Effect of Mineral Admixtures and Recycled Concrete on Concrete Compressive Strength

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Abstract

Reducing the quantity of cement used in concrete has been a goal for several years. Mineral admixtures such as silica fume, fly ash and metakaolin are used to replace cement in this research. This research aims to improve concrete compressive strength while becoming greener at the same time. Another aspect is to replace fine and coarse aggregates in concrete with others made of recycled concrete. Experimental tests are conducted by comparing the results of control concrete samples with those where 10% and 15% silica fume and fly ash are used. Metakaolin is utilized by 10%, 15% and 20% by weight of cement. Recycled fine aggregate percentages are 25%,50% and 100% by weight of new fine aggregate. Meanwhile, recycled coarse aggregate percentages are 50% and 100%. From this applied study it is found that the 90- and 28-days optimum percentage of silica fume, fly ash and metakaolin compared to other percentages is 10% which leads to an increase in compressive strength by up to 23%. As for the optimum percentage of recycled concrete coarse and fine aggregates, it is found to be 50% and it corresponds to 33% increase in compressive strength at 90 and 28 days.

Keywords Compressive strength, Fly ash, Silica Fume, Ductility, Meta Kaolin, Slag

Introduction

Replacing cement and/or different concrete constituents with greener materials and at the same time improving concrete compressive strength is nowadays a goal to achieve. Mineral admixtures (1) are used to improve consistency, setting time, workability, corrosion resistance and compressive strength of concrete. Examples of mineral admixtures: fly ash, silica fume systems and metakaolin. Shan Wu shows that using mineral admixtures improve structure of cement paste, fill the gap between cement particles and reduce hydration temperature. Jan Pizon (2) uses ground granulated blast furnace slag in concrete by 35% to decrease setting time by 40%-50% in addition to achieving required compressive strength of concrete in shorter time. Another paper (3) conducted experimental research to study the influence of crystalline, pure and marl limestone aggregates. Both concrete compactness along with chemical activity are enhanced as a result. Nabil Abdelmelek (4) investigates metakaolin percentage and water binder ratio in high temperature. Improvement in cracking and several mechanical properties in presence of elevated temperature are observed. Magudeaswaran Palanisamy (5) uses combination of different natural pozzolanic materials for instance: sand, limestone, granulated blast furnace slag, fly ash, glass cullet and ceramic waste to replace cement. The best two mixtures (6) obtained are first ordinary Portland cement, fly ash and silica fume or second replacing cement with fly ash and silica fume. The goal is to prepare high performance concrete by using mineral admixtures like fly ash and ground granulated blast furnace slag with optimum ratio relative Portland cement weight along with determining various mechanical properties of concrete. Maximum compressive and flexural strength is recorded when using 10% fly ash and 10% ground granulated blast furnace slag. Metakaolin (7, 8 and 9) replaces weight of cement by ratios 5%, 10%, 15% and 20%. The best percentage is found to be 15% with increase in compressive strength by 15%. Both metakaolin and nylon fibers are used to study various properties of concrete (10). Surprisingly, optimum ratio of metakaolin is 5% and nylon fiber is 0.5%. Sikament (11) M163 is added to concrete mixture to enhance compressive strength with ratios 0.5%, 1%, 3% by weight of cement. The highest compressive strength recorded is when using Sikament M163 with 0.5%.

Recycled aggregates present an opportunity to reduce the cost of manufactured concrete as well as solving the dilemma of getting rid of construction wastes. Accordingly, previous researchers (12) tested its properties when added to concrete. However, previous research shows that compressive strength and elastic modulus are decreased besides the difference in failure mechanism compared to traditional concrete, therefore it is important to overcome this problem. Another research (13) showed that recycled aggregate can replace cement by 25% and 100% but the result is lowered properties of concrete. Thus, the recommended percentage is found to be from 50% to 75%. Self-compacting concrete with water cement content of 0.42 is studied when using silica fumes and super plasticizers (14). Conducted tests include slump cone and V-funnel tests on fresh concrete while compressive strength, split tensile strength and flexural strength are carried out on hardened concrete. Results at 7- and 28-days show that optimum ratio of silica fumes is 10%. The effect of several admixtures including; sludge, ceramic powder, flyash, GGBS, nano silica and Silica Fume is studied by Poloju et al. (15). The results show that admixture ratios range from 10% to 30% although more detailed tests are needed. Basalt as an admixture in concrete is also studied by Karasin et al. (16) where improved concrete compressive strength is observed. Super plasticizers admixtures are added to concrete specimens by Nawabsab (17) where they improve the workability and decrease cement content up to 23%. Effect of using metakaolin, ultra-fine fly ash, and silica fume in concrete specimens is investigated by Xupeng et al. (18). Both compressive strength and the splitting tensile strength of concrete at various curing ages are studied. Metakaolin is faster in improving compressive strength of specimens than silica fume.

