

Influence of Mix Proportions on The Impact Resistance of High Strength Concrete

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Abstract:

This research aim to study the Influence of mix proportions on the impact resistance of high strength concrete, Trial laboratory batches were used including as follows:

- Normal concrete mixture (C1) as a reference mix ((w/c) = 0.45, without admixtures);
- Four concrete mixtures (C2, C3, C4, C5) prepared by fixing (w/c) = 0.45, and using different amount of super plasticizers (0.25, 0.50, 0.75, 1.00)% as a percentage of cement content, respectively;
- Four concrete mixtures (C6, C7, C8, C9) prepared by reducing and fixing (w/c) = 0.30, and using silica fume = (15)% as replacement of cement content and different amount of superplasticizers (1.25, 1.50, 1.75, 2.00)% as a percentage of cement content; and
- Three concrete mixtures (C10, C11, C12) prepared by fixing the amount of superplasticizers (1.50)% and using different (w/c) = (0.40, 0.29, 0.27).

Results show that Mixture C11 prepared with (1.50%) addition of superplasticizers and (15%) addition of silica fume leads to (90.29%) increasing in the compressive strength and records an improvement in the impact resistance by (725.56%) as compared with the reference mix. On the other hand, all of the mix proportions lead to an increase in both compressive strength and impact resistance for all the mixes.

Key words: Mix proportions, Impact Resistance, Compressive Strength, Superplasticizers, ACI 544, First-Crack Strength, Failure Strength.

تأثير نسب المزج على مقاومة الصدم للخرسانة عالية المقاومة

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الخلاصة :

يهدف هذا البحث الى دراسة تأثير نسب المزج على مقاومة الصدم للخرسانة عالية المقاومة، حيث تم القيام بعمل خلطات تجريبية تتضمن كالاتي:

- خلطة مرجعية C1 (نسبة ماء/سمنت) = 0,45 ، بدون مضافات)؛
- اربعة خلطات خرسانية (C2,C3,C4,C5) بتثبيت نسبة الماء الى السمنت = 0,45 واطافة كميات مختلفة من الملدنات الفائقة (0,25، 0,50، 0,75، 1,00) %، كنسب مئوية من وزن السمنت؛

- اربعة خلطات خرسانية (C6,C7,C8,C9) بتقليل وتثبيت نسبة الماء الى السمنت = 0,30 مع استعمال السليكا فيوم 15% كنسبة استبدال من وزن السمنت واطافة كميات مختلفة من الملدنات الفائقة (1,25، 1,50، 1,75، 2,00) %، كنسب مئوية من وزن السمنت؛
- وثلاث خلطات خرسانية (C10,C11,C12) بتثبيت نسبة الملدنات الفائقة = 1,50% واستعمال نسبة ماء الى السمنت (0,27، 0,29، 0,40).

بينت النتائج ان الخلطة الخرسانية (C11) والتي تحتوي (1,5) % من الملدنات الفائقة و (15) % سليكافيوم ادت الى (90,29) زيادة بمقاومة الانضغاط وتحسين مقاومة التآكل والبري بنسبة (725,56) % مقارنة مع الخلطة المرجعية، مع ملاحظة ان جميع نسب المزج ادت الى زيادة بمقاومة الانضغاط ومقاومة الصدم لجميع الخلطات الخرسانية.

الكلمات المفتاحية: نسب المزج، مقاومة الصدم، مقاومة الانضغاط، الملدنات الفائقة، ACI 544، المقاومة اللازمة لحدوث اول فطر، مقاومة الفشل.

1. Introduction:

Concrete has satisfied impact resistance in comparison with other construction materials. Nevertheless, existing concrete structures designed without consideration of impact or blast load can be vulnerable under unexpected extreme loads. Accordingly, to improve the resistance of concrete structures under the extreme loads, additional strengthening methods are required^[1].

Concrete is the most commonly used construction material worldwide, which, during its working process, is frequently subjected to quasi-static loadings of magnitudes that change slowly. Designs of such large structures as nuclear power plant protection devices, airport runways and fortified structures must however account for the impact of dynamic loadings of drastically changing magnitudes^[1]. The compressive strength of concrete can be increased by increasing the strength of the cement paste and improving the interfacial zone, reducing the potential stress concentration between the aggregate and the cement paste. Such an increase can be achieved by reducing the water-to-cement ratio, using fine pozzolanic materials and reducing the coarse aggregate size^[1].

Cement based materials are quasi-brittle and are known to exhibit a highly stress rate sensitive behavior. In structures that are subjected to impact forces this causes concern in two ways, first the brittleness may result in catastrophic failure without warning, and second the properties of concrete during such events may be very different from those measured in standardized quasi static test. There are no standardized test available for testing concrete under impact loading and there is significant confusion as to what constitutes an appropriate test^[2].

Concrete generally registers low tensile strain capacity and brittle nature, and therefore, develops susceptibility to the presence and development of cracks in plastic as well as hardened state^[3]. Concrete structures may be required to withstand impact loads which can result, for example, from kinetic energy weapons, turbine blade fragments, and tornado generated projectiles^[4]. Local damage can lead to concrete fragmentation from the front

surface, projectile penetration into the target, scabbing of concrete from the back face, and finally, perforation through the target. The extent of damage depends on a variety of factors, such as impact velocity, mass, geometry, material properties, and thickness of the target^[5].

