of the present numerical model, which had been tested by Yan *et al.* [46].

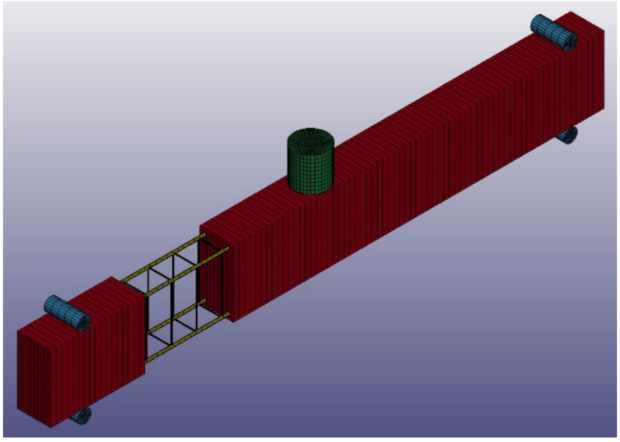

Fig. 3. The FEM model of the RC beam used for verification.

In the scope of numerical analysis, the time hisories of impact load and mid-span displacement were calculated. Besides, the damage patterns were obtained though effective plastic strain.

Table I shows peak impact forces and maximum displacement at the mid-span of the RC beam tested by Yan *et al.* [46]. Table I also contains numerical results obtained from LS-DYNA via the presented finite element code. In Table I, Ex means experimental results, while Num refers to LS-DYNA analysis results.

TABLE I. VERIFICATION OF NUMERIC MODEL

Peak Impact Force (kN)			**Mid-span Displacement (mm)**		
Ex	Num	Num/Ex	Ex	Num	Num/Ex
1245	1253	1.01	30	31.7	1.06

Fig. 4 compares damage that occurred in the RC beam during tests and also the effective plastic strain obtained by numerical analysis.

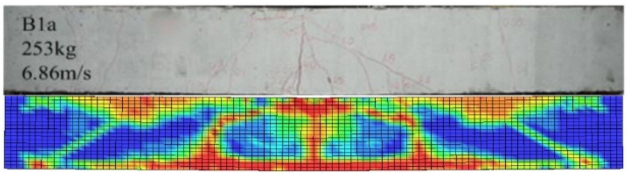

Fig. 4. The FEM model of the RC beam used for verification.

When results in Table I are examined, there is excellent accordance between numerical and experimental results taken from the study of Yan *et al.* [46]. There is only difference between numerical and experimental results was 1% and %6 for peak impact force and mid-span displacement, respectively. Besides, from Fig. 4, it has been determined that there is a good accordance between the damage that occurred during the test and the effective plastic strain. Bending cracks accumulated at the middle part of the beam, and extended towards to top of the beam for both experiments and strain contours. Furthermore, finite element code have captured shear cracks that occurred in the support area. It is concluded that the present finite element model can be safely used to evaluate dynamic responses and failure modes of the RC beams subjected to impact load. Fig. 5 and Fig. 6 show time histories of impact force and mid-span displacement, respectively, which were graphs directly obtained from the post-processing of LS-DYNA.

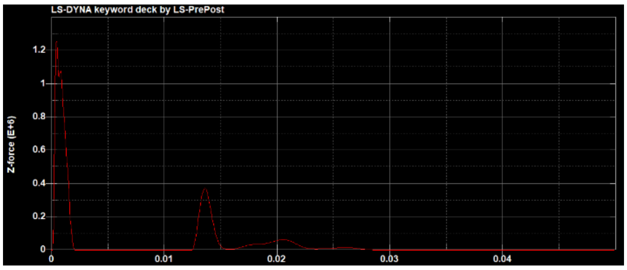

Fig. 5. The impact load history of the RC beam used for verification.