The purpose of this paper is to conduct more detailed research on the effect of replacing partially cement with mineral admixtures. The study includes Silica Fume (S.F), Fly Ash (F.A), Meta Kaolin (M.K), and Sikament M163. In addition to studying replacement of fine or coarse aggregate with recycled concrete which aims to obtain improved concrete compressive strength using optimum ratios.

Materials and methods

All experimental work is according to the Egyptian standard specification. Two groups of specimens are prepared; one to study optimum ratios of different mineral admixtures that attain maximum compressive strength and the other to study the effect of recycled aggregate on compressive strength of concrete. Experimental work is summarized as following:

Optimum percentage of mineral admixtures

It is conducted by preparing control group and different groups of cubes and cylinders are prepared as shown in Fig. (1). First control group does not contain any admixtures (C1), each group contains different admixture with various ratios of cement weight while using Sikament M163 as super plasticizer. Each group consists of three cubes and three cylinders tested at 7 days and six cubes and three cylinders tested at 28 days. Group (1) is called S.F where Silica Fume is studied with two ratios 10% and 15% as shown in table (1). Similarly, Group (2) F.A contains Fly Ash with percentages 10% and 15%, meanwhile group (3) M.k. has Meta kaolin with ratios 10%, 15% and 20%. Fig. (1) shows tested concrete containing mineral admixtures, also concrete mix design is shown in table (1) where details of each group are shown.

Replacing fine or coarse aggregate with recycled concrete

It is carried out by studying five different concrete mix proportions and comparing them to control group. Either recycled fine aggregates or coarse aggregates partially replace new ones along with using Sikament M163 as super plasticizer. Both normal and recycled coarse and fine aggregates are used where maximum nominal size of coarse aggregates is 25 mm. Control specimen contains no recycled concrete, meanwhile, RF25 replaces fine aggregate by recycled concrete by 25% by weight. RF50 and RF100 are likely to have replacement ratios 50% and 100% respectively by weight. While RC50 and RC100 represent replacing coarse aggregate by 50% and 100% respectively. On the other hand, coarse aggregate is replaced by 50% and 100%. Each mixture contains three cubes and cylinders, cubes are removed 24 hours after casting, and the curing is done by putting in water for 7 days then tested afterwards. Fig. (2) Tested concrete containing recycled aggregates. Mix design is shown in table (2).

Several experimental tests are conducted on all ingredients used in the concrete for instance: sieve analysis, specific gravity of combined aggregate, bulk density and percentage of voids for combined aggregate, absorption percentage for coarse aggregate, crushing value percentage and Los Angeles Abrasion Percentage, crushing factor for coarse aggregate. Standard water ratio, initial setting time, cement stability test, fineness of cement with sieve 170, slump test are shown in Fig. (3), splitting tensile, modulus of elasticity and compressive strength. Test machine is shown in Fig. (4) where cube specimen is placed in it.

Results and discussion

Failure mode of specimens containing mineral admixtures is shown in the following figures. Failure occurs in cement paste in cubes containing S.F as shown in Fig. (5). Outer layer near cube surface shows cracks in F.A specimens according to Fig. (6). Splitting of cylinders into equal halves is observed in M.K specimens as seen in Fig. (7). It is noticed that changing percentage of mineral admixture does not affect failure mode which is obvious in Figs. (7) and (8).

