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Nanomaterial to Improve Ferrocement Properties for Green Buildings

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Abstract

Nowadays, nanomaterial has been used extensively worldwide to improve the properties of the constructional materials due to many advantages that can be achieved especially improving strength/weight ratio which is highly desired by the engineers towards a green building concept by minimizing the material used and increasing the stresses levels that the structure can carry. The present research examined the mechanical properties of nano cement mortar which can lead to improvements in ferrocement to be used in the green building system. Thus 90 cubes, 50 mm, and 500×50 mm prisms varying thickness (t=4, 6, 8 and 10 mm) were cast and tested to determine the compressive strength, and modulus of rupture, for nano cement mortar at curing age of 28 days, In addition, 50 nano-ferrocement prisms (500×50 mm) with varying the thickness (t=4, 6, 8 and 10 mm), number of fine wire mesh layers, mix proportions were cast and flexural tests were carried out to determine the composite modulus of elasticity and modulus of rupture. It was observed that the compressive and flexural strengths were increased for the nano-ferrocement samples in comparison with the normal one which refers to the importance of developed mixture toward sustainable building.

Keywords: Nanomaterial; Ferrocement building; Cement mortar

Abbreviations: ACI: American Concrete Institute; ASTM: American Society for Testing and Materials; CNT: Carbon Nano Tube; CNF: Carbon Nano Fibre; NSCSC: Nano Sand Cement Silica Fum Clay; MWCNT: Multiwall Carbon Nano Tube

Introduction

In general, a green building which is also known as green construction or sustainable building, refers to both a structure as well as adopting processes that are environmentally friendly and uses the resources efficiently during the life cycle of the building that from the design, material, construction, air quality, maintenance and even demolition. Green buildings must be designed to meet one of certain objective such as the use of energy more efficiently which eventually will influence positively on the reduction of the CO_2 emission, and hence minimize the impact of the global warming. Many constructional trends have been implemented around the world to fulfill the green buildings requirements through the design and the material used. However, a structural system based on generic services facilities is introduced by Al-Rifaie and prefabricated ferrocement cavity walls/ and roofs within the proposed system present a series of possibilities for the solution of building construction at maximum reduction of the electrical energy. Ferrocement is recognized as a composite material of great potential made of cement- sand mortar and layers of very fine steel wire meshes. The material was found wide applications because of high tensile strength, imperviousness to water and crack free performance. The relationship between several elements such as building materials of natural and manufactured building materials and renewable energy sources and energy sources depleted should be determined.

Ferrocement is a type of thin reinforced concrete with great potential, made of cement–sand mortar and reinforced with layers of fine wire meshes with or without skeletal reinforcement [1-3]. Ferrocement is an excellent construction material due to its mechanical properties, and low cost, and it is considered to possess a high cracking strength. Cement mortar is a material used in construction of ferrocement which is cement composite material made up of Portland cement, sand, water and sometimes admixtures.

Investigators and researchers have been focusing on the substantial scientific background of the nanomaterial, where a continuous efforts have been done to improve the durability and the sustainability of concrete, and improving the mechanical properties of cementitious materials by using nano-materials [4,5]. The addition of some metal oxide nanoparticles to concretes can both reduce the permeability of concrete to ions and increase the strength of concrete, thereby improving durability. The addition Fe_2O_3 nanoparticles [6], SiO_2 nanoparticles [7] and metal oxide containing nano clays [8] have all been shown to improve concrete and/or cement mortar properties. Properties of the cement-based composites made from the CNTs/CNFs-grown cement/ mineral admixture were presented. Experimentally, Li et al. [9] studied the mechanical properties of nano-Fe_2O_3 and nano-SiO_2 cement mortars.

The flexural strength of a very thin ferrocement element, by using NSCSC mortar as a replacement to the normal cement mortar, usually used in ferrocement elements was examined. The measured results showed an increase the flexural strength of a very thin ferrocement using NSCSC mortar [10]. Zhang and Li [11] found that the addition of 1% by weight of binder of 15 nm diameter TiO_2 to concrete refined the pore structure and increased the resistance to chloride penetration by 31%.

