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Kobry El-Kobbah,
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The Effect of Using Multi Layers of Expanded Steel Mesh on Penetration Resistance of Ferrocement slabs

By

Essam Mohamed El.Tehewy* Mohammad Ali El-Sayed**

Abstract:

This paper presents results of an experimental investigation to enhance the protective layer material .A special concrete mixture with high reliability to resist the penetration of missiles was designed. Ferrocement technique is used to enhance the concrete panels' penetration resistance. An experimental investigation was performed for one specimen of plain concrete and three reinforced concrete panels in which steel blunt-nose projectile with a diameter of 23 mm and a mass of 175 g is fired with striking velocity about 980 m/s.

The main findings show that the penetration depth, the cracks and damage in the front ' rear face exhibit an overall reduction, The fragments weight in the front face of target specimens increases with increasing the number of expanded steel meshes.

Keywords:

Reinforced concrete; Ferrocement; Penetration; Missile effect.

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*Egyptian Armed Forces

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1. Introduction:

Concrete has been used extensively as a construction material for buildings, bridges, tunnels and nuclear reactor containments. In defense applications, concrete is used as a structural material for runways, command bunkers and hardened shelters. Concrete which encounter in all aspects of our everyday life is a mixture of cement grout, water, air and quartz aggregates. Variation of any of these components will lead to a change in the mechanical properties [2], it has been claimed, that concrete not an environmentally friendly material due to its destructive resource-consumption nature and severe environmental impact after its use. Nevertheless, it will remain one of the major construction materials being utilized worldwide. [3]

The end of the 19th century shows the discovery of a range of military explosives of great importance known as TNT. This became the standard explosive of the First World War. TNT can be manufactured with relative safety and economy, and because of its universal use it has become customary to class all types of explosive (conventional or nuclear) in terms of TNT as a standard.

The next major shift in the balance of attack and defense developed between 1918 &1930with the introduction of aerial warfare, widely used in World War II 1939:1945.

The “1991, 2003” Gulf War (I, II), and second Lebanon War “2006” emphasized the structural damage that can result from modern missiles which have a great accuracy and small volume (compound B) [1].

The penetration of high-velocity objects into soils, stone, metals, and concrete has historically been a subject of interest for military engineers.

In the last decades, rapid improvement has been occurring in the explosives and the ammunition; its way of transport has a heavy impact on the design and construction of the fortified structures. The improvement not only concerns the capacity but also the ability to penetrate the aimed targets. A level of protection against its response is often specified in new civil works and structures.

The missiles impact, bombs, explosive shell, aircraft crashes, mountainous rock falls, and accidental explosions became the major attacking events against the fortified structures and military targets, wherever it is, above or underground. To obtain protection against mechanical effects of weapons, it is important to build shelters entirely underground or at least soil-covered. Establishing buried structure with protective layers above it can reduce, or better vanish, the effect of the developed weapons on the main structure. Consequently, static and dynamic loads affect only a limited part of the main structure.

Much of the experimental work has been aimed at reinforced concrete structures, because, from the beginning of the present century, many of the protective structures that are built to withstand the effect of missiles, conventional bombs, or shells have been constructed with this material. It is not surprising that the research expenditure on studying the response of different types of concrete (plain concrete and ferrocement) to dynamic impact generated from the missiles impact get the attention of many researchers.

Ferrocement is a type of thin-wall reinforced concrete commonly constructed of cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh. The typically range of diameter from about 0.4 mm up to about 2.5 mm, which usually spaced between wire centers ranges from about 10 mm up to about 30 mm. The mesh may be constructed from metallic or other suitable materials. The fineness of the mortar matrix and its composition should be compatible with the used mesh [4, 5, 6].

2. ***Experimental program:***

Comparative penetration tests were conducted on varies square plain concrete and ferrocement specimens as shown in fig. (1). The projectile used was API, blunt-nose steel penetrator 23 mm diameter and 64 mm length as shown in Fig.(2) , the material properties of the penetrator shown in Table(1). The impact velocity was measured and reported for every shot with electro-optical velocity measurement device, which had connected with computer as shown in Fig.(3) and turn to be 980 m/sec.

