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Table 1. Details of slab models

Number	Slab dim. (m)	Reinforcement ratio	Rebar
1	3*3*0.15	0.5	23Φ8@13cm
2	3*3*0.15	0.5	14Φ10@22cm
3	3*3*0.15	0.5	10Φ12@30cm
4	3*3*0.20	0.5	30Φ8@10cm
5	3*3*0.20	0.5	13Φ12@24cm
6	3*3*0.20	0.5	10Φ14@30cm
7	3*3*0.15	1.0	30Φ10@10cm
8	3*3*0.15	1.0	15Φ14@20cm
9	3*3*0.15	1.0	12Φ16@25cm
10	3*3*0.20	1.0	30Φ12@10cm
11	3*3*0.20	1.0	20Φ14@15cm
12	3*3*0.20	1.0	15Φ16@20cm
13	3*3*0.15	0.5	14Φ10@22cm
14	4*3*0.15	0.5	19Φ10@21cm
		0.5	14Φ10@22cm
15	5*3*0.15	0.5	24Φ10@21cm
		0.5	14Φ10@22cm
16	5*5*0.2	0.5	31Φ10@16cm
17	5*5*0.2	1.0	32Φ14@16cm
18	5*5*0.2	0.5	31Φ10@16cm
19	5*5*0.2	1.0	32Φ14@16cm

Boundary conditions in model number 13 was simply supported but in other models were fixed. In models 18 and 19, the explosion created asymmetrically but in other models was symmetrically. The properties of concrete and rebar provided in Tables 2 and 3, respectively.

Table 2. Material properties of concrete

Compressive strength (MPa)	25
Tensile strength (MPa)	3.0
Poisson's ratio	0.15
Density (kg/m^3)	2400
Elastic modulus (GPa)	18.97

Table 3. Material properties of steel

Yield stress (MPa)	400
Poisson's ratio	0.30
Density (kg/m^3)	7800
Modulus of elasticity (GPa)	210

3- Results and Discussion

The slabs were numerically investigated under near distance explosion and medium distance explosion. The slabs 1 and 4 were failed under near explosion. Concrete cover under the slabs was taken off completely and shear failure was observed. This means that the studied slabs with usual thickness and reinforcement ratio could not tolerate near explosion. In medium distance explosion (1.1 m/kg$^{1/3}$) less extent of destruction was observed and the slabs were repairable after explosion. Deflection and surface cracking ratio were showed only minor decrease by increase of reinforcement ratio but they showed major decrease with increase in slab thickness. Simply supported slab showed more deflection and more cracking as expected. Square slabs showed better behavior than rectangular ones and the behavior changed from two ways to one way by increasing slab length to width ratio. Surprisingly, the deflection and the cracking ratio were not considerably increased by increasing span length. Specially, surface cracking ratio was nearly the same in 3 m and 5 m span slabs (less than 20 %). Changing the explosive location from the center line of slabs toward the corners decreased the explosion effect as expected.

4- Conclusions

Numerical modeling can be an appropriate alternative to difficult experimental blast loading on concrete slabs. The results showed that the slabs were completely destructed under near explosion mainly because of punching shear. Under medium distance explosion, no complete destruction was observed. The deflection and the extent of cracking depended on the thickness and reinforcement ratio and somewhat on reinforcement spacing. The slab thickness and support condition had also a significant impact on the behavior of slabs. Surprisingly, the cracking level of RC slabs did not change significantly by increasing span length.

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Behavior of Reinforced Concrete Slabs against the Blast Wave

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ABSTRACT: Most existing structures are vulnerable to the blast wave loads and therefore their resistance to such loads should be evaluated. In this study, the behavior of RC slabs under blast loading was investigated numerically. Numerical analysis can reduce the number of required expensive experimental blast tests. The variable parameters for study include: thickness, reinforcement ratio and spacing, support conditions, dimensions of slabs and location and amount of explosives. Numerical modeling was performed by the use of LS-DYNA software. It is capable of modeling the explosion and also has a wide range of material models.

The results showed that the slabs were completely destructed under near explosion mainly because of punching shear. Under medium distance explosion, no complete destruction was observed. The deflection and the extent of cracking depended on the thickness and reinforcement ratio and somewhat on reinforcement spacing. The slab thickness and support condition had also a significant impact on the behavior of slabs. Interestingly, the cracking level of RC slabs did not change significantly by increasing span length.

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1- Introduction

Blast wave includes impact of compressed air that spreads out radially [1]. Explosives can cause severe damage to buildings and sometimes progressive and complete failure. Pressures that caused by the explosion are one of the most destructive structural loads on structures. So the behavior of structural elements under the effects of explosion is important. Lots of structures are vulnerable against the blast wave, therefore, their resistance under these loads must be examined.

The explosion caused by many factors, including unanticipated events beside the vast use of reinforced concrete slabs in buildings showed the importance of this investigation. Brode offered some relationships to find the pressure of explosion with the parameters of distance and amount of explosives in 1955 [2]. The explosive nature of these correlations are not considered, because the pressure of the explosion is determined by only one parameter. In 2007, Razaqpur studied about retrofitting of RC slabs with GFRP against blast wave [3]. In 2011, Tai studied about blast pressure wave propagation and dynamic response of RC structures against blast wave [4] and showed that the dimension of finite element model elements is effective and should be selected properly. In 2016, Yao investigated about the reinforcement ratio of retrofitted slabs and noted that the deflection of slabs reduced by increasing the reinforcement ratio [5].

In this paper the dynamic behavior of RC slab under blast load and the damage caused by the explosion is investigated. Variable parameters are: the thickness of slabs, reinforcement ratio, size and the center to center spacing of rebars, size and boundary conditions of slabs and the location and amount of explosives.

2- Numerical Simulation

In this study numerical modeling was performed by the use of LS-DYNA software. It is capable of modeling the explosion and also has a wide range of material models [6]. The concrete model used in this analysis is MAT WINFRITH CONCRETE. The geometry and the reinforcements of the reinforced concrete slabs are shown in Table 1. The bond between steel reinforcements and concrete modeled through the “constrained lagrange in solid” command. MAT PLASTIC KINEMATIC that accounts strain rate was used for modelling of rebars.

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