Oscar et al. [12] studied the effect of the reagglomeration process of Multi-Walled Carbon Nanotubes (MWCNT) dispersions on the activity of silica nanoparticles at early ages when they are combined in cement matrixes. MWCNT/water/superplasticizer dispersions were produced via sonication and combined with nano silica particles in the mixing water of the cement samples. The methods and theories of *in situ* growth of CNTs/CNFs on cement/mineral admixture, including chemical vapour deposition method and microwave irradiating

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conductive polymers method, were summarized [13]. The addition of SiO_2 nanoparticles is widely reported to be effective for strengthening concrete; both normally vibrated concrete and self-compacting concrete [14].

Al-Rifaie et al. [15] examined the compressive and flexural strength of nano cement mortar by using micro cement, micro sand, nano silica and nano clay in developing a nano cement mortar which can lead to improvements in ferrocement construction. In addition, the influence of heating on compressive strength of cement mortar, whereas ferrocement eco-housing system was able to produce very energy efficient dwellings [16].

Generally, cement-based materials containing SiO_2 nanoparticles are stronger than those containing SiO_2 fume [14]. This is attributed to the accelerated cement hydration, increased pozzolanic activity, reduced pore size and improved interfacial bonding between the hardened cement paste and aggregate that is associated with the decreased average particle size of the SiO_2 [17]. The effect of elevated temperatures on chemical composition, microstructure and mechanical properties of high strength mortars with nano alumina was investigated [18]. Effect of nano clay particles on mechanical, thermal and physical behaviours of waste-glass cement mortars was investigated [19]. Finite element method was used to investigate the impact of inclusion in hypothetical nano composite [20], cracked nano composite [21], debonding between the nanofiber and the matrix [22], pre-crack existence in nanocomposite [23] as well as studying the impact of the mismatch properties [24]. Moreover, FEA has been used to investigate the effect of the nanoinclusion [25], interfacial debonding defects [26], interfacial defects [27] and fractured particulate composite [28] on the characteristics and failure of the nano composite, whereas the development of nano structural element called "nano-polymercement" which can be used for different applications [29], whereas effect of nanomaterials in cement mortar characteristics was studied by Al-Rifaie and Ahmed [30].

Towards impenimg a green building concept by improving the ferrocement properties which will reduce the material used for the construction and hence maximize the allowable stresses that can be adopted in the design of a building, the authors present a research work to examine the mechanical properties of nano particles in developing a cement mortar which can lead to improvements in the performance of ferrocement as structural elements in the structural system for green housing. Cubes and prisms were cast and tested for determining compressive strength, and modulus of rupture of nano cement mortar. The parameters considered during the investigation were micro sand, micro cement, and wire mesh layers.

Materials and Methods

Materials used

α) Micro Portland cement, conforming ASTM C150 type I.

β) Micro sand 600 μm, conforming ASTM C33-01.

χ) Fumed silica, the chemical composition is given in Table 1.

δ) Metakaoline clay (200-3) μm by burning kaoline clay up to 700°C for a period of 2 hrs. The chemical composition is given in Table 2.

ε) Wire mesh: welded square mesh used in the present work had an average wire diameter and aperture of 0.25 mm and 2.5×2.5 mm respectively. The yield strength F_y, elastic modulus E_w, and ultimate tensile strength F_u, were obtained using direct tensile tests. The test was conducted on wire mesh according to ACI-Code 549. The average values of modulus of elasticity (E_w), upper yield stress (F_y), and ultimate tensile stress (F_{ult}) of wire mesh are 66100 MPa, 320.5 MPa, and 350 MPa respectively.

Specification	Parameter
200 (160-240)	Specific surface, m^2/g
3.7-4.7	pH-value
3	Loss on drying, %
>99.0	SiO_2- concentration, %

Table 1: Chemical composition of (fumed silica).

Burn Loses%	SO_3 %	SiO_2, Al_2O_3, Fe_2O_3%
1.37	2.1	95.53
Water: Ordinary tap water was used throughout the present investigation with a pH level of 6.5–8.5 [32]		

Table 2: Chemical composition of metakaoline clay.

Testing procedure

The nano cement mortar matrices considered during the present investigation may be summarized in the following groups:

- Group A: Micro sand/ micro cement ratio 1/ 1, 1.5/1, 2/ 1, 2.5/1, 3/1 with w:c ratio=0.4.
- Group B: Micro sand/ micro cement ratio 1/ 1, 1.5/1, 2/ 1, 2.5/1, 3/1, each with fumed silica (1% of micro cement by weight) and 10% of micro cement by weight was replaced by metakaoline clay. w:c ratio=0.4.

