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EXPERIMENTAL INVESTIGATION OF TWO-WAY CONCRETE PANELS EXPOSED TO IMPACT LOAD

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ABSTRACT

Protecting existing and new structures from potential terrorist attacks and accidents is becoming an essential consideration in the design of most structures. Building façade is the first layer exposed to external loading, thus it acts as the first line of defence against external loads. Precast concrete panels are mostly used in external building's façade for modern construction, and therefore their resistance to other dynamic loads such as impact load needs further evaluation. This paper presents the results of an experimental research on two-way reinforced concrete panels as well as thin ferrocement concrete panels under impact loading. The impact test apparatus used is versatile enough to test large variety of specimens modeling façade units. The performance of the panels under impact load is evaluated in terms of: the failure mode; the maximum impact loads sustained by the panels; the number of impact loads up to failure; the maximum load transmitted to the supporting frame; and the strain induced in the panels. The effect of the different design parameters including the reinforcement amount, spacing and location across the panel thickness on the dynamic response of the panel to impact load are considered. Results clearly showed the significant effect of reinforcement on the overall resistance to impact loading. This research outcomes provide a better understanding of the performance of concrete panels under impact loading that can help enhancing structural design under such loads.

Keywords: Building façade, two-way panels, impact load testing, ferrocement panels, dynamic response.

1. INTRODUCTION

Civil and commercial buildings have became vulnerable to other types of loading such as impact and blast loading. Most military structures are located at remote and better secured areas, while civil structures are in more danger of being exposed to these loads, especially with the increase in potential attacks worldwide. Public awareness was highly raised for considering impact load design for civil and commercial structures, especially malls and shopping centers, after the World Trade Center incident in New York in 2001. Impact load can be generally defined as a relatively large dynamic load applied to a structure in a relatively short time period. According to Daudeville and Malecot (2011), impact loadings are defined as mostly extreme loading cases with a very low probability of occurrence during the life time of the structure. A building can be exposed to impact load in many forms; starting from a small strike, vehicle hitting the building reaching flying debris of explosions.

Research for impact load is not a new field of study, but it was exclusively for military applications and critical structures. According to Murthy et al., 2010, the effect of impact load on concrete structures have been investigated since the mid-1700s. It started with the design of high-performance missiles and protective barriers. When they first started designing concrete containment vessels for nuclear reactors, they wanted to ensure the absolute safety of the structure under any accidental load. D.A. Abrams was one of the first researchers to conduct compressive tests on concrete with different strain rates in 1917. The research indicated that concrete strength was rate dependent

(Haifeng and Jianguo 2009). Old researches and studies, such as that conducted by Hughes and Beeby (1982) and Miyamoto et al (1991), concluded that application of equivalent static loads or similar static-based design methods would not be adequate for designing for impact loads. In addition, according to Miyamoto et al. (1994), it is hard to produce a single design method based only on the dynamic response of concrete structures under different impact loads as they can occur in many types and no single method will be able to predict the response of the structure under all these probable types of loads.

This paper introduces a research conducted that provides a deep insight to the behaviour of two-way concrete panels, with different reinforcement configurations (including ferrocement) - under high intensity short duration load; namely impact loading. The test program included testing full scale reinforced concrete and ferrocement panels under impact load of a pendulum mass. The panels' performance under impact load is evaluated in terms of: the failure mode; the maximum impact loads sustained by the panels; the number of impact loads up to failure; and the maximum load transmitted to the supporting frame.

2. EXPERIMENTAL TESTING PROGRAM

2.1 Specimens Types

Table 1: Specimens Types

S#	Type	Reinforcement	Reinforcement Location	Testing Parameter
1	R/C	diameter 10 mm /7.5cm	Middle	Rft. spacing
2	R/C	diameter 10 mm /15cm	Middle	Control
3	R/C	diameter 10 mm /15cm	Back	Rft. location
4	R/C	diameter 8 mm /15cm	Middle	Rft.
5	F.C	2 Meshes	Front & Back	Rft.
6	F.C	1 Mesh	Middle	Rft.