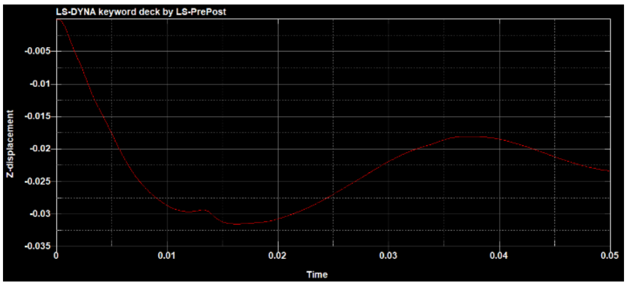

Fig. 6. The displacement history of the RC beam used for verification.

IV. THE PARAMETRIC ANALYSIS

The present study aims to investigate the impact performance of RC beams, of which the design phase does not contain any exclusive precautions against impact load, but it countered design requirements under seismic effect. At this point, two RC beams have been designed; one of them was seismically detailed according to the Turkish Earthquake Code 2018 (TEC-2018) [55], and the other was shear deficient. Fig. 7 depicts the geometric dimensions and reinforcement details of seismically detailed and non-seismically detailed RC beams used in the parametric analysis. The compressive strength of concrete and the yield strengths of longitudinal bars and stirrups in the parametric analysis were the same as those of the RC beam used for verification. While the balanced rebar ratio for the beams is 0.0230, the beams were designed the way the rebar ratio is 0.007. The static bending capacity of both seismic and non-seismic detailed RC beams is 144 kNm, and the maximum shear that occurs is 80 kN when the bending capacity is reached. Codes recommend that the contribution of concrete to the shear capacity of the section may be neglected when the earthquake effect is dominant for safety. This is because concrete lost its shear strength rapidly under a reversed cyclic load. Therefore, shear capacities were calculated by neglecting concrete contribution. The shear capacities of seismic detailed beams are 191.7 kN and 95.8 for the confinement zone and center zone, respectively; however, the shear capacity of non-seismic detailed beams is 84.5 kN. In conclusion, the seismic detailed beam collapses in bending mode, while shear failure is critical for a non-seismic detailed beam.

In the parametric analysis, on top of seismic detailing, the effects of parameters such as input impact energy transferred to the RC beam during impact loading and the location of impact load application point were also investigated on the impact behaviour of the RC beam. The mass of hammer was kept constant and it was 200 kg. Three different input impact energies were applied to the RC beams by considering three drop heigth of 2.4 m, 1.8 m and 1.0 m.

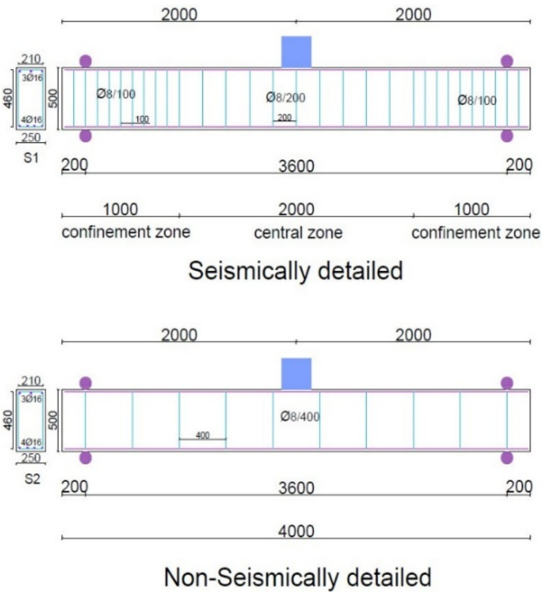

Fig. 7. The RC beams used in the numerical analysis.

TABLE II. PROPERTIES OF RC BEAMS IN PARAMETRIC ANALYSIS

RC beams	Rebar Detail	Mass	Drop Height	Impact Velocity	Impact Location
S1	SD	200 kg	2,4 m	6,86 m/s	MS
S2	NSD	200 kg	2,4 m	6,86 m/s	MS
S3	SD	200 kg	2,4 m	6,86 m/s	QS
S4	NSD	200 kg	2,4 m	6,86 m/s	QS
S5	SD	200 kg	1,8 m	5,94 m/s	MS
S6	NSD	200 kg	1,8 m	5,94 m/s	MS
S7	SD	200 kg	1,8 m	5,94 m/s	QS
S8	NSD	200 kg	1,8 m	5,94 m/s	QS
S9	SD	200 kg	1.0 m	4,43 m/s	MS
S10	NSD	200 kg	1.0 m	4,43 m/s	MS
S11	SD	200 kg	1.0 m	4,43 m/s	QS
S12	NSD	200 kg	1.0 m	4,43 m/s	QS