Compressive strength, the following tests were conducted according to ASTM C109:

a) Compressive strength at age of 28 curing days:

Twenty five 50 mm mortar cube specimens with mortar group A.

b) Compressive strength at age of 28 curing days:

Seventy five 50 mm mortar cube specimens with mortar group B.

Modulus of rupture:

The prisms considered in the present work are detailed in Table 3.

a) Four point bending tests were performed on 30 prisms 160×40×40 mm of mortar groups A and B after 28 curing days according to ASTM C348.

b) Four point bending tests were performed on 50 ferrocement prisms 500×50×t (t=4, 6, 8, 10 mm) using the developed nano cement mortar (Figure 1).

Each ferrocement prisms has been tested with its two ends simply supported over as span of 450 mm as shown in Figure 1. The load from a Universal testing machine with a capacity of 150 kN with a least count of 0.01 kN was applied. During the test, the deflections at the third point of the ferrocement prisms were provided by the testing machine with a least count of 0.01 mm. Each group of prisms was cast together with three cubes of 50 mm to determine the compressive strength (f_{cu}) at a curing age of 28 days. The following expression is used to determine the deflection at mid span:

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s	s/c	t	n	s	s/c	t	n	s	s/c	t	n	s	s/c	t	n	s	s/c	t	n
1	1	4	2	**11**	1.5	4	2	**21**	2	4	2	**31**	2.5	4	2	**41**	3	4	2
2	1	6	2	**12**	1.5	6	2	**22**	2	6	2	**32**	2.5	6	2	**42**	3	6	2
3	1	6	4	**13**	1.5	6	4	**23**	2	6	4	**33**	2.5	6	4	**43**	3	6	4
4	1	8	2	**14**	1.5	8	2	**24**	2	8	2	**34**	2.5	8	2	**44**	3	8	2
5	1	8	4	**15**	1.5	8	4	**25**	2	8	4	**35**	2.5	8	4	**45**	3	8	4
6	1	8	6	**16**	1.5	8	6	**26**	2	8	6	**36**	2.5	8	6	**46**	3	8	6
7	1	10	2	**17**	1.5	10	2	**27**	2	10	2	**37**	2.5	10	2	**47**	3	10	2
8	1	10	4	**18**	1.5	10	4	**28**	2	10	4	**38**	2.5	10	4	**48**	3	10	4
9	1	10	6	**19**	1.5	10	6	**29**	2	10	6	**39**	2.5	10	6	**49**	3	10	6
10	1	10	8	**20**	1.5	10	8	**30**	2	10	8	**40**	2.5	10	8	**50**	3	10	8

s: specimen; s/c: sand/cement ratio; t: prism thickness, mm; n: number of wire mesh layers

Table 3: The specimens considered in the present investigation.

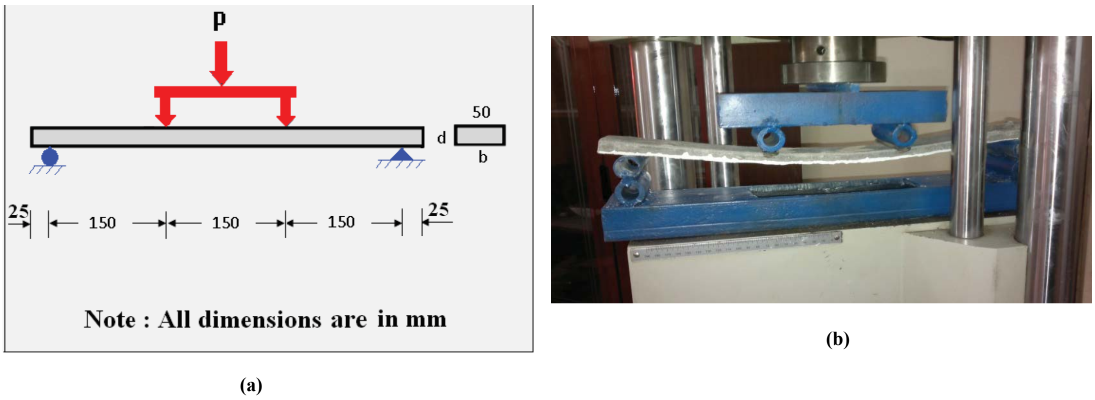

Figure 1: Flexural test of ferrocement prisms. (a) Dimension details of prisms considered in the flexural test. (b) Photo of a typical ferrocement prisim under the flexural test.

