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Effects of Using “Nicoflok” Polymer on the Strength of Construction and Demolition Wastes

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ABSTRACT: Construction and demolition wastes are always a trouble for construction and agriculture activities. In this study samples from bricks, cement mortar, and gypsum and their composition which comes from building construction and demolition were collected. The effect of adding Nicoflok Mineral polymer (NMP) with cement was investigated on samples in the stabilized form. Thus the feasibility of increasing compressive and tensile strength and durability by stabilizing with 3, 6, and 12 percent cement and adding a mineral polymer which is known as Nicoflok with the amount of 10% of cement’s weight for 7 and 28 days was investigated by collecting brick (burned clay), cement contained waste (waste of cement block workshop) and gypsum waste (passing from the sieve #40). The results showed that NMP generally increases compressive and tensile strength but the amount of increase depends on the material and the used mixture; samples with cement waste had more compressive strength in comparison with other samples, and samples with brick waste had the lowest strength. Adding 10% crushed gypsum to the mixture of brick and cement waste, improved the tensile strength in some cases. The results obtained from the compaction curve also showed that the materials including cement and block pieces have the highest compaction potential, while the materials including bricks have the lowest dry density.

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1- Introduction

To build new structures in dense urban areas, old structures are demolished and new buildings are built; these materials are called Demolition wastes. On the other hand, some materials are damaged during the transporting and building process, these materials are called construction wastes[1]; the sum of these materials is called construction and demolition (C&D) wastes. C&D wastes are always useless and commonly deposited in suburban areas which makes the environment polluted, diseases, etc, in addition to undesirable scenes. In a research conducted within the US Strategic Highway Research Program (SHRP), about 46 different ways of improving soil quality were studied [2]. One of those was stabilization, stabilization is the modification of the physical and mechanical properties of the soil to achieve preset goals [3]. Additive use in stabilization can be divided into two groups of conventional materials such as cement, lime, and tar, and new materials like silicates, mineral additives, enzymes, acids, salts, polymers, and resins [4].

Leite et al (2011) divided the C&D wastes into 4 groups: cement materials, ceramic materials with high porosity, ceramic materials with low porosity, and crushed stones [5]. Jain (2019) evaluated the potential of using C&D wastes in different parts of the building in economic and environmental conditions [6]. Arulrajah et al (2012) conducted grading, compaction, CBR, and triaxial tests on the recycled concrete grains and compared their properties with the Sub-Base layer requirements [7]. Contreras et al (2016) substituted construction wastes for natural aggregates in brick making and pressed by uniaxial hydraulic force and after 21 days of curing, they underwent a compressive strength test. The results showed a strength of more than 4 MPa, which is higher than the standard required for brick production [8]. Ulugöl et al (2021) investigated the effect of using C&D wastes and glass at various temperatures and by various curing and also various Na concentrations. The compressive strength and micro-structural investigation of these blends were evaluated. The results showed the high strength of hollow brick wastes in some cases [9]. Mousavi and Karamvand (2017) investigated the potential of using a nano polymer stabilizer called CBR Plus to stabilize soft clay. The results showed an increase in the amount of CBR and compressive strength by using this polymer [10]. Cristelo et al (2018) investigated the use of fly ash on C&D wastes. The results showed an improvement in compressive strength and modulus of elasticity when using fly ash after 28 days of curing at ambient temperature and relative humidity [11]. Arulrajah et al (2021) investigated the use of polyethylene terephthalate (PET) and C&D wastes as a substitute for traditional materials. For this purpose, different proportions of materials were combined. The results showed all the geo polymer-stabilized blends using 5% fly ash + 5% slag and 10% slag satisfied the minimum

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Table 1. XRF test results on Cement materials

Element	SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	Na_2O	SO_3	CL
Wt%	26.85	6.5	3.2	56.5	1.1	44	<1	<5