Therefore, input impact energies were 4709 Joule (high), 3532 Joule (moderate), and 1962 Joule (low), respectively. Impact velocities of 6.86 m/s2, 5.94 m/s2, and 4.43 m/s2 corresponds to these input impact energies, respectively. Furthermore, impact load was applied mid-span and quarter-span of the RC beams. The properties of the RC beams used in the parametric analysis were presented in Table II. In Table II, SD and NSD refer to seismically detailed and non-seismically detailed RC beams. MS and QS mean mid-span and quarter-span. The displacement and impact load time histories were calculated, and also effective plastic strain distribution was obtained during numerical analysis. The displacement time histories for high, moderate and low input impact energies (or corresponding impact velocities) have been presented in Fig. 8, Fig. 9, and Fig. 10, respectively. Furthermore, Fig. 11 shows time histories of impact loads for selected specimens representing three input impact energy levels. For the RC beams subjected to impact loading with the same energy levels, their impact time histories almost coincided.. Table III presents maximum impact loads, maximum displacement and residual displacement values. In Table III, peak impact forces are in units of kN, while displacements are in units of mm. Fig. 11 depicts effective plastic strain distributions of some selected beams.

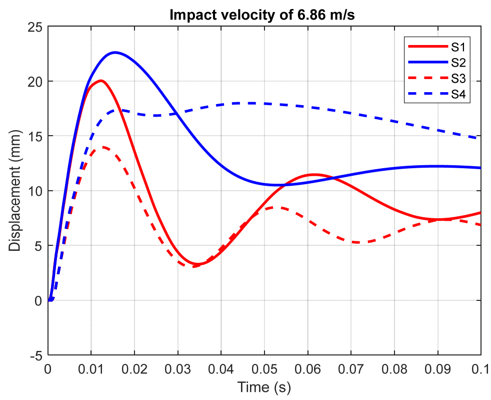

Fig. 8. Displacement responses of specimens subjected to impact velocities of 6.86 m/s.

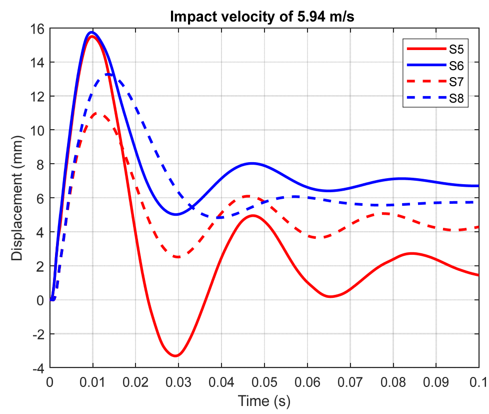

Fig. 9. Displacement responses of specimens subjected to impact velocities of 5.94 m/s.

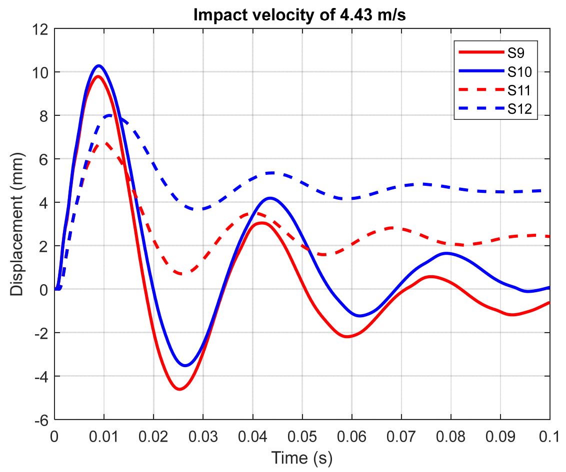

Fig. 10. Displacement responses of specimens subjected to impact velocities of 4.43 m/s.