A total of six concrete specimens will be tested; four reinforced concrete (R/C) and two ferrocement (F/C). All panels are of dimensions 1480 mm x 1480 mm and thickness of 75 mm and 25 mm for R/C and F.C, respectively. These dimensions were chosen for ease of construction and movement. The research aims in studying the effect of changing the amount and location of reinforcement, keeping the impact loading and the drop height constant. A summary of all specimen types is presented in Table 1 above. Specimen # 2 was chosen to be the control specimen for all R/C panels as its reinforcement (diameter 10 mm/ 15 cm) is the most repeated type of reinforcement in all specimens and its reinforcement location is common in concrete panels. The yield strength of the steel bars used in R/C panels is 360 MPa for diameter 10 mm (high tensile) and 250 MPa for diameter 8 mm (mild steel). The mesh used for the ferrocement panels is a galvanized wire square mesh, to minimize rust and corrosion, of 1 mm diameter with 15 mm mesh opening and of yield strength 400 MPa. R/C specimens are of a compressive strength (fcu) of 43 MPa, where F/C are of 50 MPa.

2.2 Test Apparatus

The test apparatus is a pendulum type impact loading one, designed to hold specimens of different structural elements. This apparatus was designed for a previous research (Cherif, 2009). A winch is used to raise the pendulum mass to the desired height and then release it to hit the specimen. A load cell is attached to the mass striking the reinforced concrete slab to measure the impact force. Different load cells can be placed on the frame supporting the specimen to measure the reaction forces. Figure 1 shows a picture of the impact apparatus.

The apparatus is designed to support pendulum mass between 80 and 500 kg (Cherif 2009). The impact mass, shown in Figure 2, is constant throughout the test and is equal to 357 kg, as well as the drop height of the mass that is equal to 150 mm, measured from a constant datum. All the details about the experimental testing program is elaborated more in Bayoumy (2014). The impact force caused by the applied impact weight is recorded by the action load cell placed at the center of the face of the impactor. Four load cells, placed approximately at the corners of the panels, with equal distance in between, were used to measure the reaction forces transmitted to the supports. For the surface of contact, a square steel plate of minimal thickness and dimensions chosen to have the same rectangularity of the panel is fastened facing the impact load cell to ensure smooth transfer of load to the panel and to avoid having the surface of contact variable. Data measurements start concurrently with impact mass release and record for the first five seconds. The test is terminated when the specimen reaches the mechanism of failure or maximum ten hits.

Figure 1: Impact apparatus (Bayoumy 2014)

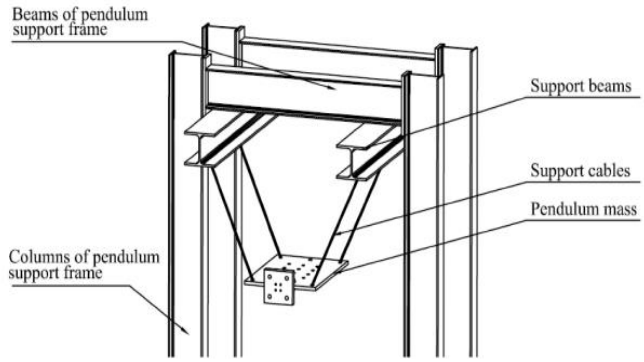


Figure 2: Pendulum mass (Cherif 2009)

3. EXPERIMENTAL TEST RESULTS AND DISCUSSIONS

Reinforced concrete and ferrocement panels of different reinforcement amount and location were tested under impact loading to simulate the behaviour when subjected to such type of loading. Ferrocement is a special form of reinforced concrete, but with different structural behaviour and strength. It was meaningful to test both materials under the same testing conditions to compare the behaviour and study the capability of each to sustain impact. Each panel was hit till it reaches failure or maximum ten hits, whichever happens first. This section presents and analyzes the output results obtained for both R/C and ferrocement specimens tested. For the purpose of simplicity in presenting the results, the hits will be simplified to three typical hits; initial, intermediate and final. A comparison between the results obtained for the two different materials will be presented in terms of studying the maximum action force carried by the panel, reaction forces transmitted to the supporting frame, strain measurements induced on both sides of the panel and the failure mode.

3.1 Action force and load-time history

Table 2: Peak action loads and t_d at 1st hit

S #	Peak Action Load (kN)	Time (sec)	T_d (sec)
1	25.17	0.791	75
2	17.63	1.028	97
3	28.70	1.586	62
4	1.21	1.472	127
5	4.12	1.407	89
6	21.17	1.989	38