$\delta_{(1/2)\text{-span}} = 1.15\ \delta_{(1/3)\text{-points}}$

Ultrasonic Pulse Velocity Test (UPV) for measuring static and dynamic modulus of elasticity: Ultrasonic Pulse transit times were measured by direct transmission method [31]. This test was carried out according to reference [5]. The Velocity of Ultrasonic Pulse transmitted through cubes 50 mm made of nano cement mortar as developed in the present investigation at 28 curing days to determine the elastic modulus of elasticity (static and dynamic) using portable ultrasonic concrete tester known as (PUNDIT). A thin layer of grease was applied on the surface to prevent dissipation of transmitted energy. The time of transit was recorded to the order of 0.1 microsecond and the path length was measured accurately in mm, after obtaining the pulse velocity (km/sec), then the elastic modulus can be estimated [5].

Results and Discussions

Tables 4 and 5 give the outcomes of the measured values of compressive strength f_{cu} and modulus of rupture f_r at 28 curing days. It may be noted that the normal cement mortar is usually used in producing ferrocement elements [5].

Compressive strength f_{cu}=P/A in which P (N) is the maximum axial load, and modulus of rapture f_r=3PL/2bd^2 in which P (N) is the maximum flexural load, A=2500 mm^2, L(mm) is the tested span, b=width of the prism (mm) and d=thickness of the prism (mm).

Table 6 gives the measured values of compressive strength of nano cement mortar used for producing ferrocement prisms, volume fraction of reinforcement V_f, specific surface S_r, $(P/\delta)_{av.}$, $I_{comp.}$, $E_{comp.}$, $M_{cr.}$, and $f_{r.comp.}$ of ferrocement prisms after 28 curing days.

It may be noted that each of the compressive strength and modulus of rapture value is the average of three values and each of $(P/\delta)_{av}$ is the average of two measured values of identical prisms.

In which,

$$V_f = \frac{N\pi d_b^2}{4h}\left(\frac{1}{D_l}+\frac{1}{D_t}\right)\times 100$$

$$S_r = \frac{4V_f}{d_b}$$

$$\mathbf{E}_{\mathbf{com}} = \frac{11.5\mathbf{L}^3}{648\mathbf{I}_{\mathbf{com}}}(\mathrm{P}/\delta)_{av},\ f_r = \frac{\mathbf{M}_{\mathbf{cr}}.\mathbf{y}}{\mathbf{I}_{\mathbf{com}}}$$

Where, I_{com} is determined from the following expression:

$$\mathbf{I}_{\mathbf{com}} = \frac{\mathbf{b\,h}^3}{12} + (n-1)\sum_{j=1}^{N} \mathrm{A}_{sj}.(\mathrm{d}_j)^2$$

$$\mathbf{n} = \frac{\mathbf{Es}}{\mathbf{Em}}$$

Where,

E_s: Modulus of elasticity of steel wire mesh

E_m: Modulus of elasticity of cement mortar

N: Number of layers of mesh reinforcement

d_b: Diameter of mesh wire (mm)

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Mix proportion (cement: sand) by weight	f_{cu} (MPa) for normal cement mortar*	f_{cu} (MPa) for nano cement mortar*
1:1	47.15	52.13
1:1.5	51.2	58.4
1:2	38.11	43.53
1:2.5	33.27	35.71
1:3	26.36	32.18

Table 4: Measured values of compressive strength f_{cu}.

Mix proportion (cement: sand) by weight	f_r (MPa) for normal cement mortar*	f_r (MPa) for nano cement mortar*
1:1	5.46	5.73
1:1.5	5.78	5.86
1:2	4.81	5.06
1:2.5	4.33	4.72
1:3	3.52	3.66
*Each value is the average of three specimes		

Table 5: Measured values of modulus of rupture f_r.