Failure mode of specimens containing recycled concrete

When placing a cube that contains recycled concrete in the testing machine, upon reaching cracking load crashing of outer layers along with tiny parts of the specimen as shown in Fig. (9). It is noticed that when either fine or coarse aggregates are replaced the same failure shape occurs.

Compressive and tensile strength results

Since each group is composed of three cubes and the authors aim to highlight the difference in results, the results of each group is compared with average results of the control group. No increase in compressive strength is noticed in all groups except in group 1 where 15% of S.F causes an increase equal to 29% in compressive strength as shown in table (3) and Fig. (10) because of filling internal pores of concrete. It is worth to mention that effect of most admixtures is not attained at 28 days which is attributed to their characteristics that are associated with late strength enhancement.

Concrete cubes that contain recycled concrete show an increase in compressive strength by up to 16% in RF50 as seen in table (5) when compared to control specimen. Also, RC100 shows improvement in compressive strength by 6% compared to control values. RF100 and RF25 have a minimum increase of 5% and

3% in compressive strength respectively when compared to corresponding control values. Finally, RC50 shows a decrease in strength compressive when compared to control compressive strength.

The results of tensile strength of cubes at 7 days are shown in table (4) and Fig. (11). Adding mineral admixtures to concrete decreased the results when compared to control group. The maximum decrease in results is by 39% observed in group 2 when F.A is 15%. Concrete cubes that contain recycled concrete show an increase by 4% in tensile strength in RF50 as seen in table (5) when compared to control specimen. Also, RC100 shows improvement in tensile strength by 15% when compared to control values. RF100 has decrease in tensile strength by 3% because of comparison with control results. RF25 show a decrease in tensile strength by 7% regarding control values. Finally, RC50 shows a decrease in tensile strength.

Compressive strength at 28 days, when adding S.F by 10% increases by 23% compared to the control specimen at 28 days as shown in table (6) and Fig. (10). An increase with 20% is noticed in F.A 10% when compared to control specimen. Group 3 shows that MK influence varies based on its ratio in the specimen where M.K 10% is used, an improvement in compressive strength by 12% is noticed. Similarly, when 20% M.K is used in cubes, improvement in compressive strength is only 4%. However, a slight decrease by 4% is observed when M.K is 15%. Hence the optimum ratio is 10% which disagrees with previous research conducted by Magudeaswaran Palanisamy (5) where the optimum ratio is 15%. Cubes with recycled concrete show increase in compressive strength by 31% in specimen with RF25 when compared to control specimen because cement paste gaps are filled with it, as a result strength improves. As RF percentage increases, bond between coarse aggregate and cement paste decreases and more water content is needed to complete the cement reaction and full strength is attained where specimen with RF100 corresponds to increase 11% in compressive strength. Finally, RC50 and RC100 show increase by 33% and 27% in compressive strength respectively when compared to control specimen due to their role in mechanical strength and decrease cement and water consumption.

Studying the results of tensile strength of S.F 15% at 28 days, shows increase by 34% more than tensile strength of control specimen according to table (7) and Fig. (11). All specimens containing S.F 10% shows decrease in tensile strength by up to 16% when compared to control specimen. Most researchers focus on the role of S.F in compressive strength of concrete without noticing its influence on tensile strength. The nature of S.F which consists of very fine particles has negative impact on tensile strength of concrete. On the contrary, table (8) shows improvement in tensile strength by 13%, 30% and 26% respectively when comparing cylinders containing RF25, 50 and 100 with control cylinder. Clearly, optimum RF percentage to fill voids is 50. Fine aggregates are associated with increasing bond between aggregate and binder substances, however increasing their ratios reduce bond strength between concrete particles. The maximum increase in tensile strength is in RC100 which reaches 43% when compared to control specimen. This is associated with nature of large particles of coarse recycled concrete which plays key role in concrete strength in general.