Researchers and designers are not able to use impact resistance as a design parameter, simply because it cannot be fully quantified due to the lack of a standard impact test for concrete^[6]. The absence of a standard impact test prompted researchers to propose their own impact tests to estimate the impact resistance of concrete. Some of these tests are relatively difficult to perform and require complicated equipment. None of these tests, however, have been claimed to be a standard test due to the lack of statistical data on the variation of the results^[7]. In this regard, ACI Committee 544^[8] has proposed a drop weight impact test to demonstrate the relative brittleness and to quantify the impact resistance of fiber-reinforced concrete (FRC). The test is widely used because it is simple and economical. The results obtained from this test are often noticeably scattered.

Large variation is a common problem in impact testing, and it is difficult to devise systems that give reproducible results. This might be attributed to the nature of the impact process itself and the number of factors controlling the impact resistance compared with other mechanical properties^[7, 9].

In this investigation, the impact resistance of high strength concrete incorporating with chemical and mineral admixture will be discussed.

2. Experimental work:

The experimental work of this investigation included two categories:

2.1. Manufacturing the impact resistance rig:

The apparatus, which was used in measuring the impact resistance, was manufactured with all its accessories in accordance to the technique suggested by the ACI committee 544 on fiber reinforced concrete^[8]. In the technical college of Mosul. **Figures (1 and 2)** show the details of the impact test apparatus.

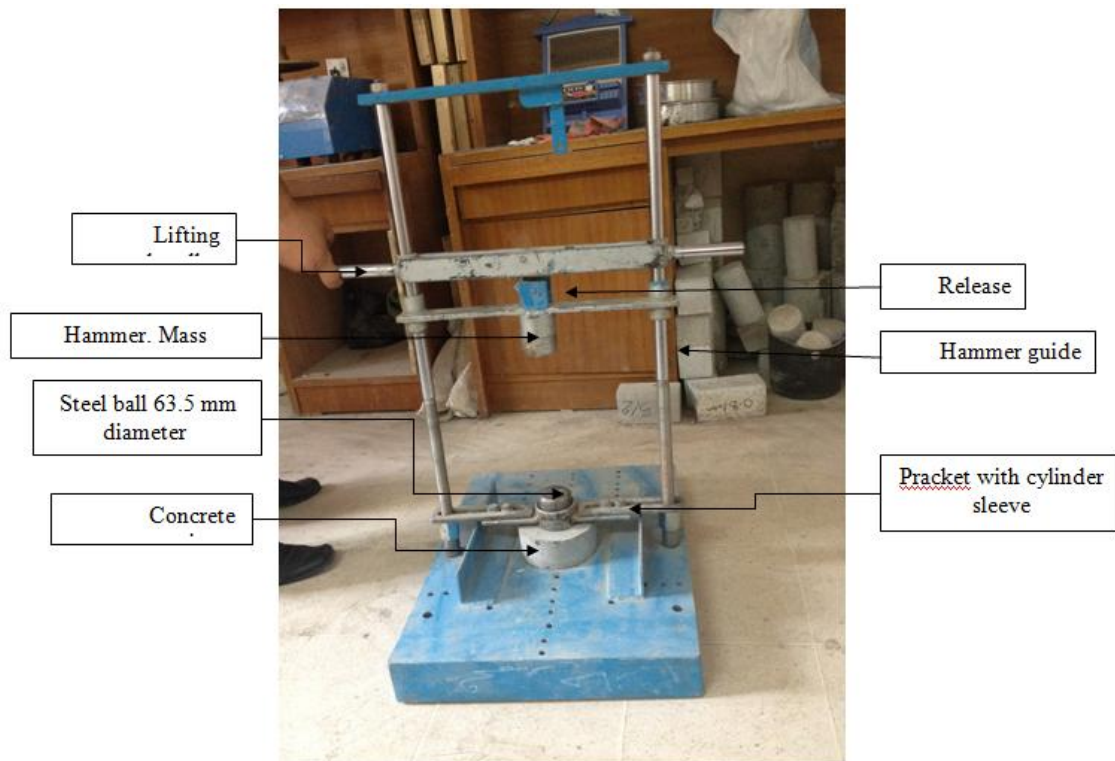


Fig .(1): Drop weight machine (impact resistance rig)