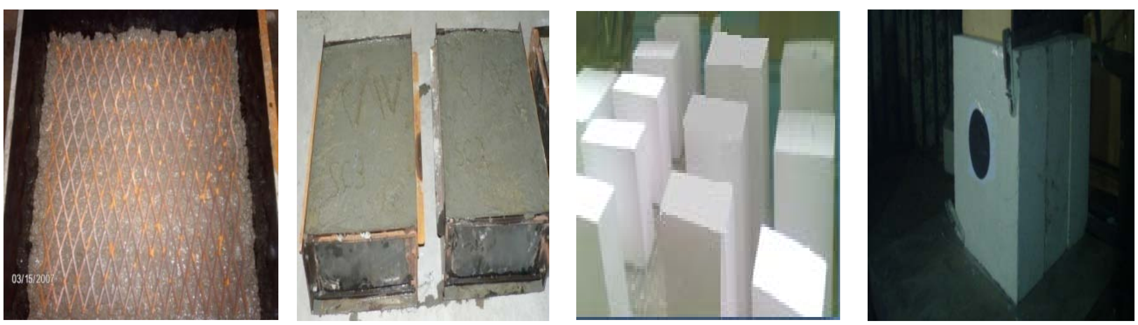


Figure (1): *square plain concrete and ferrocement specimens*

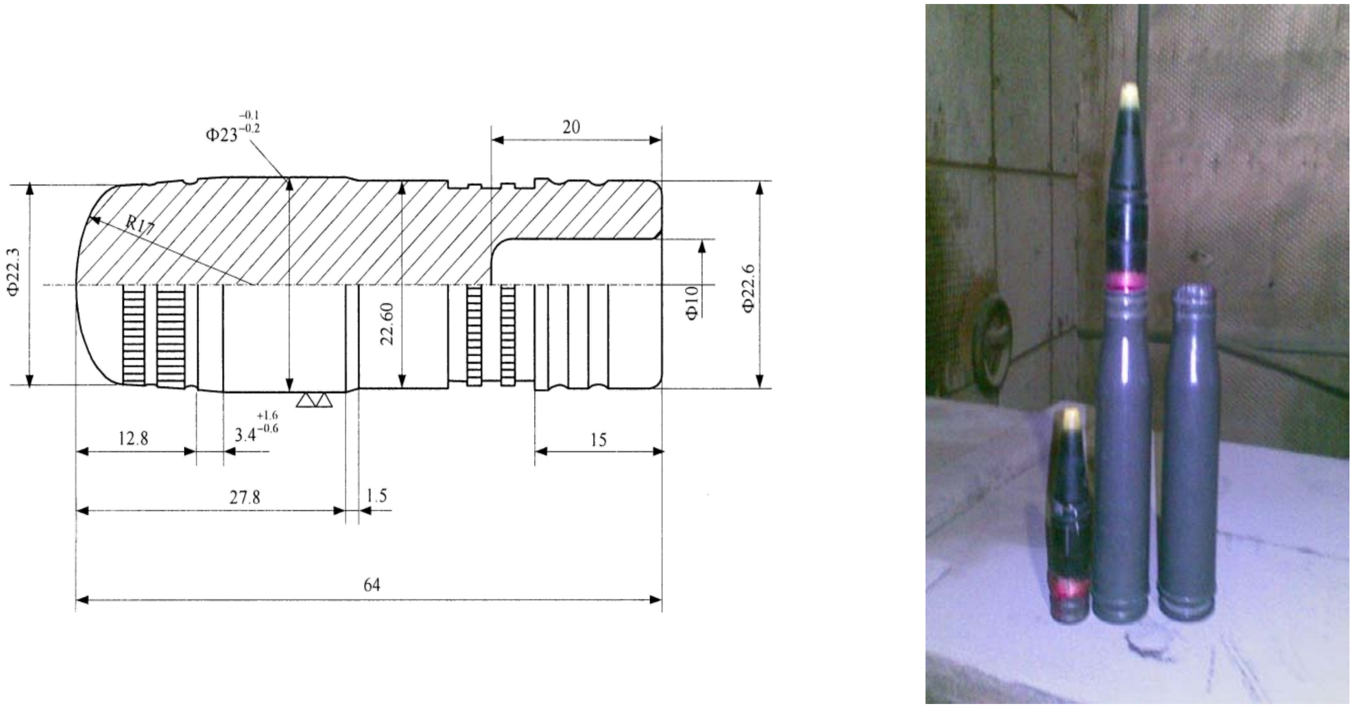


Figure (2): *Dimensions of 23 mm API missile*

Figure (3): *Velocity measurement device*

Table (1) *Mechanical properties of the projectile materials*

Brinell hardness number,	**Yield strength [MPa]**	**Ultimate strength [MPa]**	**Strain to fracture [%]**
475	1726	1900	**7**