Compressive and tensile strength results at 90 days

When specimens are compared to control group at 90 days where adding S.f by 10% shows increase in compressive strength by up to 23% as shown in table (9) and Fig. (10). On the other hand, when S.F 15% is added to concrete, the increase in compressive strength is only up to 16%. The result of F.A 10% is 20% increase in compressive strength, while 15% F.A corresponds to 12% improvement in results of compressive strength. Group 3 shows the influence of M.K, where when 10% M.K is used in cubes highest improvement in compressive strength is obtained by up to 12%. On the contrary, a decrease in results by 4% is noticed when M.K ratio is 15% and a slight increase by 4% is observed when M.K is 20%.

When comparing specimen with S.F 10% to control specimen, a decline of 10% is observed, while when S.F is 15%, an escalation in tensile strength of 30% is noticed. As shown in table (10) and Fig. (11), Group 2 shows a decrease in tensile strength by 10% for specimen with F.A equal 10%. Group 3, where M.K. in specimen is 15%, the improvement in results is 10%, however no change is observed in other specimens with different M.K. ratios.

Conclusions

Based on the conducted tests and the analyzed results, concrete withstands higher compressive strength up to 23% when adding 10% silica fume to concrete. On the other hand, optimum percentage of fly ash is 10% which corresponds to 20% increase in compressive strength. It is advisable to add 10% Metakaolin to the concrete specimen which leads to improve the compressive strength by 12%. Using recycled aggregate by 50% replacement increases compressive strength by 33%. Regarding tensile strength of concrete, using 50% fine recycled concrete is associated with 30% enhancement. Meanwhile, using 100% coarse recycled concrete promotes 43% higher tensile strength.

References

1. Shan Wu, “Application of Mineral Admixture in High Performance Concrete”, Global Journal of Researches in Engineering: G Industrial Engineering, (19) 1, 2019
2. Jan PizoĔn,*, Patrycja Mieraa , Beata àaĨniewska-Piekarczyka “Influence of Hardening Accelerating Admixtures on Properties of Cement with Ground Granulated Blast Furnace Slag”, World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium 2016, WMCAUS 2016.
3. Y. Biskri , *, D. Achoura , N. Chelghoum , R. Jauberthie, ” Effect of mineral admixtures and aggregate natures on the behavior of high performance concrete”, J. Mater. Environ. Sci. 7 (7), 2617-2628, 2016.
4. Nabil Abdelmelek, Eva Lubloy” Evaluation of the mechanical properties of high-strength cement paste at elevated temperatures using metakaolin”, Journal of Thermal Analysis and Calorimetry, 2019.
5. Magudeaswaran Palanisamy, Vaishali Panneer Selvam” Incorporating Mineral Admixtures in High Performance Green Concrete”, International Journal of Applied Engineering Research 10(47):32359-32367, 2015.