Impact load at the first hit illustrates the full capacity of the specimen to carry the load, hence, only action loads of the first hits will be presented in the results and will be used to calculate the period of the load (t_d). For each hit, the impact mass rebounds to hit the specimen again with a much lower force due to the effect of damping. Table 2 presents the values of the maximum action loads of the first hit, the time of occurrence and the period of the load for each specimen of both the reinforced concrete and ferrocement panels tested. It can be noted from the table below that the lowest magnitude of action load and the highest period is recorded by S# 4 (diameter 8 mm / 15 cm - middle). It is expected that this specimen to be the weakest as it has the lowest reinforcement, so the specimen was not strong enough to resist higher load. The maximum value of the force was recorded by S# 3 (diameter 10 mm / 15 cm - bottom), where it reached a value of 28.7 kN. The action loads of the R/C specimens (S# 1, S# 2 & S# 3) are to some extent close, but much more than that of S# 4. The period of the action forces of the first hit for all R/C specimens ranged from 62 ms to 127ms. Generally, it was noted that there is a relationship between the action load and the time period it takes; as the magnitude of the action load increases, the time it takes decrease. For the ferrocement specimens, S# 6 (one mesh) surprisingly recorded much higher value of action load than that for S# 5 (two meshes). Other results than the action forces need to be analyzed before making a solid conclusion.

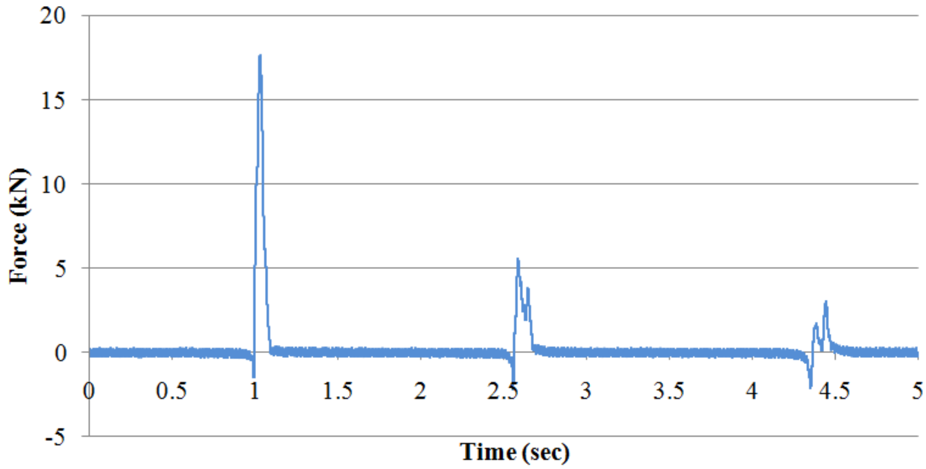


Figure 3: Load - time history (S# 2-1st hit)

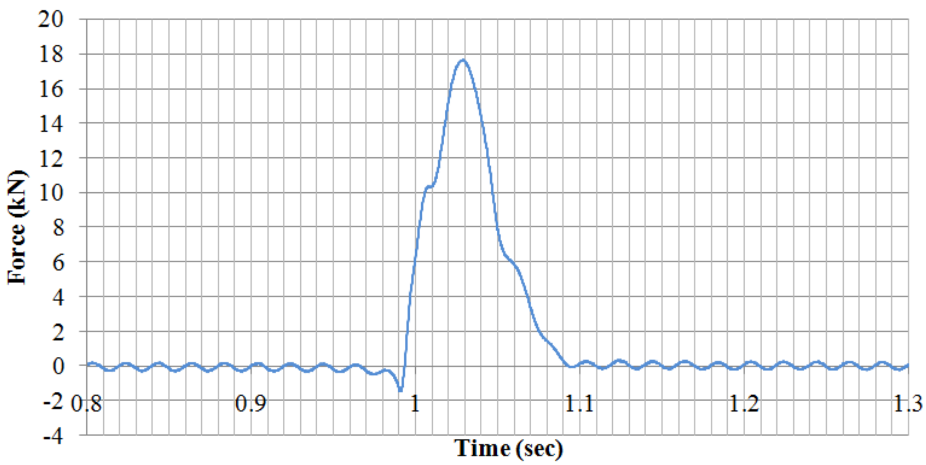


Figure 4: Period of load- t_d (S# 2-1st hit)

The load-time history for the control specimen S# 2 is illustrated in Figure 3. It presents a typical load-time history and a good representative for other R/C specimens under impact load. Ferrocement panels did not sustain more than one hit and they failed, so the load cell recorded one peak force only at the time of the impact. S# 2 recorded a maximum action load of magnitude 17.63 kN at time 1.02 sec. A typical shape for the first wave of the impact load for S#2 is shown in Figure 4, where it also shows a clear illustration of the period load t_d (97 ms).