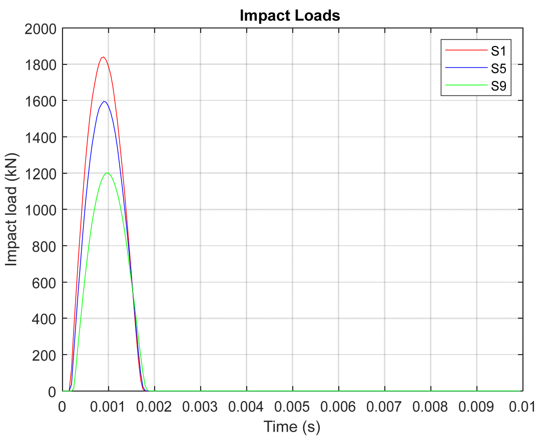

Fig. 11. Time histories of impact loads for specimen groups.

TABLE III. NUMERICAL ANAYSIS RESULTS

RC beams	Impact Force	Maximum Displacement	Residual Displacement
S1	1840.0	20.0	8.0
S2	1840.0	22.6	12.1
S3	1840.5	14.0	6.9
S4	1840.5	18.0	14.7
S5	1595.0	15.5	1.4
S6	1595.0	15.7	6.7
S7	1595.0	11.0	4.3
S8	1595.0	13.3	5.7
S9	1200.8	9.8	-0.6
S10	1199.6	10.3	0.1
S11	1199.6	6.8	2.4
S12	1199.6	8.0	4.5

When numerical analysis results are examined, it has been determined that the increase in impact energy of 80% and %140 have increased maximum impact loads acting on the RC beams by 33% and 53%, respectively. Under the applied input impact energy, RC beams have experienced up to the maximum displacement of 22.6 mm and residual displacement of 12 mm. The increase in impact energy of %140 caused an increase in maximum displacement approximately twice. It is also observed that the applied input impact energy with high levels caused remarkable damage by enhancing the width and number of cracks.

Numerical results reveal that applying load at mid-span instead of quarter span increased mid-span maximum displacement responses by 43% and 24% for seismic and non-seismic detailed RC beams, respectively. For the same input impact energy level, approximately the same impact load is transferred to beams, so there is a greater bending effect when the load is applied to the mid-span, and it causes more deflection.

When numerical analysis results are examined, it has been determined for mid-span loading that seismic detailing has been effective in decreasing maximum displacements when RC beams are subjected to high-level input impact energy. In this case, seismic detailing has decreased maximum displacements in the RC beams by 11.5% and improved impact resistance. However, for mid-span impact loading with low and moderate input impact energies, seismic detailing has a negligible effect on maximum displacement responses. For impact loading at a quarter-length of the beams, seismic detailing has decreased the maximum displacement responses at mid-span for all cases independent of applied input impact energy levels. For the loading at a quarter length of the beam, the decrease of maximum displacement due to the effect of seismic detailing was 22.2, 17.3 and 15 for high, moderate and low input impact energies. Furthermore, it was found that the primer effect of seismic detailing was on the residual displacements experienced by the RC beams. Seismic detailing increased the shear strength capacities of RC beams and provided more ductile behaviour, and correspondingly it limited damage that occurred, the width and number of the cracks. Therefore, seismic detailing has reduced the residual displacements up to 4.8 times.

When Fig. 12 is examined, both mid-span and quarter span impact loadings, seismic detailed beams have experienced less damaged. When Specimens 1 and 2 are compared, non-seismic detailed Specimen 2 has two large cracks at quarter spans of the beam, where the erosion algorithm has removed elements that have lost bearing property from the solution. However, Specimen 1 has only one large crack, and there is less damaged element reaching the top surfaces. Similarly, non-seismic detailed Specimen 4 has larger cracks than Specimen 3 which is seismically detailed. There is more fragmented concrete material in Specimen 4, also damage has reached up to the right support.