6. Anjali Prajapati, Piyush Prajapati, Mohammed Qureshi” An experimental study on high performance concrete using mineral admixtures”, International Journal of Engineering Development and Research, 5 (2), 2017.
7. M. Narmatha and T. Felixkala” Metakaolin –The best material for replacement of cement in concrete”, International Journal of Advanced Research 4(7) : 1690-1696, 2016.
8. R. Sivakumar, N. Mohanraj , D. Saratahkumar , T.S. Venkatachalam” Effect of Metakaolinon Strength Characteristics of Concrete”, International Journal of Chem Tech Research 10(4) : 213-218, 2017. Same as 7
9. Adel Al Menhosh, Yan Wang, and Yu Wang” The Mechanical Properties of the Concrete Using Metakaolin Additive and Polymer Admixture”, Hindawi Publishing Corporation Journal of Engineering, 2016.
10. Mohd Hanif Ismail , Noor Syuhaili Mohd Rusly, Rafikullah Deraman” Strength and Water Absorption of Concrete Containing Metakaolin and Nylon Fiber”, International journal of sustainable construction engineering and technology 11(1) 230-242, 2020.
11. محمد الكيلانى يحي, حمزة حمودة أحمد محمد بشير محمد تأثير مادة السيكامنت (163) المضافة على مقاومة الضغط للخرسانة, Journal of Pure & Applied Sciences 18 (4), 2019
12. Minkwan Ju , Kyoungsoo Park and Won-Jun Park, “Mechanical Behavior of Recycled Fine Aggregate Concrete with High Slump Property in Normal- and High-Strength”, International Journal of Concrete Structures and Materials 13:61
13. Lucy Feleke Nigussie , Muge Mukaddes Darwish and Tewodros Ghebrab, “Comparative Investigation of the Effect of Recycled Fine Aggregate from New and Old Construction Wastes in C-25 Concrete in Ethiopia”, *Sustainability 11*(24), 7116; 2019.
14. Muskaan Shaker, and Ashish Kumar” A Study on Understanding the Effects of Admixtures on the Properties of Self Compacting Concrete”, *International Journal of Innovative Research in Engineering & Management (IJIREM)9* (6), 2022.
15. Kiran Kumar Poloju, Chiranjeevi Rahul, Ram Kishore Manchiryal,” Impact of Admixtures on Strength Properties of Concrete”, *Proceedings of First National Conference On Sustainable Innovative Trends In Civil Engineering*;138-144, 2021.
16. Abdulhalim Karasin, Marijana Hadzima-Nyarko, Ercan Isık, Murat Do ˘gruyol, Ibrahim Baran Karasin and Sławomir Czarnecki” The Effect of Basalt Aggregates and Mineral Admixtures on the Mechanical Properties of Concrete Exposed to Sulphate Attacks”, *Materials,* 2022.
17. Shaikhdar Mufiturrahemanwahed Nawabsab Prof. Hamane A. A. “The Effect of Admixtures on Concrete Properties”, *International Journal of Advances in Engineering and Management (IJAEM)4* (8), 1141-1147;2022.
18. Chen Xupeng, Sun Zhuowen and Pang Jianyong “Effects of active mineral admixture on mechanical properties and durability of concrete, *Materials research express 8*; 2021.