3.2 Support reaction

This section will be presenting an analysis of the relationship between the action force and each reaction force recorded at the four supports. Reaction forces anticipate the behaviour of columns or the supporting system carrying the structure. The design target for building façade is to design panels that can sustain the impact load and transmit it to the supporting system with minimal failure and risk on human lives.

Table 3: Reactions & time delay

S #	Hits	Force (kN)	TR (kN)	T Delay (ms)	TL (kN)	T Delay (ms)	BR (kN)	T Delay (ms)	BL (kN)	T Delay (ms)
1	Initial	25.17	11.8	2	18.9	36.4	9.67	6.2	10.0	7.4
	Intermediate	24.11	13.8	-1	14.9	39	9.81	5.4	10.2	5
	Final	21.29	10.3	0	16.0	33.2	9.23	0	9.53	0
2	Initial	17.63	5.82	-5.8	9.77	36.8	8.1	-2.2	6.32	-0.8
	Intermediate	12.50	6.36	-3	7.04	28.2	7.49	2.2	7.15	2.4
	Final	8.46	6.49	-9.6	6.85	37.8	7.28	-2	7.33	-2.2
3	Initial	28.70	10.2	-2	8.29	-1.2	11.6	0	10.8	0.8
	Intermediate	20.37	10.6	5.2	9.73	4.8	10.8	8.6	10.8	9.2
	Final	18.88	10.3	6.2	9.95	5.6	10.8	10.2	10.3	10.8
4	Initial	1.21	4.68	4.6	4.12	2.4	4.41	-2.6	4.90	-1.2
	Intermediate	1.21	5.59	-10.6	4.38	5.6	4.97	-2	5.94	-1.2
	Final	1.29	5.86	-5.6	4.27	-3.8	4.62	2.6	5.67	0.4
5	---------	4.12	1.74	-31	2.44	-31.8	1.34	-3.8	1.78	-3.6
6	---------	21.17	1.74	16.5	3.0	30.5	5.2	20	3.2	12

*TR: Top-Right Support, TL: Top-Left Support, BR: Bottom-Right Support, BL: Bottom-Left Support

The values of action forces, reaction forces and the time delay between their occurrence for both R/C and ferrocement specimens at the initial, intermediate and final hits are presented in Table 3. For the R/C panels, all specimens failed after ten hits with the exception of S# 4, the one with the lowest amount of reinforcement; it sustained only three hits. None of the ferrocement panels sustained more than a single hit. It can be noted from the table that the values of the supports reactions are not equal, cause of load cells sensitivity or specimen setting up, but they are generally close with some exceptions. In an ideal situation, when the panel is rigid, load is transferred to the supports at the exact time of the impact without any time delay in the reaction forces. This was the case for some panels, while others recorded a time delay that ranged mostly from 0.8 ms to 10.8 ms reaching 39 ms only at one of the supports (top-left), which indicates an noticeable problem with the setting of that specific support, and 20 ms for the single mesh F.C panel. There happen to be some negative values of time delays of very small insignificant values. Most of the values of all time delays are small compared to the load duration. Recall, that the load duration for the R/C tests ranged from 62 to 127 ms. Reaction forces delay can be explained due to the following; load cells accuracy, as they may be not that sensitive to read the load at the exact time of impact; the specimen may be not perfectly in touch with the load cell or the nature of the specimen itself; slab may be very flexible so that it takes time for the load to reach the support.

The relationship between the maximum action force and all the maximum values of reaction forces recorded for each support for the control specimen S# 2 is shown in Figure 5. The illustration is presenting the values at the first hit, where the load cell recorded the highest load values. By analyzing the results of this specimen, it was noted that at the first hit, there was much difference between the action force and each reaction force, but then, this difference started to decrease at later hits. At the first hit, the specimen shows large action force; much larger than the reactions. The action force in all hits is always higher than each support reaction force and the values of support reactions usually are close to each other except for two load cells at the first hit.