2.1. Materials used:

Concrete panels with Portland cement, sand and coarse aggregate of 19 mm maximum aggregate size were casted. The mix proportions by weight for 1 m³ of concrete are given in table (2). The ratios of water, sand and coarse aggregate, to cement by weight were 0.5, 2, and 4, respectively. 500 x 500 mm Expanded steel meshes were employed to reinforce the concrete panels. Data sheet of steel meshes used are given in table (3)

Table (2): *Mix proportions of concrete*

Material	Portland cement	Fine aggr. (Sand)	Coarse aggr. (Dolomite)	Water
Kg/m³	350	700	1400	175

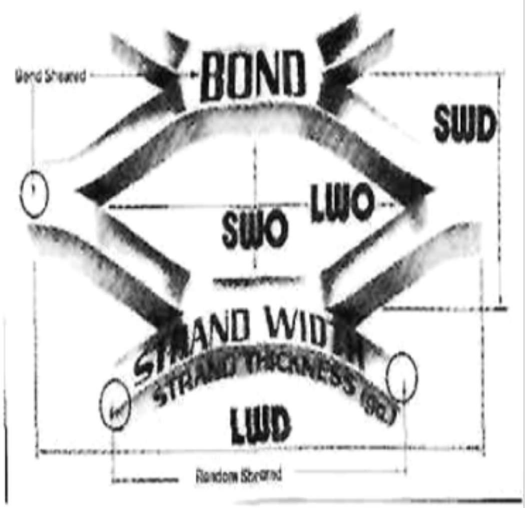
Table (3): *Data sheet of expanded steel mesh used*

MULTI M GROUP

MULTI M GROUP

METAL-X- SECTOR

SWD SHORT WAY OF DIAMOND OR DESIGN DIMENSION
LWD : LONG WAY OF DIAMOND OR DESIGN DIMENSION
SWO : SHORT WAY OF OPENING DIMENSION, USED TO INDICATE CLEAR OPENIN IN THE SHORT DIRECTION.
LWO : LONG WAY OF OPENING DIMENSION, USED TO INDICATE CLEAR OPENIN IN THE LONG DIRECTION
STRAND THICKNESS: EQUAL TO THE THICKNESS OF METAL USED IN MM
STRAND WIDTH: AMOUNT OF METAL FED UNDER THE DIE TO PRODUCE ONE STAND
BOND SHEARD: WHERE TWO STRANDS INTERSECT ELIMINATES PRONGS OR JAGGED EDGES
RANDOM SHEARED: THIS TYPE OF SHEARING LEAVES PRONGS OR JAGGED EDGES.



DIM. EXPENDED METAL (MM)

SHEET SIZE	MATRIAL DESCRIPTION	SHEET WEIGHT KGS	SHEETS QTY/TON	STYLE	THICKN	LWO	LWD	SWO	SWD	SW
100X800CMS		14..00 KG		1038	1 MM	30MM	38MM	12MM	14.5MM	1.7MM

2.2 Material characterization:

Characterizations of the concrete material were investigated. This include the mass density ρ_c and compressive strength f_{cu} of 150 x 150 x 150 mm cubes in uniaxial stress, The tensile strength f_t via split testing of cylinders Φ100 x 200 mm, The results are given in Table (4).

***Table (4)**: The mechanical properties of concrete*

Properties	Density (kg/cm²)	Compressive strength (MPa)	Tensile strength (MPa)
value	2.36	35	3.1

2.2. Specimens:

Two classes of target were considered unreinforced (plain) and reinforced concrete (ferrocement) the specimen dimensions were 550 x 550 mm with thickness of 400 mm. The total numbers of specimens were four. The details of them are listed in Table (5). Fig. (4) show the dimensions and details of the specimen and Preparation of slabs.