Fig. (1) Tested concrete containing mineral admixtures

Fig. (2) Tested concrete containing recycled aggregates

Fig. (3) Slump test for fresh concrete

Fig. (4) Test machine

Fig. (5) Failure in S.F 10%

Fig. (6): **Failure shape of specimen F.A 15%**

Fig. (7): **Failure shape of specimen M.K 10%**

Fig. (8): Failure shape of specimen M.K 20%

Fig. (9): Failure shape of specimen with recycled concrete

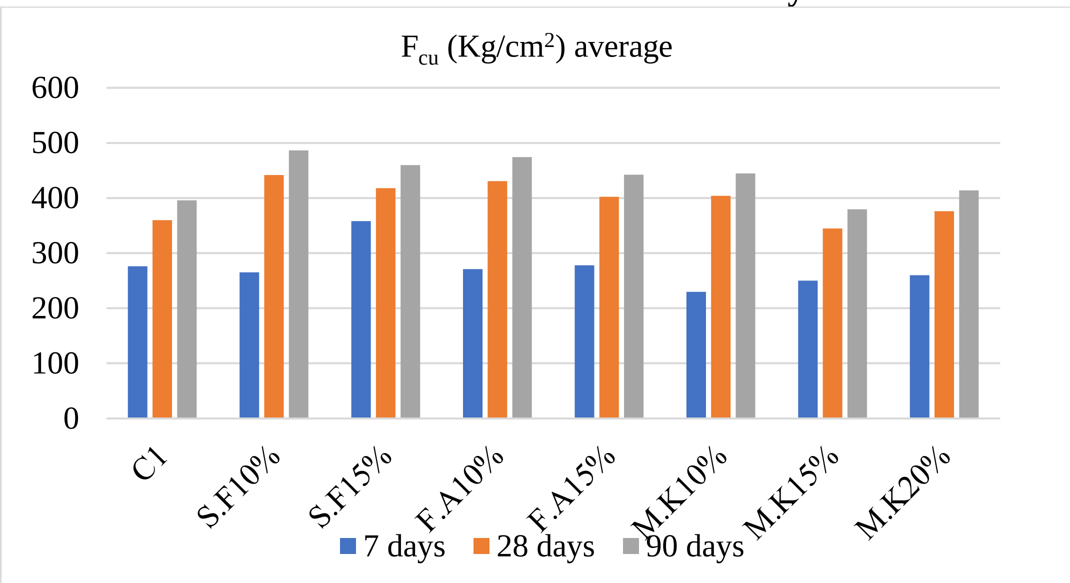

Fig. (10) Compressive strength of cubes for all groups at 7, 28 and 90 days

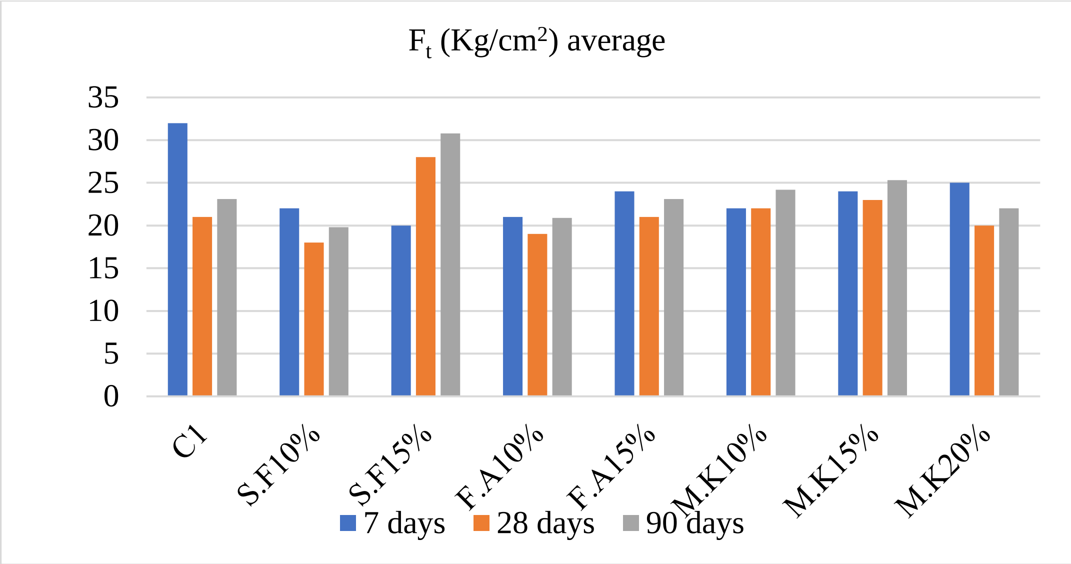

Fig. (11) Tensile strength of cylinders for all groups at 7,28 and 90 days

Table (1) Concrete mix proportions of five groups with mineral admixtures

Mix	code	The ratio %	Cement	Coarse Aggregate	Fine Aggregate	Water	Sika mint	Additional Kg
Control	C1	-	350	1087	673	183	43	—
Group1	S.F	10	350	1087	673	183	43	35
		15				184	43	52
Group2	F.A	10	350	1087	673	183	43	35
		15				185	43	52
Group3	M.K	10	350	1087	673	183	43	35
		15				185	43	52
		20				214	43	69

Table (2) Concrete mix proportions of recycled concrete

Mix Name	Cement (kg)	Water (liter)	Sikament (gm.)	F.A (kg)	C.A (kg)	R.F.A (kg)	R.C.A (kg)
Control	389	206	50	756	1223	0	0
RF25	389	206	50	567	1223	189	0
RF50	389	206	50	378	1223	378	0
RF100	389	206	50	0	1223	756	0
RC50	389	206	50	756	612	0	611
RC100	389	206	50	756	0	0	1223

Table (3) The 7 days compressive strength results.

Mix	code	Specimen	F_{cu} Kg/cm^2	$F_{cuav.}$ Kg/cm^2	Density Kg/m^3
Control	C1	Cube 1	242	276	2380
		Cube 2	288		2402
		Cube 3	299		2415
Group1	S.F10%	Cube 1	238	265	2447
		Cube 2	272		2424
		Cube 3	285		2441
	S.F15%	Cube 1	376	358	2439
		Cube 2	362		2427
		Cube 3	335		2400
Group2	F.A 10%	Cube 1	290	271	2400
		Cube 2	279		2397
		Cube 3	245		2492
	F.A 15%	Cube 1	272	278	2430
		Cube 2	281		2419
		Cube 3	281		2412
Group3	M.K 10%	Cube 1	217	230	2400
		Cube 2	236		2473
		Cube 3	238		2437
	M.K 15%	Cube 1	156	250	2383
		Cube 2	238		2405

		Cube 3	263		2376
	M.K 20%	Cube 1	270	260	2477
		Cube 2	247		2445
		Cube 3	263		2426

Table (4) The 7 days splitting tensile strength results.