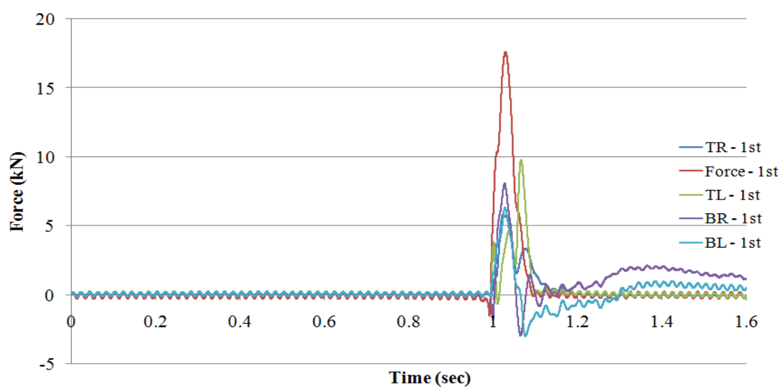


Figure 5: Action - reactions (S# 2 - 1st hit)

3.3 Total reaction

Table 4: Peak loads & total reactions

	Initial hit			Intermediate hit			Final hit		
S#	Peak Load (kN)	Peak Total Reaction (kN)	Ratio	Peak Load (kN)	Peak Total Reaction (kN)	Ratio	Peak Load (kN)	Peak Total Reaction (kN)	Ratio
1	25.17	42.08	1.67	24.11	45.16	1.87	21.29	38.76	1.82
2	17.63	30.03	1.7	12.50	28.05	2.24	8.46	27.97	3.3
3	28.70	40.86	1.42	20.37	42.02	2.06	18.88	41.54	2.2
4	1.21	18.13	14.92	1.21	20.90	17.2	1.29	20.43	15.77

	Initial hit		
	Peak Load (kN)	Peak Total Reaction (kN)	Ratio
5	4.12	7.318	1.78
6	21.17	13.142	0.62

*Ratio: Total Reaction / Action

The amount of force transmitted to the supports is one of the most important criteria in evaluating the overall slab behaviour under loading. Reaction loads of all the supports were combined together to present the slab reaction force-time history. Table 4 presents a summary of the values of the peak impact load reached and the peak total reactions recorded by the four load cells together with the ratio (Total Reaction / Action), that shows the percentage increase of reactions.

As the slab is exposed to several impact loads, its stiffness decreases, so the magnitude of the action force resisted by the slab decreases and the reaction forces transferred to the supports increase causing an increase in the ratio between the total reaction and the action force. The results for all specimens showed the same trend; as the number of hits increase, the ratio of the total reaction forces to the action force increases. This phenomena repetition validates the explanation of the earlier behaviour. And this indicates that S# 1 is a stiff specimen, as it shows the lowest ratio, while S# 4 is a very weak one. Higher forces are transmitted to the supports as the specimen gets weaker. S# 6 is an exception, as the total reaction force was found to be less than the action force. This can be explained by the possibility of having a loose contact between the steel plates placed in front of the load cells with the panel, so the force was dissipated as a result. These results need to be supported by a detailed numerical non-linear analysis of panels under short duration load, which is outside the scope of this research, that takes into account cracking and the dynamic effect.

3.4 Average reaction

Table 5 presents the values of the peak action load and the ratio for the typical three hits. The relationship between the action force and the average reaction force of all four supports is of significant importance as it shows the correspondence of the forces magnitude to each other along the increase in the number of load strikes. In an ideal static load situation of a rigid slab, the total reaction forces should be equal to the action force, which makes each reaction force to be 0.25 of the magnitude of the applied action force. Since it is a dynamic impact test, vibrations and other dynamic characteristics are considered. As the panel's stiffness decreases with the number of impact hits, the action force decreases and the corresponding reaction forces increase. The values show that the ratio is above 0.25 and it increases with the increase of the number of hits for S# 1,2 & 3, ranging from 0.36 to 0.83. As expected, S# 4 showed the highest average reaction/action ratio of value 4.3, as it is the weakest specimen. As the specimen gets weaker, the reaction force is getting higher than the action force resulting in an increase in the ratio between the average reaction and the action.

For the ferrocement slabs, S# 5 (2 meshes) had an average reaction force of value equals to 0.4 of the action force. For S# 6 (1 mesh), the average reaction is much less than the expected to be; it recorded a value of 0.16 of the action force. This specimen had a total reaction force less than the action force and recorded the highest average time delay of all specimens. The force was dissipated till it reached the supports due to a loose contact of steel plates with the load cell or the specimen itself was misplaced and not touching the load cells.