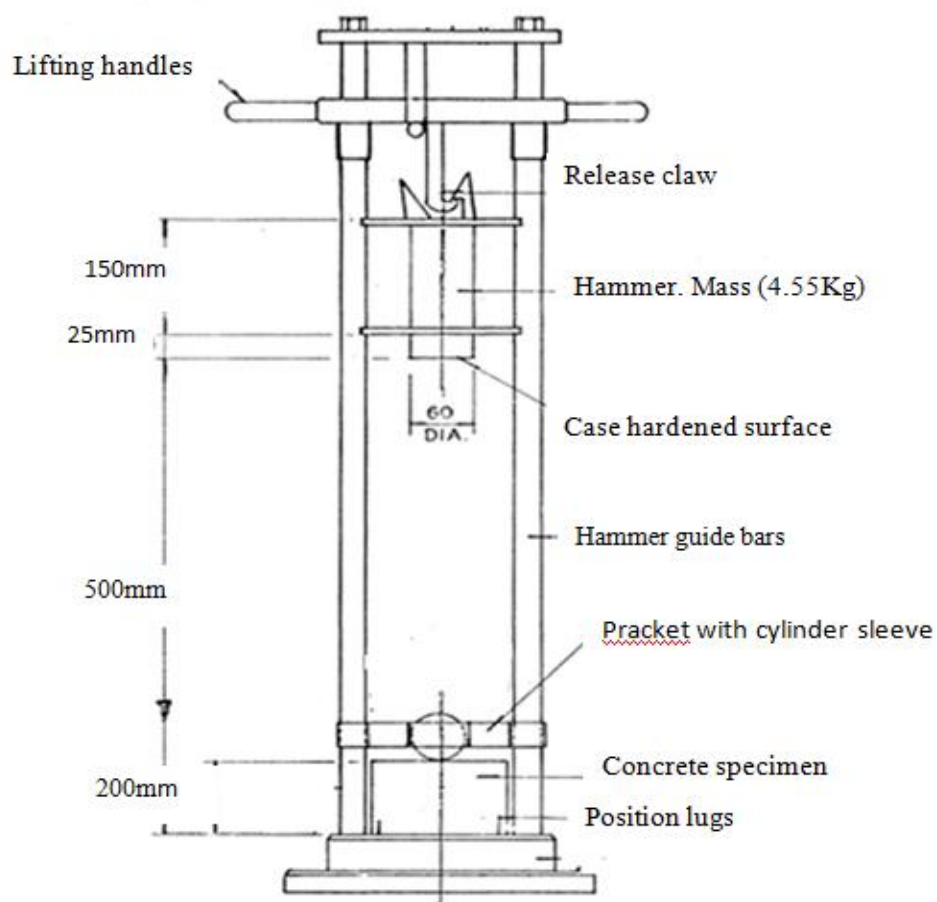


Fig .(2) Design details of impact resistance rig

2.2. Practical Work:

This part of the investigation includes preparation of all the concrete mixes as well as the tests performed on the concrete specimens.

2.2.1. Materials:

2.2.1.1. Cement:

Sulfate–resistance cement (Type V) obtained from Hammam-Al-Alil was used. The cement conforms to the Iraqi specifications specifications No. 5 / 1984^[10]. Physical and chemical properties of the used cement are given in **Tables (1 and 2)**.

Table .(1): Physical properties of sulfate–resisting Portland cement

Physical properties	Test results of sulfate-resisting cement	Iraqi specifications No. 5 / 1984 ^[10]
Specific surface area by Blain method, m ² /kg	280	≥ 230
Initial setting time (hrs : min)	1 : 30	≥ 45 minute
Final setting time (hrs: min)	3 : 18	≤ 10 hours
Compressive strength, MPa		
3 days	21	≥ 15
7 days	29	≥ 23

Table.(2): Chemical compositions of sulfate–resisting Portland cement

Chemical analysis (%)	Test results of sulfate-resisting cement	Iraqi specifications No. 5/1984 (% by weight) ^[10]
MgO	1.9	≤ 5.0
SO ₃	2.3	≤ 2.5
CaO	62.92	-
SiO ₂	20.3	-
Fe ₂ O ₃	5.4	-
Loss on Ignition	1.1	≤ 4.0
Insoluble Residue	0.85	≤ 1.5
C ₃ A	2.3	≤ 3.5
C ₃ S	58.9	-
C ₂ S	13.6	-
C ₄ AF	15.38	-

2.2.1.2. Coarse aggregate:

Coarse aggregate with M.A.S (10) mm. obtained from Mosul city was used. Its sieve analysis is shown in **Table(3)**.

Table.3: Sieve analysis of the used coarse aggregate

Sieve size (mm)	Cumulative passing %	Limits of Iraqi specification No. 45/1984 ^[11]
14	100	100
10	94.6	85-100
5	4.8	0-25
2.36	0	0-5

2.2.1.3. Fine aggregate:

Fine aggregate (zone II) obtained from Mosul city was used. Its sieve analysis shown in **Table(4)**.

Table .(4) Sieve analysis of the used fine aggregate

Sieve size (mm)	Cumulative passing (%)	Limits of Iraqi specification (zone II) No. 45/1984 ^[11]
4.75	98.4	90-100
2.36	94.6	85-100
1.18	92	75-100
0.60	66	60-79
0.30	40	12-40
0.15	10	0-10

Main properties of the used coarse and fine aggregates shown in **Table(5)**.

Table .(5) Main properties of coarse and fine aggregates

Property	Coarse aggregate	Fine aggregate
Dry sp. Gravity	2.63	2.59
S.S.D. sp. Gravity	2.64	2.65
App. sp. Gravity	2.66	2.79
Absorption capacity (%)	0.5	2.9
Rodded unit weight (kg/m ³)	1716	1765
Fineness modulus	6.55	2.61
SO ₃	0.1%	0.4%

2.2.1.4. Chemical admixtures:

Sika Visco Crete -5930, is a third generation of superplasticizers for concrete and mortar, was used. It meets the requirements for superplasticizers according to ASTM C 494 Types G and F and BS EN 934 Part 2 : 2001^[12]. Main properties of the used superplasticizers shown in **Table(6)**.