Sep.	fcu (MPa)	Vf (%)	Sr (mm-1)	(P/δ)av. (N/mm)	I com (mm^4)	E com (MPa)	M cr (N.mm)	f r-com (MPa)
1	50.3	5.026	50.26	9.141	276.72	53421.18	3000	21.68
2	54.12	3.351	33.51	7.772	940.2	13368.2	3000	9.57
3		6.702	67.02	9.396	962.8125	15781.98	3750	11.68
4	52.81	2.513	25.13	5.846	2223.78	4251.35	2250	4.04
5		5.026	50.26	7.384	2286.6	5222.3	3000	5.24
6		7.539	75.39	11.83	2326.79	8222.19	8250	14.18
7	48.87	2.01	20.1	6.633	4327.47	2478.77	3000	2.04
8		4.021	40.21	9.351	4450.58	3397.83	4500	5.05
9		6.031	60.31	13.744	4541.032	4894.62	9750	10.73
10		8.042	80.42	17.494	4603.845	6145.09	12750	13.84
11	55.62	5.026	50.26	9.523	284.358	54158.76	3750	26.37
12	57.2	3.351	33.51	7.623	970.752	12699.24	3000	9.27
13		6.702	67.02	10.194	1010.55	16313.5	4500	13.36
14	57.67	2.513	25.13	9.671	2292.522	6822.1	3750	6.54
15		5.026	50.26	10.466	2403.072	7043.27	3750	6.24
16		7.539	75.39	16.912	2473.824	11055.7	9000	14.55
17	58.44	2.01	20.1	7.563	4449.678	2748.7	3750	4.21
18		4.021	40.21	12.912	4666.356	4474.82	6000	6.43
19		6.031	60.31	17.597	4825.548	5897.28	11250	11.65
20		8.042	80.42	21.906	4936.098	7176.94	16500	16.71
21	45.23	5.026	50.26	4.566	288.538	25591.35	1500	10.39
22	43.9	3.351	33.51	8.417	987.475	13784.52	2250	6.83
23		6.702	67.02	11.341	1036.68	17691.6	3750	10.85
24	42.37	2.513	25.13	8.055	2330.149	5590.39	2250	3.86
25		5.026	50.26	10.963	2466.83	7187.04	3000	4.86
26		7.539	75.39	17.065	2554.3	10804.25	6750	10.57
27	45.76	2.01	20.1	9.221	4516.57	3301.64	3750	4.15
28		4.021	40.21	8.683	4784.463	2934.92	3750	3.92
29		6.031	60.31	14.271	4981.282	4633.12	8250	8.28
30		8.042	80.42	19.977	5117.962	6312.38	10500	10.25
31	32.46	5.026	50.26	4.296	297.423	23358.77	750	5.04
32	33.83	3.351	33.51	6.361	1023.012	10055.53	1500	4.4
33		6.702	67.02	5.565	1092.206	8239.88	1500	4.12
34	35.54	2.513	25.13	6.031	2410.107	4046.81	1500	2.49
35		5.026	50.26	9.798	2602.313	6088.89	3000	4.61
36		7.539	75.39	15.314	2725.325	9087.21	5250	7.7
37	32.77	2.01	20.1	7.092	4658.718	2461.85	2250	2.41
38		4.021	40.21	8.664	5035.442	2782.53	3000	2.98
39		6.031	60.31	13.577	5312.219	4133.21	6750	6.35
40		8.042	80.42	20.049	5504.425	5890.35	9000	8.17
41	31.5	5.026	50.26	2.851	306.87	15024.61	750	4.89
42	32.48	3.351	33.51	3.826	1060.8	5832.72	750	2.12
43		6.702	67.02	8.233	1151.25	11565.08	1500	3.9

44	30.42	2.513	25.13	3.208	2495.13	2079.22	750	1.2
45		5.026	50.26	6.378	2746.38	3755.64	1500	2.18
46		7.539	75.39	9.043	2907.18	5030.38	3000	4.12
47	30,68	2.01	20.1	6.451	4809.87	2168.97	1500	1.56
48		4.021	40.21	7.622	5302.32	2324.68	2250	2.12
49		6.031	60.31	11.204	5664.12	3198.9	3750	3.31
50		8.042	80.42	14.867	5915.37	4064.45	6000	5.07

Table 6: Measured values of nano ferrocement prisms.