Table 5: Peak loads & average reactions

	Initial hit			Intermediate hit			Final hit		
S#	Peak Load (kN)	Average Reaction (kN)	Ratio	Peak Load (kN)	Average Reaction (kN)	Ratio	Peak Load (kN)	Average Reaction (kN)	Ratio
1	25.17	10.52	0.42	24.11	11.29	0.47	21.29	9.69	0.46
2	17.63	7.5	0.43	12.50	7.01	0.56	8.46	6.99	0.83
3	28.7	10.21	0.36	20.37	10.50	0.52	18.88	10.38	0.55
4	1.21	4.53	3.73	1.21	5.22	4.3	1.29	5.10	3.94

	Initial hit		
	Peak Load (kN)	Average Reaction (kN)	Ratio
5	4.12	1.83	0.44
6	21.17	3.29	0.16

*Ratio: Average Reaction / Action

3.5 Strain measurements

The results of strain induced at the back and front sides of each panel were recorded to determine a general range of the magnitude and the rate of strain on both the tension and compression sides of the different slabs tested under impact loading. A total of three strain gauges were used for each specimen; two at the middle and the quarter of the back side and one at the middle of the front side. Data of strains recorded for specimen #3 at the first hit were chosen to be the representative for all R/C slabs, as the strain gauges of the control specimen (S# 2) were malfunctioned and gave inadequate results. Table 6 presents the maximum values recorded by the three strain gauges for all specimens.

Table 6: Values of strains

	St. 1 (**μ**)			St. 2 (**μ**)			St. 3 (**μ**)		
S#	Initial	Intermediate	Final	Initial	Intermediate	Final	Initial	Intermediate	Final
1	-912.6	-857.88	-785.86	27.4	33.5	27.2	1248.5	1457.7	547.3
2	-1045	-1625.7	-1538.3	5186.3	5186.3	5186.3	5186.3	5186.3	5186.3
3	-1155	-1300.1	-1301.1	1301.5	1812.6	1966.4	1592.3	1851.9	1687.9
4	-714.1	-934.96	-1167.5	5186.3	5186.3	5186.3	170.3	85.2	-1060

	St. 1 (**μ**)	St. 2 (**μ**)	St. 3 (**μ**)
5	-1395.1	5186.3	553.2
6	-870.4	947.8	947.8

*St.1 : front - middle strain gauge St.2 : back - middle strain gauge St.3 : back - quarter strain gauge

3.5.1 Front - Middle Strain Gauge (St.1)

Negative strains are induced at the front side of the panel facing the impact as the force is of a compressive type. The values of the strains for St.1 for all R/C specimens were all negative and ranged from 714.16 to 1625.7 μ. As the panel is exposed to more impact strikes, the measurements of the strains induced is expected to increase throughout the test. Specimen #1 was an exception, as the strain readings were decreasing with the hits. Also, for S# 2, the strain slightly decreased between the intermediate and the final strike, however, the difference in both specimens was not high. Other than that, strain recorded for all the panels was increasing with the hits. A good illustration for the change of strain with time is presented in Figure 6, where it presents the values of St.1 for S# 3 at the first hit. The maximum value measured by the strain gauge happened to be at exact the same time of the impact load with a zero time delay. The load cell rebounded twice for S# 3, so this was shown in the corresponding peak values measured by the strain gauge in the figure below. The values of the negative strains at the front side of both ferrocement panels were within the same range of that of the reinforced concrete ones. When comparing between both F.C panels, it is was found that more strain was induced at the specimen with the double mesh reinforcement than the single mesh slab. As specimen #6 (single-mesh reinforcement) was damaged severely more than the other one, the strain was released at the surface where cracks happened, thus decreasing the values of strains.

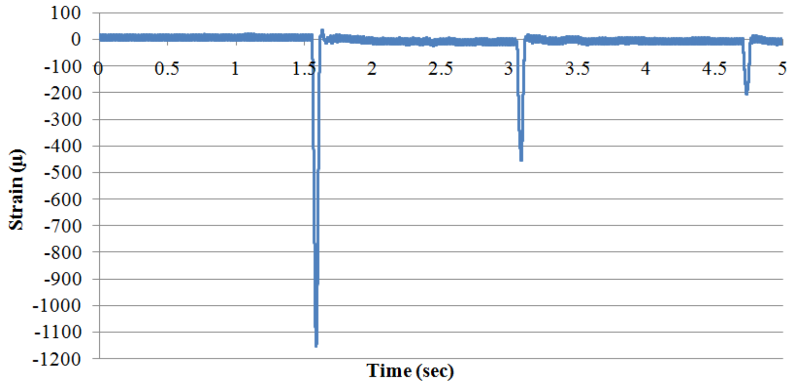


Figure 6: Strain - time St.1 (S# 3 - 1st hit)