Mix	code	Specimen	F_t Kg/cm^2	$F_{tav.}$ Kg/cm^2
Control	C1	Cylinder 1	34	32
		Cylinder 2	31	
		Cylinder 3	32	
Group1	S.F10%	Cylinder 1	22	22
		Cylinder 2	22	
		Cylinder 3	22	
	S.F15%	Cylinder 1	19	20
		Cylinder 2	21	
		Cylinder 3	20	
Group2	F.A 10%	Cylinder 1	21	21
		Cylinder 2	21	
		Cylinder 3	21	
	F.A 15%	Cylinder 1	24	24
		Cylinder 2	24	
		Cylinder 3	24	
Group3	M.K 10%	Cylinder 1	22	22
		Cylinder 2	21	
		Cylinder 3	22	
	M.K 15%	Cylinder 1	24	24
		Cylinder 2	24	
		Cylinder 3	24	
	M.K 20%	Cylinder 1	24	25

Table (5) Test results of cubes and cylinders of recycled concrete at 7 days

Mix Name	Compression (Kg/Cm^2)			Tension (Kg/Cm^2)		Avg. Comp.	Avg. Tens.
	Cube1	Cube2	Cube3	Cylinder1	Cylinder2	σ_c	σ_t
Control	234	240	247	26	25	241	26
RF25	227	268	247	21	27	248	24
RF50	263	295	277	25	29	279	27
RF100	254	238	268	29	21	254	25
RC50	204	231	195	23	25	210	24
RC100	236	277	254	28	32	256	30

Table (6) Test results of cubes at 28 days

Mix	code	Specimen	Compression Kg/cm^2	Avg. Comp. Kg/cm^2	Density Kg/m^3
Control	C1	Cube 1	335	360	2578
		Cube 2	317		2399
		Cube 3	353		2495
		Cube 4	421		2620
		Cube 5	440		2479
		Cube 6	294		2388
Group 1	S.F10%	Cube 1	444	442	2400
		Cube 2	385		2415
		Cube 3	521		2380
		Cube 4	439		2504
		Cube 5	449		2407
		Cube 6	412		2466
	S.F15%	Cube 1	376	418	2439
		Cube 2	362		2427
		Cube 3	335		2400
		Cube 4	535		2492
		Cube 5	453		2442
		Cube 6	390		2610
Group 2	F.A 10%	Cube 1	417	431	2400
		Cube 2	430		2397
		Cube 3	476		2492
		Cube 4	453		2471
		Cube 5	421		2593
		Cube 6	390		2373

	F.A 15%	Cube 1	417	402	2430
		Cube 2	476		2419
		Cube 3	421		2412
		Cube 4	326		2495
		Cube 5	403		2474
		Cube 6	367		2501
Group 3	M.K 10%	Cube 1	410	404	2412
		Cube 2	426		2510
		Cube 3	335		2615
		Cube 4	485		2445
		Cube 5	390		2613
		Cube 6	381		2581
	M.K 15%	Cube 1	340	345	2640
		Cube 2	353		2566
		Cube 3	372		2522
		Cube 4	322		2548
		Cube 5	340		2513
		Cube 6	344		2646
	M.K 20%	Cube 1	408	376	2542
		Cube 2	453		2559
		Cube 3	340		2511
		Cube 4	299		2610
		Cube 5	64		2652
		Cube 6	62		2604

Table (7) Test results of cylinders at 28 days

Mix	code	Specimen	Tension Kg/cm^2	Avg. Tens. Kg/cm^2
Control	C1	Cylinder 1	19	21
		Cylinder 2	22	
		Cylinder 3	22	
Group1	S.F10%	Cylinder 1	21	18
		Cylinder 2	14	
		Cylinder 3	18	
	S.F15%	Cylinder 1	29	28
		Cylinder 2	31	
		Cylinder 3	24	
Group2	F.A 10%	Cylinder 1	19	19
		Cylinder 2	20	
		Cylinder 3	19	
	F.A 15%	Cylinder 1	16	21