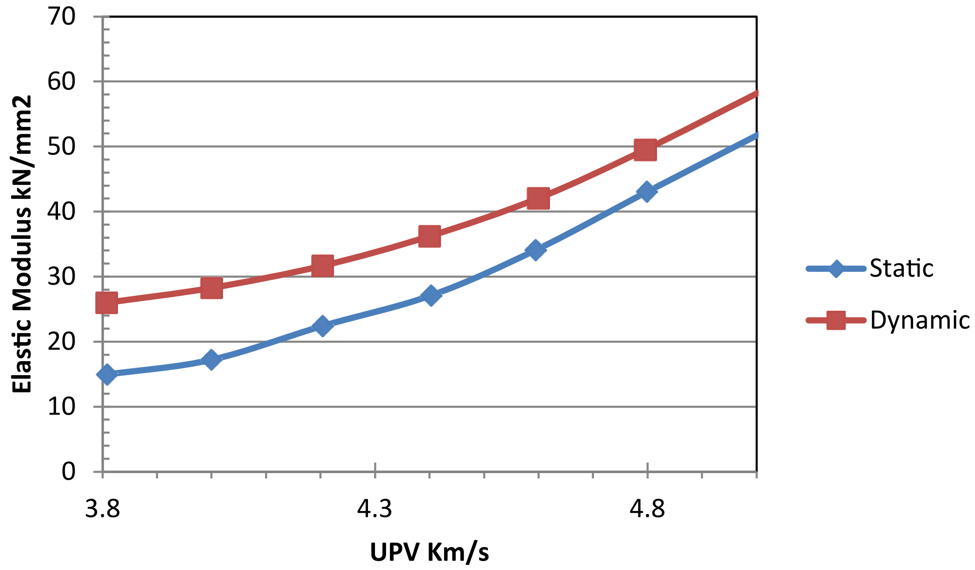

Figure 2: Elastic modulus vs. UPV relation.

Mix proportion (cement/ fine aggregate) by weight	Nano cement mortar as developed in the present investigation			Ordinary cement mortar used in ferrocement (reference)*		
	Pulse velocity (km/ sec)	Modulus of elasticity (GPa)		Pulse velocity (km/ sec)	Modulus of elasticity (GPa)	
		Dynamic	Static		Dynamic	Static
1:1	4.824	50.67	43.85	-	-	-
1:1.5	4.64	43.766	35.12	4.425	36.659	27.983
1:2	4.512	39.852	31.644	4.31	33.988	24.542
1:2.5	4.374	35.671	26.132	4.237	32.494	22.586
1:3	4.196	31.745	21.831	4.098	30.024	19.353

Table 7: Measured values of static and dynamic modulus of elasticity.

Spe.	Load, kN		Pu/Pc	Mid-span deflection, mm		μ = δu/δcr
	Pcr	Pu		δcr	δu	
1	0.04	0.09	2.25	4.34	21.18	4.88
11	0.05	0.12	2.4	5.1	24.33	4.77
21	0.02	0.06	3	4.17	18.35	4.4
31	0.01	0.04	4	3.42	16.77	4.903
41	0.01	0.02	2	3.06	13.16	4.3
2	0.04	0.09	2.25	4.15	20.44	4.925
12	0.04	0.13	3.25	4.86	22.78	4.687
22	0.03	0.08	2.667	3.94	17.76	4.507
32	0.02	0.04	2	3.56	17.28	4.854
42	0.01	0.03	3	3.12	12.88	4.128
3	0.05	0.16	3.2	4.88	28.16	5.77
13	0.06	0.2	3.333	4.72	26.41	5.595
23	0.05	0.14	2.8	4.24	21.15	4.988
33	0.02	0.09	4.5	4.08	18.56	4.55
43	0.02	0.09	4.5	3.33	14.6	4.384
4	0.03	0.1	3.33	4.42	22.35	5.056
14	0.05	0.15	3	4.51	22.67	5.026