Table .(6) Typical properties of superplasticizers

Form	Aqueous solution of modified Polycarboxylate
Colour	Turbid liquid
Density	1.08 Kg/lt. \pm 0.005
Odor	None
Boiling	100 °c
pH value	7 - 9

2.2.1.5. Water:

Tap water was used in preparing and curing all mixtures in accordance with ASTM C1602^[13].

2.2.2. Mix design of Normal Strength Concrete (NSC):

Mix proportions used in this investigation were obtained using three methods (ACI, British, and Road Note No. 4 "RN4" methods)^[14], as shown in **Table (7)**.

Table .(7) Mix proportions

Mix design method	Mix proportions	(A/C) Ratio
ACI	1 : 2.2 : 2.0 , w/c = 0.61	4.2
British	1 : 1.8 : 1.8 , w/c = 0.5	3.6
Road Note No. 4	1 : 1.9: 2.4 , w/c = 0.45	4.3

Since all methods of concrete mix design shown in **Table (7)** give the same compressive strength 25 MPa, therefore, the mix proportions obtained by the (Road Note No.4) was chosen because it gives (A/C) ratio higher than the other two methods and this will be the best mix design method from economical as point of view.

2.2.3. Mix design of High Strength Concrete (HSC):

The mixture proportions were selected from a number of trial laboratory batches as follows :

2.2.3.1. By fixing (w/c)ratio and using different amount of superplasticizers as a percentage of cement content as shown in **Table (8)**.

Table .(8) Mix proportion for trial mixes

Code	Mix proportion	Cement Kg/m ³ .	Silica fume Kg/m ³	Super plasticizers Kg/m ³ .	Fine aggregate Kg/m ³ .	Coarse aggregate Kg/m ³ .	(w/c) ratio	28-day Compressive strength(MPa).	Slump (mm)
C1	1 : 1.9 : 2.4	420	0	0.00	822	1016	0.45	33.06	60
C2	1 : 1.9 : 2.4	420	0	1.05	822	1016	0.45	33.34	90
C3	1 : 1.9 : 2.4	420	0	2.10	822	1016	0.45	34.97	120
C4	1 : 1.9 : 2.4	420	0	3.15	822	1016	0.45	36.612	170
C5	1 : 1.9 : 2.4	420	0	4.20	822	1016	0.45	39.62	190

2.2.3.2. By reducing and fixing (w/c)ratio and using silica fume and different amount of superplasticizers as a percentage of cement content as shown in **Table(9)**.

Table .(9) Mix proportion for trial mixes

Code	Mix proportion	Cement Kg/m ³ .	Silica fume Kg/m ³	Super plasticizers Kg/m ³ .	Fine aggregate Kg/m ³ .	Coarse aggregate Kg/m ³ .	(w/c) ratio	28-day Compressive strength(MPa).	Slump (mm)
C6	1 : 1.9 : 2.4	357	63	5.25	822	1016	0.30	53.664	5
C7	1 : 1.9 : 2.4	357	63	6.30	822	1016	0.30	57.360	5
C8	1 : 1.9 : 2.4	357	63	7.35	822	1016	0.30	55.764	5
C9	1 : 1.9 : 2.4	357	63	8.40	822	1016	0.30	53.232	5

2.2.3.3. By fixing amount of superplasticizers and using different (w/c) ratios as shown in **Table (10)**.

Table .(10) Mix proportion for trial mixes

Code	Mix proportion	Cement Kg/m ³ .	Silica fume Kg/m ³	Super plasticizers Kg/m ³ .	Fine aggregate Kg/m ³	Coarse aggregate Kg/m ³	(w/c) ratio	28-day Compressive strength(MPa).	Slump (mm)
C10	1 : 1.9 : 2.4	357	63	6.3	822	1016	0.40	52.638	15
C11	1 : 1.9 : 2.4	357	63	6.3	822	1016	0.29	62.912	5
C12	1 : 1.9 : 2.4	357	63	6.3	822	1016	0.27	49.896	5

2.2.4. Mixing and preparation of specimens:

All batches of concrete were cast in the laboratory using a drum mixer. Mixing, casting, and curing was conformed to ASTM C192^[15]. Each batch was used to cast the 6 cubes of (100*100*100) mm. and 6 disk of (150*63.5) mm. to perform both the compressive strength and impact resistance tests. The mixing procedures were performed according to the following sequences:

- (a) The fine and coarse aggregates were placed in the mixer, mixed for two minutes.
- (b) The cement was added to the mixed aggregate, and mixed for two minutes also.
- (c) Two-third of the mixing water was mixed with half quantity of the superplasticizers and added to the mixer, mixed for two minutes.
- (d) The rest quantity of water and superplasticizers were added to the mixer and mixing till there are no dry balls of cement and the mixture have a slump of (120 - 180 mm).
- (e) Molds were oiled and placed on the vibration table while the concrete was poured ,The cylinder specimens were cast in three layers and each layers compacted by the vibrator until no further air bubbles appeared on its surface, while the cubes specimens were casted in two layers and compacted as the same manner, then
- (f) After completing the compaction operation, the top of the specimen was smooth finished by means of a trowel.