***Table (5)**: Specimens detail*

NO.	Code	Specimens description	Thick. (cm)	No. of mesh	
				front	rear
1	SC 1	(2x20cm) plain concrete	40	-	-
2	SE 1-1	(2x20cm) ferrocement panel with 2 meshes (style 1038)	40	1	1
3	SE 1-2	(2x20cm) ferrocement panel with 4 meshes (style 1038)	40	2	2
4	SE 1-3	(2x20cm) ferrocement panel with 3 meshes (style 1038)	40	3	3

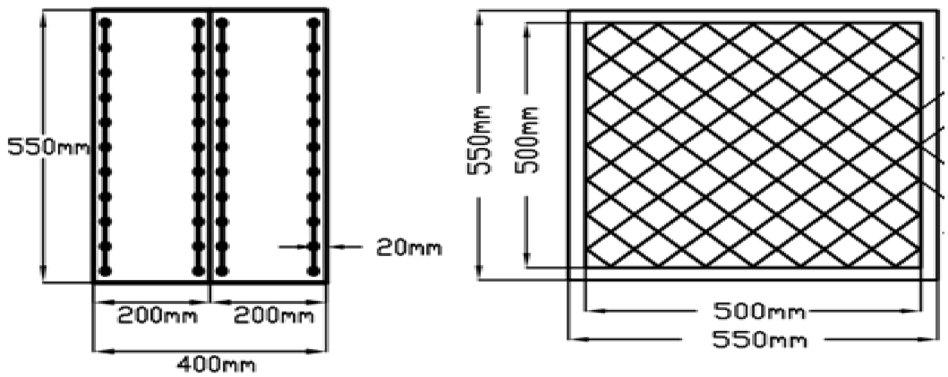


Figure (4): *Dimensions and details of the specimen*

3. Test results:

The response of the experimental program specimens was examined and recorded. The concrete parameters were :

(a) The penetration depth.
(b) The front face crack pattern.
(c) The rear face crack pattern.
(d) The front face damaged areas.
(e) The rear face damaged areas.
(f) The front face fragments weight.

Table (6) and Figure (5) show The results of the penetration test

Table (6): *Results of penetration Test*

NO	**Name**	**Velocity (m/sec)**	**Pentration depth (X)**		**Crack diameter (front face)**		**Crack diameter (rear face)**		**Diam. of damage (front face)**		**Diam.of damage (rear face)**		**Frag wt (*kg*)**
			cm	**%**	**cm**	**%**	**cm**	**%**	**cm**	**%**	**cm**	**%**	
1	SC 1	978	40	100	Full	100	Full	100	Full	100	Full	100	Full
2	SE 1-1	987	28.5	71.2	70	100	56	80	45	80.4	19	33.9	1.45
3	SE 1-2	996	26.5	66.2	65	92.8	10.5	15	32	57.1	5	8.9	2.43
4	SE 1-3	988	23.5	58.7	54	77.1	0	0	25	44.6	0	0	2.74

Damage in Front Face of plain concrete slab   Damage in rear Face of plain concrete slab

Damage in Front Face of ferrocement slab   Damage in rear Face of ferrocement slab   projectile stopped inside the panel

Figure (5): *The results of the penetration test*

Discussion:

In case of high velocity (about 980 m/sec), the effect of using ferrocement technology on the penetration resistance of concrete panels had been studied. From previous results in Table (6), and as shown in Fig.(5) the following findings are obtained:-

3.1 Penetration depth

- Effect of using ferrocement on penetration depth:

In comparison with plain concrete specimen [SC1] in which the penetration depth was 40 cm, the penetration depths in Ferrocement specimens (SE1-1, SE1-2 and SE1-3) were (28.5, 26.5 and 23.5cm) respectively. That’s means using Ferrocement in these specimens' leads to reduction in the penetration depth by about 41.25 %, see Fig. (6).