		Cylinder 2	24	
		Cylinder 3	24	
Group3	M.K 10%	Cylinder 1	19	22
		Cylinder 2	20	
		Cylinder 3	26	
	M.K 15%	Cylinder 1	29	23
		Cylinder 2	20	
		Cylinder 3	19	
	M.K 20%	Cylinder 1	20	20
		Cylinder 2	19	
		Cylinder 3	20	

Table (8) The 28 days compressive and tensile strengths results

Mix Name	Compression (Kg/Cm^2)			Tension (Kg/Cm^2)		Avg. Comp.	Avg. Tens.
	Cube1	Cube2	Cube3	Cylinder1	Cylinder2	σ_c	σ_t
Control	363	317	295	22	23	325	23
RF25	404	376	498	26	26	426	26
RF50	402	390	406	27	33	399	30
RF100	380	327	376	26	32	361	29
RC50	215	221	216	25	26	217	26
RC100	385	378	476	36	29	413	33

Table (9) The 90 days compressive strength results

Mix	code	Specimen	Compression Kg/cm^2	Avg. Comp. Kg/cm^2	Density Kg/m^3
Control	C1	Cube 1	369	396	2836
		Cube 2	349		2639
		Cube 3	389		2745
		Cube 4	463		2882
		Cube 5	483		2726
		Cube 6	324		2627
Group 1	S.F10%	Cube 1	488	486	2641
		Cube 2	424		2656
		Cube 3	573		2618
		Cube 4	483		2755
		Cube 5	493		2648
		Cube 6	453		2712
	S.F15%	Cube 1	414	460	2682
		Cube 2	399		2669
		Cube 3	369		2640
		Cube 4	588		2741
		Cube 5	498		2686
		Cube 6	429		2871
Group 2	F.A 10%	Cube 1	458	474	2640
		Cube 2	473		2637
		Cube 3	523		2741
		Cube 4	498		2718
		Cube 5	463		2852
		Cube 6	429		2611
	F.A 15%	Cube 1	458	442	2673
		Cube 2	523		2661
		Cube 3	463		2653
		Cube 4	359		2744
		Cube 5	444		2721
		Cube 6	404		2751
Group 3	M.K 10%	Cube 1	451	445	2653
		Cube 2	468		2761
		Cube 3	369		2877
		Cube 4	533		2690
		Cube 5	429		2875
		Cube 6	419		2839
	M.K 15%	Cube 1	374	380	2904
		Cube 2	389		2823

		Cube 3	409		2774
		Cube 4	354		2803
		Cube 5	374		2764
		Cube 6	379		2911
	M.K 20%	Cube 1	449	414	2796
		Cube 2	498		2814
		Cube 3	374		2762
		Cube 4	329		2871
		Cube 5	424		2917
		Cube 6	409		2865

Table (10) The 90 days tensile strength results

Mix	code	Specimen	Tension Kg/cm^2	Avg. Tens. Kg/cm^2
Control	C1	Cylinder 1	21	23
		Cylinder 2	25	
		Cylinder 3	24	
Group1	S.F10%	Cylinder 1	23	19
		Cylinder 2	15	
		Cylinder 3	20	
	S.F15%	Cylinder 1	32	31
		Cylinder 2	35	
		Cylinder 3	26	
Group2	F.A 10%	Cylinder 1	21	21
		Cylinder 2	23	

		Cylinder 3	21	
	F.A 15%	Cylinder 1	17	23
		Cylinder 2	26	
		Cylinder 3	26	
Group3	M.K 10%	Cylinder 1	21	24
		Cylinder 2	23	
		Cylinder 3	29	
	M.K 15%	Cylinder 1	32	25
		Cylinder 2	23	
		Cylinder 3	21	
	M.K 20%	Cylinder 1	22	22
		Cylinder 2	21	
		Cylinder 3	23	