24	0.03	0.1	3.333	4.1	18.13	4.422
34	0.02	0.05	2.5	3.6	17.36	4.822
44	0.01	0.03	3	3.21	12.95	4.034
5	0.04	0.18	4.5	4.69	26.55	5.661
15	0.05	0.21	4.2	4.57	25.87	5.66
25	0.04	0.15	3.75	4.26	22.27	5.227
35	0.04	0.11	2.75	4.11	18.4	4.477
45	0.02	0.08	4	3.65	15.11	4.14
6	0.11	0.37	3.36	6.58	32.09	4.877
16	0.12	0.35	2.916	5.87	29.1	4.957
26	0.09	0.29	3.222	5.36	26.12	4.873
36	0.07	0.2	2.857	4.78	22.12	4.627
46	0.04	0.15	3.75	4.18	18.34	4.387
7	0.04	0.11	2.75	4.6	22.96	5
17	0.05	0.15	3	4.68	23.18	4.953
27	0.05	0.1	2	4.26	19.26	4.52
37	0.03	0.05	1.667	3.64	17.1	4.7
47	0.02	0.05	2.5	3.1	13.04	4.206
8	0.06	0.23	3.83	4.83	26.78	5.54
18	0.08	0.26	3.25	4.77	26.7	5.6
28	0.05	0.18	3.6	4.52	24.3	5.376
38	0.04	0.11	2.75	4.21	19.14	4.546
48	0.03	0.11	3.667	3.46	14.86	4.294
9	0.13	0.41	3.15	6.8	33.48	4.92
19	0.15	0.43	2.866	6.58	31.06	4.72
29	0.11	0.32	2.909	5.9	25.91	4.39
39	0.09	0.24	2.667	4.93	23.05	4.675
49	0.05	0.19	3.8	4.15	17.92	4.318
10	0.17	0.67	3.94	8.11	38.4	4.73
20	0.22	0.74	3.36	7.45	34.73	4.661
30	0.14	0.51	3.643	6.55	31.29	4.777
40	0.12	0.42	3.5	5.4	27.9	5.167
50	0.08	0.33	4.125	4.76	22.43	4.712

Table 8: Ductility ratio of nano ferrocement prisms.

Spe.	t, mm	n	$f_{r\text{-com, MPa}}$ nano ferrocement
11	4	2	26.37
12	6	2	9.27
13	6	4	13.36
14	8	2	6.54
15	8	4	6.24
16	8	6	14.55
17	10	2	4.21
18	10	4	6.43
19	10	6	11.65
20	10	8	16.71
t: prism thickness, mm; n: number of wire mesh layers			

Table 9: Modulus of rupture of nano ferrocement using sand/ cement ratio=1.5.

h: Thickness of ferrocement panel (mm)

D_l: Spacing of wires aligned longitudinally in mesh (mm)

D_t: Spacing of wires aligned transversely in mesh (mm)

As it was mentioned above the static and dynamic elastic modules are determined from the curves given in Figure 2. The Ultrasonic Pulse Velocity (UPV) is determined using the following expression:

V=L/T

Where;

V: Ultrasonic Pulse Velocity (km/sec)

L: Path length (mm)

T: Transit time (microsecond)

The measured values of Ultrasonic Pulse Velocity and elastic modulus values are presented in Table 7 together with values of static and dynamic of normal ferrocement mortar given in reference [32,33].

In Table 8 the P_u/P_{cr} and the ductility ratio μ=δu/ δcr in which P_u, P_{cr}, δu and δcr are the measured values of first cracking, ultimate loads, and first cracking, ultimate deflections respectively of nano ferrocement prisms are tabulated.

In general, It is seen from the above tables that the highest values can be achieved by using cement mortar as developed in the present investigation with the ratio of sand/ cement=1.5.

In reference [5] tests were carried out to determine the flexural strength of normal ferrocement prisms with 22 mm thickness and 4, 6, 8, 10 wire mesh layers and mix proportion plain sand/ cement ratio of 1.5 and the measured flextural strength were 5.74, 8.42, 8.48, 10.9 MPa respectively.

It may be seen that the flexural strength values of nano ferrocement prisms as tabulated in Table 9 is higher than that of normal ferrocement.

Conclusion

The mechanical properties of nano cement mortars as developed in the present work to improve ferrocement properties were experimentally investigated. The measured results showed that the compressive and flexural strengths measured at 28 curing days of the developed nano cement mortars were higher than that of a plain cement mortar. In addition, the flexural strength of nano ferrocement using nano cement as developed in the present investigation is higher than that of normal ferrocement prisms having 22 mm thickness and reinforced by 10 layers of wire mesh.

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