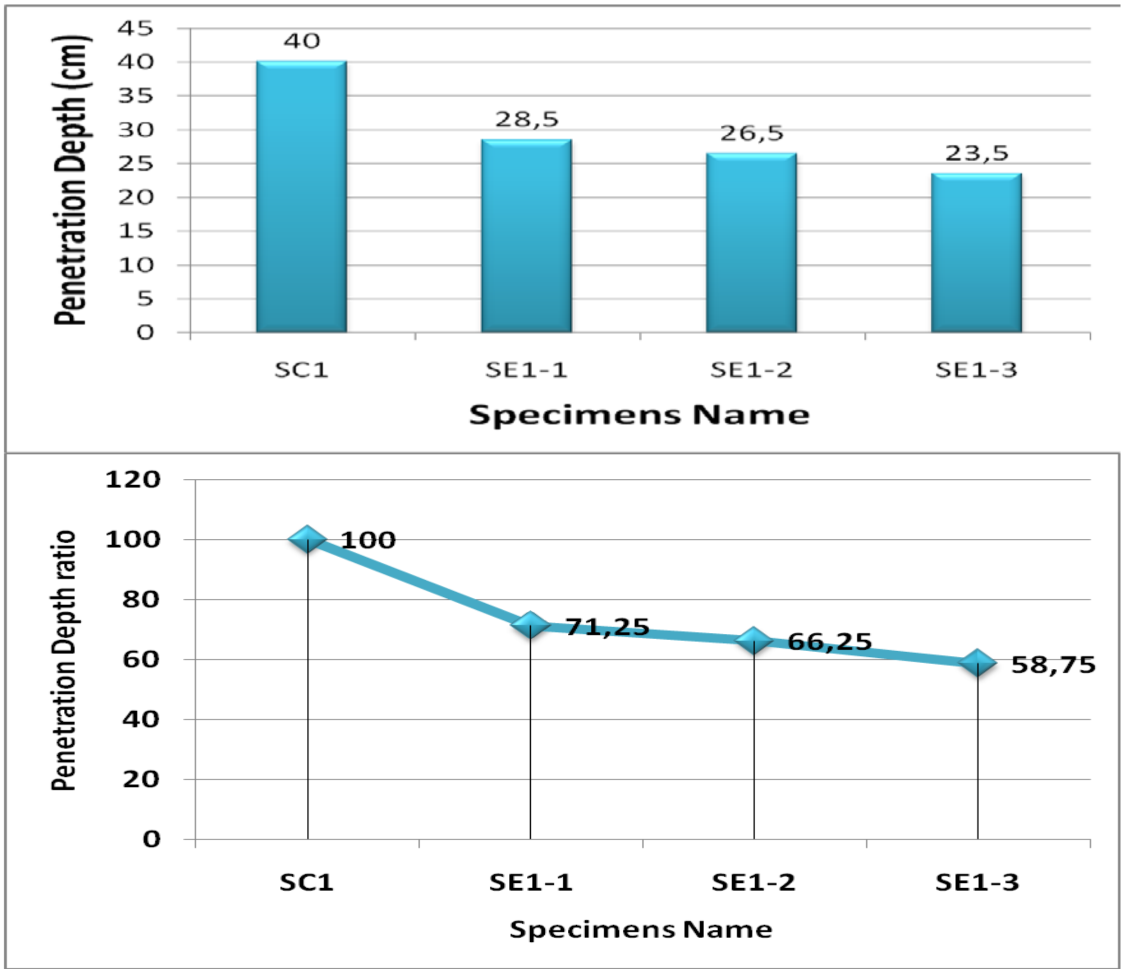


***Figure (6):** Effect of using ferrocement on penetration depth*

3.2 Front face crack pattern

Effect of using ferrocement on cracks in front face:

In comparison with plain concrete specimen (SC1), in which the damage in front face was full damage, the crack diameter in front faces in Ferrocement specimens (SE1-1, SE1-2and SE1-3)were (70 , 65 and 54cm) respectively. That's means using Ferrocement in these specimens' leads to reduction in cracks in front face by about (22.86) % . See Fig. (7).