2.2.5. Curing

The specimens were demolded after (24±2) hrs, and subjected to the standard moist curing by immersing them in curing tank at 23 °C and relative humidity more than 90% till testing at 28 days.

2.2.6. Tests of specimens:

2.2.6.1. Compressive strength test:

The cube specimens were taken out from the curing tank, and the compressive strength of the specimens was determined in accordance with BS 1881: Part 116 : 2003^[16].

2.2.6.2. Impact resistance test:

Surface of the cylindrical specimens were grinding^[14], and the impact resistance of concrete were measured in compliance with ACI 544. The testing procedure was as follows:

- 1- Rests a specimen on the base plate within positioning lugs.
- 2- The specimen bottom has received a thin layer of heavy grease to reduce the friction between the specimen and the base plate.
- 3- The positioning bracket of the base plate is bolted in place. Then, A 4.54 kg hammer consecutively falls from a 457 mm height onto a standing at the center of the disc, subjecting the disc to repeated impact blows.

- 4- The number of blows developing the first visible crack on the disc record as the first-crack strength.
- 5- The falling operation continues to trigger the ultimate failure of the disc containing cracks. The ultimate failure is the opening-up of the disc to touch three of the four lugs. The number of blows triggering the ultimate failure is the failure strength.

3. Test results and discussions:

Results of the existing investigation were tabulated in **Tables (11 to 14)**, and diagrammatically illustrated in **Figures. (3 to 11)**.

3.1. Slump test results:

Results of the slump test tabulated in **Table 11**, and diagrammatically illustrated in **Figures (3 to 6)**.

Table . (11): Slump test results

Mixture Designation	Slump.(mm)	28-day Compressive strength. (MPa)
C1	60	33.0
C2	90	33.3
C3	120	34.9
C4	170	36.6
C5	190	39.6
C6	5	53.6
C7	5	57.3
C8	5	55.7
C9	5	53.2
C10	15	52.6
C11	5	62.9
C12	5	49.8



Fig .(3) Slump test for mixture C1



Fig .(4): Slump test for mixture C5



Fig .(5): Slump test for mixture C10



Fig.(6) Slump test for mixture C11

It was clear from **Table (11)** that, for normal strength concrete mixtures (C2, C3, C4, and C5) that, increasing of the percentages of superplasticizers lead to improve the workability and increase in compressive strength for all mixes, as compared with reference mixture C1. Whilst for high strength concrete mixtures (C6 to C12) had the worst workability and records an improvement in compressive strength, This result was expected due to the proportions of water and water reducers in the different mixes.

The slump results in **Table (11)** show that mixture C3 had the best consistency When in its fresh state be plastic or semi-fluid and generally capable of being molded by hand.

3.2. Compressive strength test results:

Results of the compressive strength test tabulated in **Table (12)**.

Table (12) : Compressive strength test results

Mixture designation	7-day Compressive strength(MPa)	28-day Compressive strength(MPa)	56-day Compressive strength(MPa)
C1	28.4	33.0	40.7
C2	28.5	33.3	41.2
C3	29.1	34.9	42.6
C4	30.7	36.6	46.2
C5	33.0	39.6	58.7
C6	44.7	53.6	63.0
C7	47.8	57.3	66.4
C8	46.4	55.7	64.6
C9	44.3	53.2	61.9
C10	43.8	52.6	61.4
C11	52.2	62.9	73.2
C12	41.5	49.8	61.2

Table (12) presents the compressive strength results of NSC and HSC mixtures cured under standard conditions. The compressive strength for NSC and HSC mixtures at (7, 28, and 56) days vary according to admixture. The highest compressive strength is achieved by mixture C11 followed by mixtures C7 and C8 for each (7, 28, and 56)days.

Table (12) also show that, the addition of different amounts of chemical and mineral admixture gain average 28-day compressive strength values range from (33.3 to 62.9) MPa as compared with the reference mixture.

The maximum 28-day compressive strength value of 62.9 MPa (90.29% increasing), was recorded in mixture C11 with 1.5 % of superplasticizers and 15% silica fume, whilst the minimum compressive strength value 33.34 MPa (0.85% increasing), was obtained with the 0.25% superplasticizers in mixture C2.

The 28-day compressive strengths for mixture C12 are considerably lower than the compressive strength for mixture C11, where the w/c ratio for mixtures C12 and C11 are (0.27, and 0.29) respectively, we expect that, reducing in w/c ratio with high percentage in super plasticizers may cause in not completing in hydration.

3.3. Impact strength test results:

Results of the impact test tabulated in **Tables (13 and 14)** and diagrammatically illustrated in **Figures (7 to 11)**.