3.5.2 Back - Middle Strain Gauge (St.2)

The difference between the values of the strains at the compression and the tension sides is not significant. Some of the back strain gauges were damaged during the test due to a disruption in the internal sensor caused by the impact shock or possible manufacture faults. The readings for back-side strain gauges recorded positive strain as they are under a tensile force. Values recorded for S# 1 were significantly low compared to other readings, which indicates an instrumental error while testing. The strain gauges of S# 2 and S# 4 were damaged after the first strike, reading both a constant reading of 5186.3 μ. These results for both specimens were discarded. Figure 7 shows the strain of St.2 for S# 3 at the first hit, where it best represents strain at the back side as strain is increasing with the hits. Both strain gauges for the ferrocement panels failed after reaching the limit of the gauge, but the gauge placed for S# 6 recorded much less value than that of S# 5.

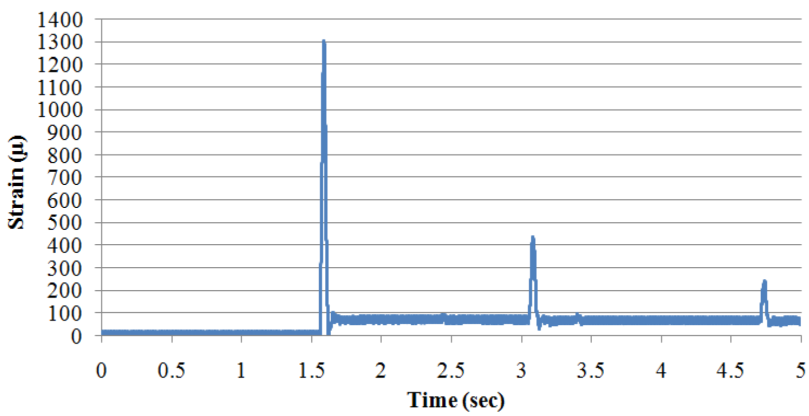


Figure 7: Strain - time St.2 (S# 3 - 1st hit)

3.5.3 Back - Quarter Strain Gauge (St.3)

Values recorded for St.3 were as anticipated, except for S# 2 and S# 4 as they failed by reaching the limit of the gauge after the third hit. S# 4 recorded the lowest value at the first hits compared to other R/C specimens, but it then recorded an inconvenient high negative value, which can be due to sensor malfunctioning or poor gluing of the gauge. Figure 8 shows the strain values of St.3 for S# 3 after the initial hit. By comparing the readings of strain gauges at the two different locations along the panel; middle and quarter, it was noted that the values were within the same range for all specimens, except S# 1, where the readings at the middle were much lower than that at the back. In general, it is expected that the values of strain at the middle of the span to be more than that at the quarter. For the ferrocement panels, St.3 recorded the highest noise vibrations of all specimens. The gauges recorded maximum value of 553.2 and 947.8 μ for the double mesh and single mesh slabs (S# 5 and S# 6), respectively. Unlike St. 2, St. 3 recorded less value at double mesh specimen than that at the single mesh panel.