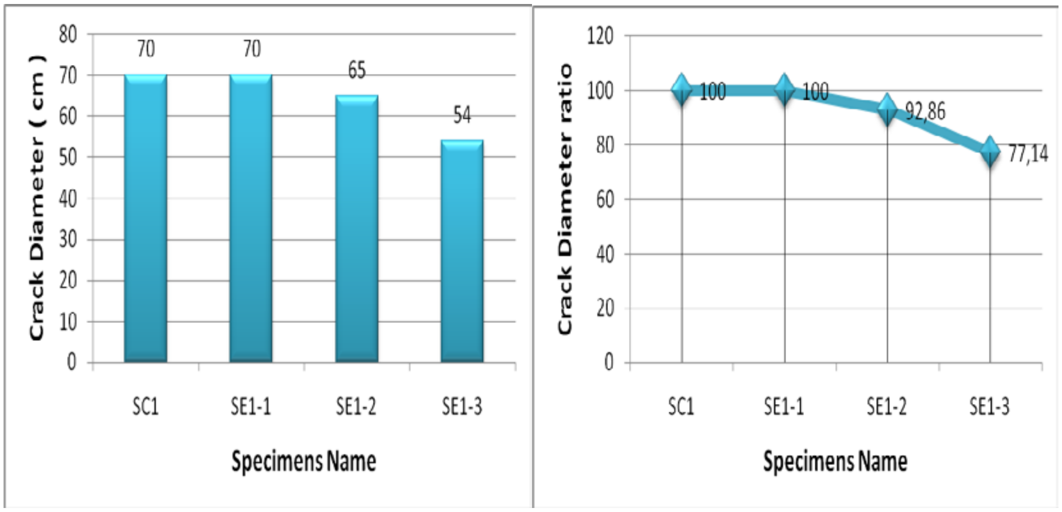


Figure (7): *Effect of using ferrocement on cracks in front face*

3.3 Rear face crack pattern

Effect of using ferrocement on cracks in rear face:

In comparison with plain concrete specimen (SC1), in which the damage in rear face was full damage, the crack diameter in rear faces in Ferrocement specimens (SE1-1, SE1-2and SE1-3)were (56, 10.5 and 0 cm)respectively. This lead to conclude that using Ferrocement in these specimens' leads to reduction in cracks in rear face between (20-100) % . See Fig (8).

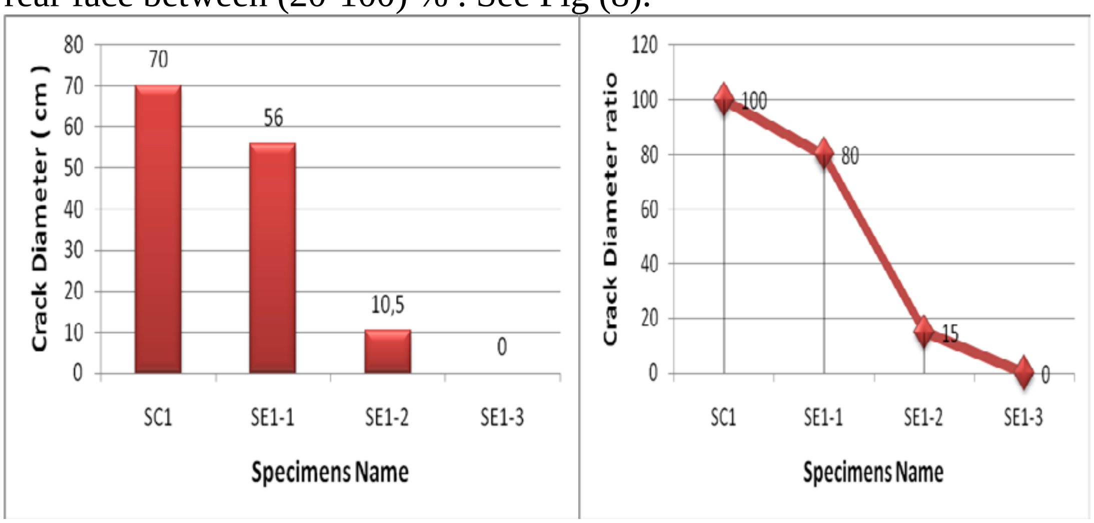


Figure (8): *Effect of using ferrocement on cracks in rear face*

3.4 Front face damage

Effect of using ferrocement on damage in front face:

In comparison with plain concrete specimen (SC1), in which the damage in front faces was full damage, the damage in front faces in Ferrocement specimens (SE1-1, SE1-2and SE1-3)were (45 , 32 and 25cm) respectively. It is clear that using Ferrocement in these specimens' leads to reduction in the damage in front face between (19.6 – 55.4) %. See Fig. (9).