Table.13: test results for each concrete mixture

Mixture code	Type of Concrete	Compressive strength (MPa)	Average Number of blows for first crack	Average Number of blows for failure crack	Percentage increase in compressive strength(%)	Percentage increase in impact resistance(%)
C1 (Reference)	–	33.06	29	30	–	–
C2	NSC	33.3	29	31.3	0.85 %	4.4%
C3	NSC	34.9	37.3	41.7	5.78 %	38.88%
C4	NSC	36.6	68.7	72.7	10.74 %	142.2%
C5	NSC	39.6	130.0	146	19.84 %	386.67%
C6	HSC*	53.6	189	204.3	62.32 %	581.1%
C7	HSC*	57.4	205.7	225.3	73.50 %	651.1%
C8	HSC*	55.8	194.7	216	68.67 %	620%
C9	HSC*	53.2	187.3	203.7	61.01 %	578.9%
C10	HSC*	52.6	183.7	200.3	59.21 %	567.76%
C11	HSC*	62.9	235	247.7	90.29 %	725.56%
C12	HSC*	49.9	174	190	50.92 %	533.34%

* HSC are those that attain cylinder compressive strength of at least 41 MPa at 28 days [ACI 318-11].

Table .(14) Impact test results

Mixture code	Specimen number	Number of blows		First crack impact energy (kN mm)	Average First crack impact energy (kN mm)	Failure impact energy (kN mm)	Average failure impact energy (kN mm)
		First crack	Failure				
C1	1	19	19	392.73	599.43	392.73	620.1
	2	25	25	516.75		516.75	
	3	43	46	888.81		950.82	
C2	1	25	27	516.75	599.43	558.09	647.66
	2	27	29	558.09		599.43	
	3	35	38	723.45		785.46	
C3	1	30	33	620.1	771.68	682.11	861.25
	2	35	41	723.45		847.47	
	3	47	51	971.49		1054.17	
C4	1	50	54	1033.5	1419.34	1116.18	1502.02
	2	65	67	1343.55		1384.89	
	3	91	97	1880.97		2005	
C5	1	70	76	1446.9	2694	1570.92	3017.82
	2	86	91	1777.62		1880.97	
	3	235	271	4857.45		5601.57	
C6	1	124	133	2563.08	3906.63	2749.11	4223.57
	2	145	163	2997.15		3369.21	
	3	298	317	6159.66		6552.39	
C7	1	131	147	2707.77	4251.13	3038.49	4657.64
	2	168	182	3472.56		3761.94	
	3	318	347	6573.06		7172.49	
C8	1	126	142	2604.42	4023.76	2935.14	4464.72
	2	151	171	3121.17		3534.57	
	3	307	335	6345.69		6924.45	
C9	1	121	129	2501.07	3872.18	2666.43	4209.79
	2	143	159	2955.81		3286.53	
	3	298	323	6159.66		6676.41	
C10	1	114	127	2356.38	3796.4	2625.09	4140.89
	2	142	162	2935.14		3348.54	
	3	295	312	6097.65		6449.04	
C11	1	151	163	3121.17	4857.45	3369.21	5119.27
	2	189	211	3906.63		4361.37	
	3	365	369	7544.55		7627.23	
C12	1	109	118	2253.03	3596.58	2439.06	3927
	2	132	150	2728.44		3100.5	
	3	281	302	5808.27		6242.34	

* A significant variation in the number of blows required for causing the first crack and failure among the test samples of the same mix was observed for mixture concrete samples. Swamy and Jajagha ^[17] and Gopalaratnam and Shah ^[18] have also reported a wide spread in the results of their impact tests.