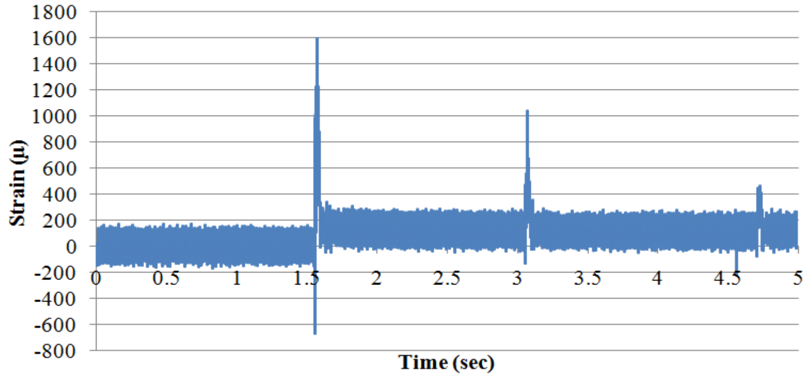


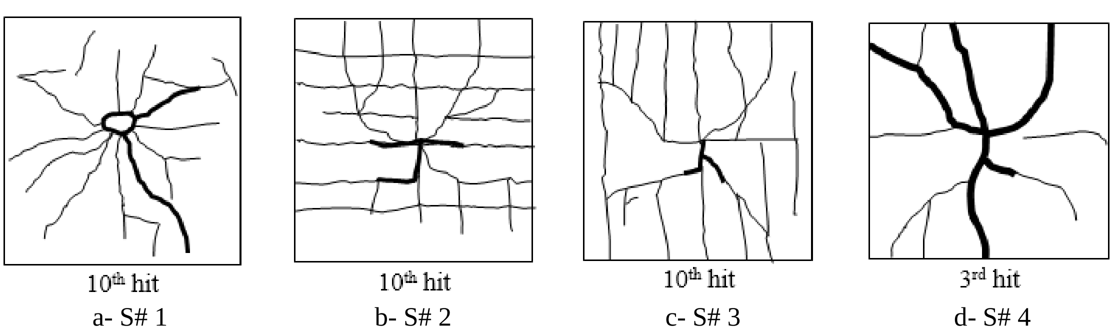
Figure 8: Strain - time St.3 (S# 3 - 1st hit)

3.6 Failure Mode

The observations of the failure mode and the cracking that happened at each specimen type is presented in this section. Figures 9a-c shows a sketch of the final cracking pattern for each of the four reinforced concrete specimens. For S # 1, the cracks on the back surface showed a fanned pattern coming out of the centre of the impact point and propagating. At first it started as minimal hair cracks and then these hair cracks were developed and got widen around the center of the impact region by the end of the test. This specimen was stiff enough to sustain the load and it did not fail after impacting ten hits. The cracking pattern of S# 2 is of a different type. At first, horizontal (transverse) cracks started to appear and by the fifth hit, few longitudinal cracks started from the center of the impact region and propagated along the longitudinal direction of the slab. By the end of the test, cracks at the center became wider and deeper and slab deflection remarkably increased.

For S# 3, long and wide cracks appeared right after the first hit. Along the test, few more cracks were developed and there was an increase in the crack width of cracks at the middle of the slab. Cracking increased rapidly during the last five hits. As shown in Figure 9-c**,** a rigid region appears near the middle and the left side of the back surface. Cracks were developed above and below this area. This may be explained as during casting, the reinforcement at this specific region was shifted more towards the back of the slab thus, increasing the effective depth and the tensile reinforcement at this area. Slab damage observation of S# 4 is very distinctive from all other R/C specimens. This specimen is a weak one as concluded from studying the reaction forces. It completely failed after the first three hits only and then the test was terminated. Starting from the first hit, the slab experienced cracks of very high thicknesses and depths. The overall number of cracks is minimal, but most of the cracks were wide and deep. The widest crack was found to be near the center, indicating that this is the slab's weakest point.

Ferrocement specimens showed the weakest behaviour of all specimens tested. Both specimen did not withstand more than one strike and they completely failed. The panels were fractured into totally separate parts after only one impact hit. For the one with double reinforcing mesh, the slab was split horizontally from the middle into two almost equal-sized parts. There were some cracks at the back side originated from the centre and propagating along the slab. The other specimen with only one reinforcing mesh was broken into several parts. It showed very weak resistance to the load and it is obvious from slab damage observation.



a- S# 1 b- S# 2 c- S# 3 d- S# 4

Figure 9: Cracks sketch- back side of R/C specimens

4. CONCLUSIONS

This paper introduces an experimental research conducted on reinforced concrete and ferrocement two-way panels exposed to impact loading. Reinforcement amount, spacing and location were changed, keeping all other testing parameters constant, such as impact mass and drop height. The results clearly show the significant influence of reinforcement on the overall structure resistance to impact loading. As the amount of reinforcement increases, the action load increases indicating a higher section capacity to resist more load and delay cracking and yielding of reinforcement. Reinforcement location helps in improving the panels behaviour. Panels of facades in risk of being subjected to impact loading are best designed with reinforcement placed at both sides as to account for all the possible directions of load as well as the rebound after impact. Façade panels subjected to impact should be designed in a way to sustain damage with enough ductility to break without shattering and thus avoids possible risks of causalities and injuries resulted from flying debris, as cracking in a nature manner acts as a mean of load absorption. Strain induced at both compressive and tensile sides increases with the increase in the number of hits.

As for the supporting system , it was found that the total reaction force is always higher than the action load. The fact that it is a dynamic and not static problem, inertia forces are also applied, so this ratio keeps increasing with the increase in the number of strikes, as the slab is getting weaker and its capacity to sustain the load is decreasing.

Results emphasize that ferrocement panels can be used as sacrificial layers for building subjected to low impact loads. Both specimens with single and double reinforcing mesh showed very weak resistance to impact load relative to the reinforced concrete panels.

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