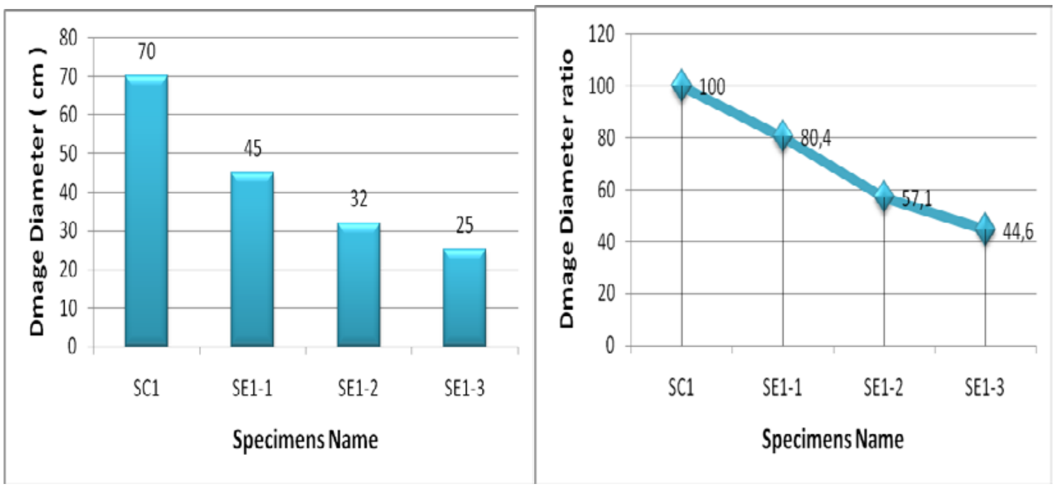


Figure (9): *Effect of using ferrocement on damage in front face*

3.5 Rear face damage

Effect of using ferrocement on damage in rear face:

In comparison with plain concrete specimen (SC1), in which the damage in rear face was full damage, the damage in rear faces in Ferrocement specimens (SE1-1, SE1-2and SE1-3)were(19, 5 and 0 cm) respectively. This analysis show that using Ferrocement in these specimens' leads to reduction in the damage in rear face between (72.86 – 100) %. See Fig. (10).

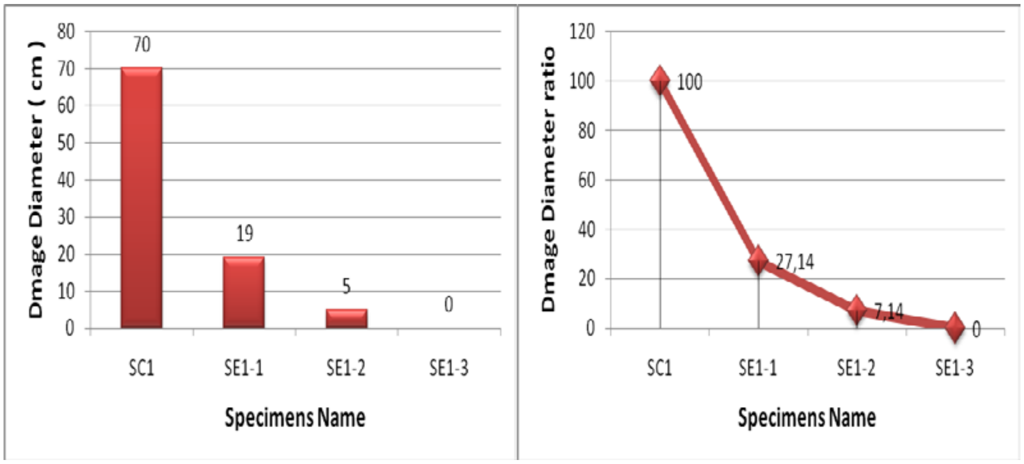


Figure (10): *Effect of using ferrocement on damage in rear face*

3.6 fragments weight in front face

Effect of using ferrocement on fragments weight in front face:

In comparison with plain concrete specimen (SC1), in which the damage in front face was full damage, the fragments weight in front faces in Ferrocement specimens (SE1-1, SE1-2and SE1-3)were(1.452 , 2.425 and 2.735kg) respectively. It is clear that using multi layers of expanded steel meshes in these specimens' leads to increasing the damage in front face by about (67 – 88.36) %. See Fig. (11).