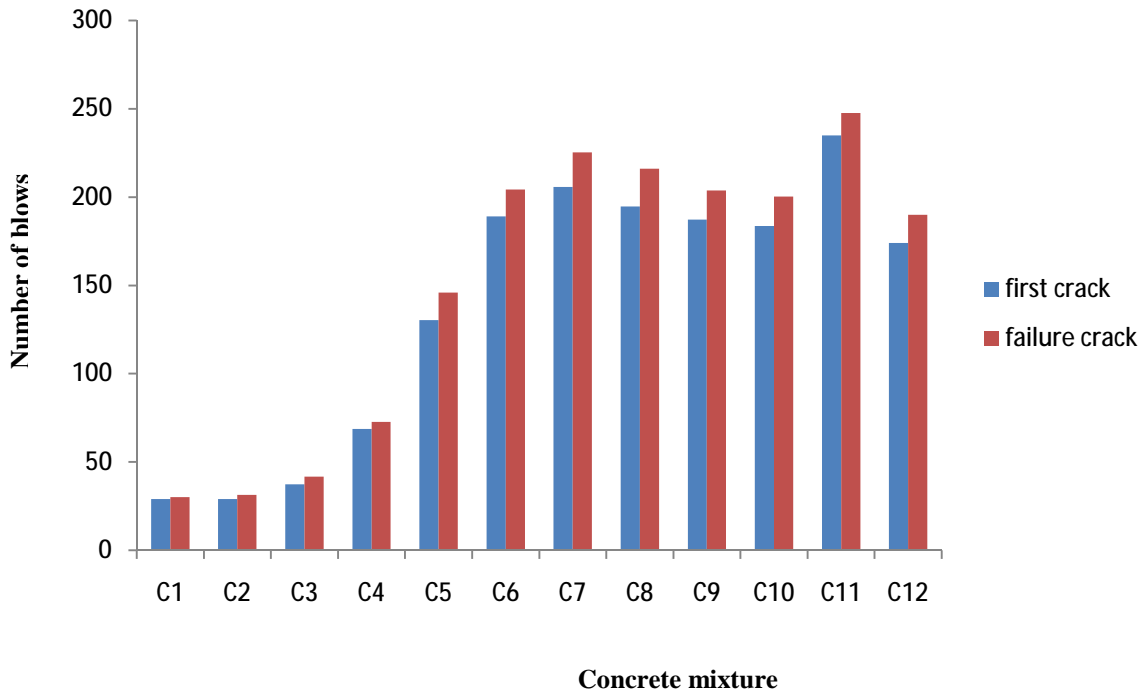


Fig .(7) Impact resistance results

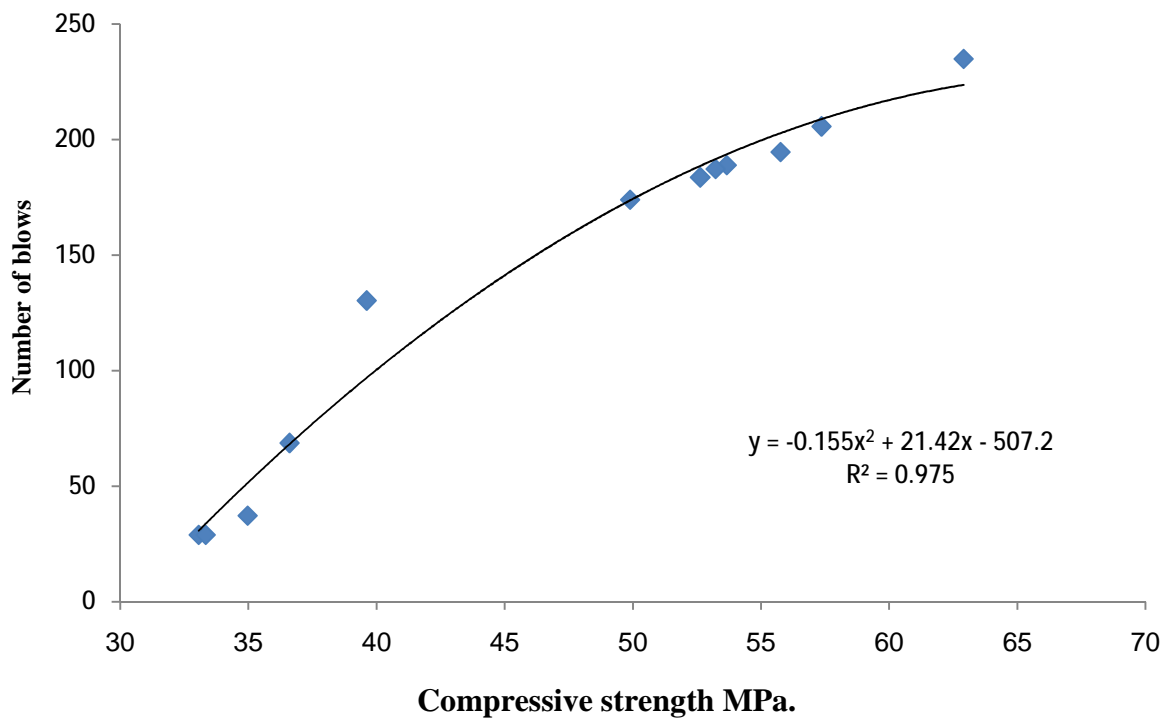


Fig .(8) Number of blows to first crack in concrete mixtures.