Consequently, as a result of numerical analysis, it has been found that seismic detailing, in other words, designing RC beams considering sufficient shear strength and ductile behaviour, enhanced impact performance of RC beams, reducing maximum and residual displacement values, limited damage and the widths and numbers of the cracks.

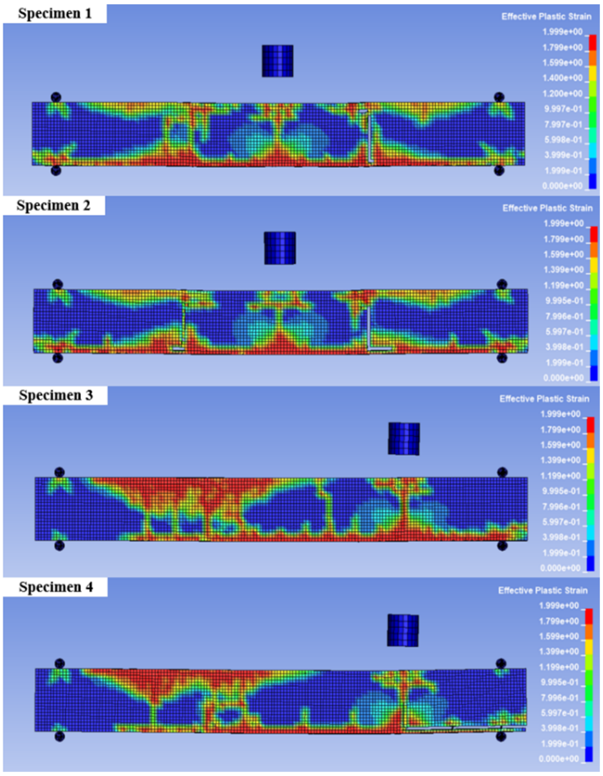

Fig. 12. Effective plastic strain distribution of selected specimens.

V. CONCLUSIONS

The present study focused on the impact behaviour of RC beams whose design has been performed considering dead, live, and earthquake loads but disregarding impulsive impact load. Naturally, the design phase of these beams did not include any special precautions against impact effects, however, the RC beams correspond to seismic requirements. In the first part of the study, a novel finite element code has been developed, which considers the strain rate effects of materials, and includes an erosion algorithm for consistency of the solution. The present code was verified with experimental data previously presented in the literature. Based on the perfect match between numerical and experimental results, it has been demonstrated that the presented finite element code can be safely used for the evaluation of impact responses and correspondingly occurred failure modes of the RC beams. The second part of the study included a parametric analysis where the effects of seismic detailing, input impact energy and application point of impact load on dynamic responses and failure modes of the RC beams. The findings can be summarized as follows:

The increase in impact energy of 80% and 140% have increased maximum impact loads acting on the RC beams by 33% and 53%, respectively. The increased impact load caused more shear damage and also increased crack widths and numbers. Therefore, the increase in impact energy of 140% caused a rise in maximum displacement approximately twice.

Results show that applying load at mid-span instead of quarter span increased mid-span maximum displacement responses by 43% and 24% for seismic and non-seismic detailed RC beams, respectively.

For mid-span loading, the reducing effect of seismic detailing on maximum displacements only emerged when RC beams were subjected to high-level input impact energy. In the case of impact loading performed with low and moderate input impact energies, seismic detailing has a negligible effect on maximum displacement responses. However, for impact loading at a quarter-length of the beams, seismic detailing has always decreased the maximum displacement responses independent of applied input impact energy levels.

The main effect of seismic detailing was on the residual displacements that occurred in RC beams. Seismic detailing has reduced the residual displacements up to 4.8 times.

Numerical results also unveiled that for both mid-span and quarter-span impact loadings, seismic detailed beams have been lower damaged than those which have non-seismic detail.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Tolga Yılmaz and Ahmet Muhammed Uludoğan established finite element code and verification; Irem Can, and Enes Erdem performed parametric analysis; Tolga Yılmaz and Mehmet Kamanlı prepared the subject and structure of the article; all authors had approved the final version.

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