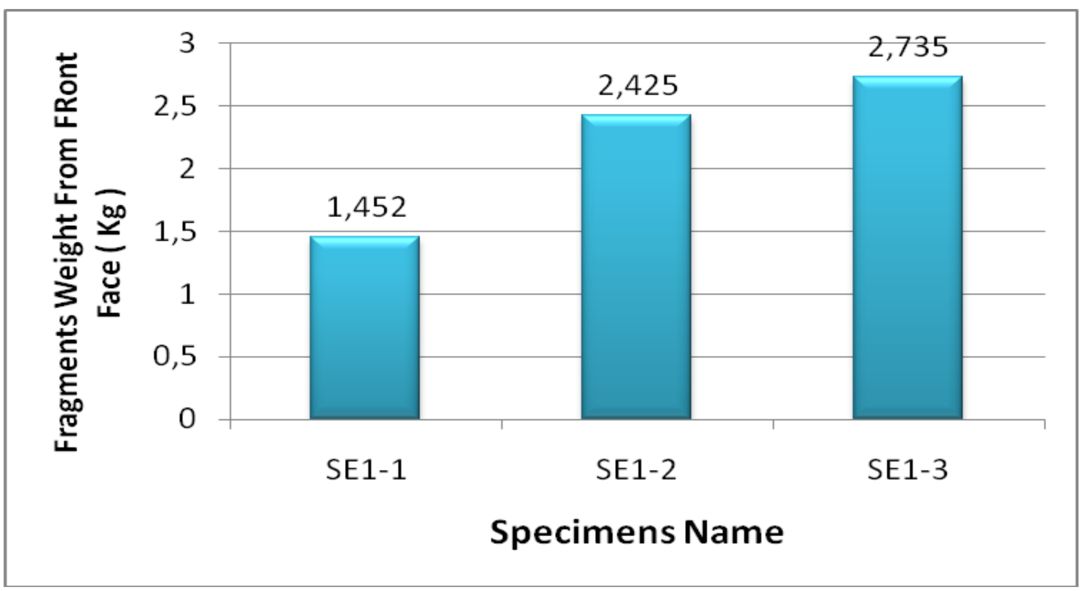


Figure (11): *Effect of using ferrocement on fragments weight in front face*

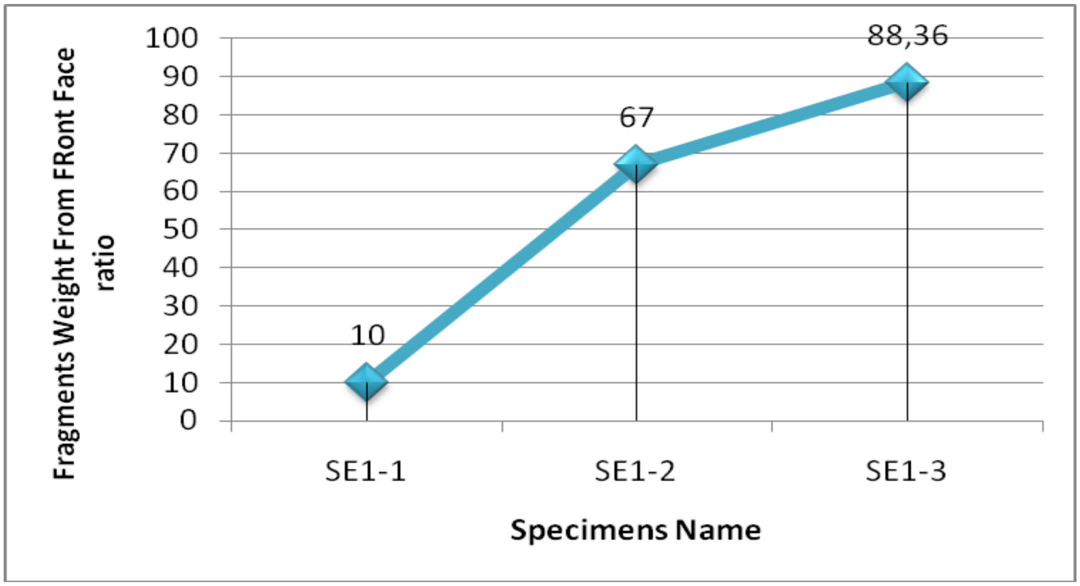


Figure (11): *Effect of using ferrocement on fragments weight in front face (cont.)*

4.Conclusions:

The following general conclusions could be derived Based on the carried out experimental studies and the performed analysis:

- Using Ferrocement technique enhances the penetration resistance of concrete panels. That is through reducing the penetration depth by about 41.25 %.
- Using Ferrocement technique reducing the front and rear face cracks by about (22.86%) and (20-100%) respectively.
- Using Ferrocement technique reducing the front and rear face damage by about (19.6 – 55.4) and (72.86 – 100) respectively.
- Using multi layers of expanded steel meshes in Ferrocement panels increasing the fragments weight in front faces by about (67 – 88.36%).

5. References:

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