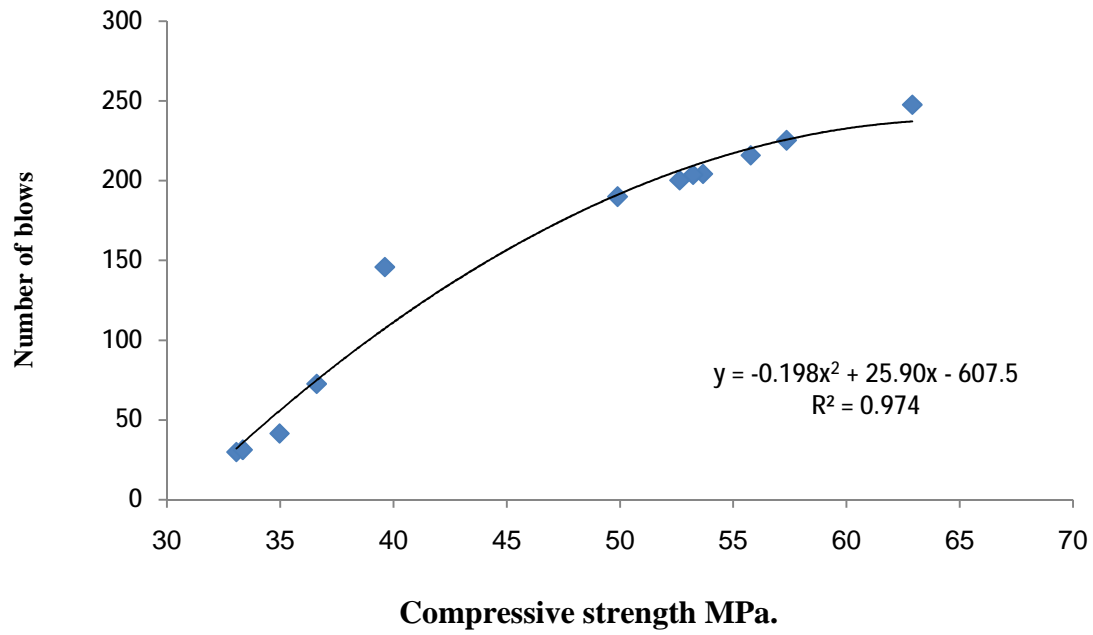


Fig .(9): Number of blows to failure crack in concrete mixtures



Fig .(10) First crack for cylindrical specimen mixture C5



Fig .(11) Failure crack for cylindrical specimen mixture C5

ultimate failure took place simultaneously. A significant variation in the number of blows required for causing the first crack and failure among the test samples of the same mix was observed for mixture concrete samples. Swamy and Jajagha^[17] and Gopalaratnam and Shah^[18] have also reported a wide spread in the results of their impact tests. The sources of large variations in results obtained from the ACI impact test may be attributed to the following reasons^[19]:

- The subjectivity of the test due to the visual identification of the first crack, which may occur in any direction.
- The impact resistance of concrete is based on a single point of impact, which might happen to be on a hard particle of coarse aggregate or on a soft area of mortar.
- The absence of criteria for preparing test specimens allows trowled, cut or smooth mould-faced surfaces to be tested, adding another source of variability.
- No criteria are stated for accepted or rejected failure mode.

These tables also indicate the calculated impact energy required for first visible crack and at failure for different specimens tested in this investigation. The impact energy imparted by the hammer per blow can be calculated by the following expressions:

$$H = \frac{g \cdot t^2}{2} \dots\dots\dots (1)$$

$$V = g \cdot t \dots\dots\dots (2)$$

$$\text{Impact energy } U = \frac{M \cdot V^2}{2} \dots\dots\dots (3)$$

$$m = \frac{W}{g} \dots\dots\dots (4)$$

where U = impact energy per blow of the hammer(KN.mm) ,
 V = velocity of the hammer at impact(mm/s) ,
 g = acceleration due to gravity($n \cdot \text{mm/s}^2$) ,
 t = time(seconds) taken by the hammer to fall a height of 457 mm ,
 H = height of fall(mm) ,
 m = mass of the hammer(kg),and
 W = the weight of hammer(N).

Substituting the relevant values in Eq. (1)

$$457 = \frac{9810 t^2}{2}$$

$$t = 0.305 \text{ s} \quad \text{and} \quad V = 9810 * 0.305 = 2992.05 \text{ mm / s.}$$

Impact energy per blow U ,of the hammer can be obtained by substituting the values in Eq.(3.3)

$$U = \frac{4.53 * (2992.05)^2}{2 * 9810}$$

$$= 2067 \text{ kg.mm or } 20.67 \text{ KN.mm}$$

The results, in terms of number of blows for first crack and for ultimate failure are plotted against compressive strength in Figs.(8 and 9), respectively. It can be observed in general from of the tables and figures that for a particular admixture mix proportion, the best performance in terms of first crack as well as failure impact resistance of the concrete is given by concrete having 1.50% superplasticizers content and 15% silica fume with (w/c)ratio 0.29 followed by concrete containing 1.50 % superplasticizers content and 15% silica fume with (w/c)ratio 0.30 content **Reason is that** due to confinement provided by superplasticizers bonding characteristics of concrete increases and improving the interfacial zone, reducing the potential stress concentration between the aggregate and the cement paste.

In general, it can be concluded that on increasing the percentage compressive strength , the impact resistance at first crack as well as at ultimate failure increases. Further, it can also be concluded that incorporation of superplasticizers content in the plain concrete has significantly improved the impact resistance of concrete.

4. Conclusions:

The data collected in this investigation may be led to the following conclusions:

1. Compressive strength increases for all dosage of chemical and mineral admixture than normal concrete. The high early age strength achieved with the addition of micro-silica may be attributed to its finer particle size, resulting in an increased hydration rate.
2. The compressive strength for NSC and HSC mixtures at 28 days vary according to admixtures. The highest compressive strength is achieved by mixture C11 followed by mixtures C7 and C8 for both seven and 28 days.
3. The addition of different amounts of admixture gave average compressive strength values range from (33.34 to 62.912) MPa as compared with the reference mixture.
4. The addition of (0.25) of superplasticizers as a percentage of cement content with 0.45 (w/c)ratio leads to an increasing in the impact resistance by (4.4 %), while the increasing in the impact resistance was (725.56 %) with the addition of (1.5) super plasticizers as a percentage of cement content and 15.0% of silica fume and 0.29 (w/c)ratio as compared with the reference mixture.
5. Mixture C11 containing 1.5 superplasticizers as a percentage of cement content and 15.0% of silica fume and 0.29 (w/c)ratio shows the highest compressive strength (62.912 MPa), and increasing in the impact resistance by (725.56 %) as compared with the reference mixture.
6. All mixtures exhibited substantially higher rates of impact resistance gain as compared with the reference mixture.

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