UCS limit [12]. Gobieanandh and Jayakoya (2016) tested the wastes in a region in Sri Lanka. In this investigation, construction waste was mixed with different proportions of natural materials, and stabilized samples with cement were made and then they undergo compaction and CBR tests[13]. Cement as a cohesive material is used to stick gravel, sand and other materials [14]. Ibrahim et al (2020) investigated the possibility of using concrete with recycled concrete aggregate (RCA) and with recycled fine aggregate (RFA) [15]. Parmenevich and Vladmirovich (2013) evaluated the effect of adding three stabilizers with the names "ANT", "Nano-STAB" and "NMP" on the materials made of different percent of sand and crushed stone. The results show an increase in compressive and tensile strength for 5 and 7-day samples in the case of using "NMP". They chose 10% of the cement's weight for the amount of "NMP" [16]. Gosev and Nekhoroshkov (2013) stated the results of using the powder of NMP for improving the compressive and tensile strength of the materials used in road construction: for Dobrbolyo Street in 2010, compressive and tensile strength of asphalt grains with 5% cement and 0.5% NMP were 6.5 and 1.25 MPa respectively; for a street in Suchi area in 2010, compressive and tensile strength for crushed materials with 5% cement and 0.5% NMP were 7.7 and 1.1 MPa, respectively; for Velam area in 2010, for the surface of the sieved granite grain pavement which was stabilized with 6% cement and 0.6% NMP, compressive and tensile strength were 6.9 and 0.9 MPa respectively [17]. Rezaie moghaddam et al (2020) evaluated the effect of adding NMP and cement as a stabilizer on coastal and desert sands. In this research compacted samples with 3, 6, and 12 percent of cement and 10 weight percent of cement with NMP were made. The results showed that the samples that had NMP polymer had 7 and 28 days of compressive and tensile strength more than the samples without NMP polymer. Also, NMP-stabilized samples have more Durability than other samples [18]. Gavrilina & Bonder (2018) have performed uniaxial compressive strength on samples with cement and NMP. The results of this study showed that adding NMP increases the compressive and bending strength of samples by 20%. The amount of NMP in this study is 8-10 percent [19]. Moradi et al (2021) researched to investigate and compare the effect of chemical and biological stabilizers on clay subgrade soil. For chemical stabilization polymers called cationic polyelectrolyte (CPE) and NMP were used. The results showed an increase in soil compressive strength and resilient modulus (MR) due to use of NMP polymer [20]. Zirrak baroughi et al (2020) evaluated the effect of using NMP and cement on granular soils and recycled asphalt materials (RAP). In this research the optimal value of NMP for use in the samples is 0.9 percent. Also, the use of this type of polymer has improved the resistance conditions in different layers of pavement [21].

In this study, the possibility of using (C&D) materials with cement and Nicoflok, which is a mineral polymer powder and has been imported from Russia, as a stabilization way in road construction was investigated. In this way, environmental pollution will decrease. In addition, the use of materials which are extracted from mines and consequently the cost will decrease significantly.

2- Experimental Study

2- 1- Materials

The materials used in this study include cement, water, NMP, and C&D wastes. The properties of each of these materials are as follows:

2- 1- 1- Cement

The cement used in this study is type II pozzolan cement which was produced by Ardebil Cement Co. The Density of this cement is 3130 kg/m3. The results of the XRF test on the sample of cement are given in Table 1.

2- 1- 2- Water

The water used in this research is the beverage water of Ardebil City. In most mix design schemes, beverage water is the adequate one for the mix [22]. the compounds in the water used in making the samples are presented in Table 2.

2- 1- 3- NMP Polymer

NMP additive is produced in the north of Russia according to TU5743–003–13881083–2006 Standard. This ash-like material has 800-1200 kg/m^3 density and less than 2% moisture. Also, more than 90% of it passes through a 0.315 mm sieve. This material is not toxic, flammable, and dangerous and has a hygienic certificate. It can be transported and stored in low temperatures and keeps its properties in temperatures lower than 40-50° C. It is a hydrophobic material and should not have direct contact with water during storage. Fig. 1 shows NMP.

To recognize the ingredients, the XRF test was conducted by PW 1480 machine and IQ+ software in Iran University Science and Technology (IUST) central laboratory according to ASTM E1621[24]. The results are shown in Table 3.

As shown in Table 3, all ingredients are the same as

Table 2. The results of physical and chemical of water in Ardabil city [23]

Indicator	Minimum	Maximum	Average
pH	6.82	8.41	7.38
Turbidity (NTU)	0.21	1.1	0.05
Carbonate (mg/lit)	0	27	1.09
Nitrate (mg/lit)	15.5	36	27.9
Sulphate (mg/lit)	23	525	245.3
Phosphate (mg/lit)	0.07	0.36	0.234
Colorine (mg/lit)	25	215	132.4
Total Hardness (mg/lit)	47	770	663

Fig. 1. NMP materials

Table 3. XRF test results on NMP polymer

Element	**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**SO_3**	**K_2O**	**CaO**	**TiO_2**
Wt%	2.930	0.735	0.786	48.046	0.118	2.969	0.505	33.134	<<
Element	V_2O_5	Cr	Mn	Fe_2O_3	Ni	ZnO	Sr	Y_2O_3	PbO
Wt%	-	-	<<	0.775	<<	-	<<	-	-
Element	Ba	ZrO_2	Cl	CO	Ce	MO	F	Cu	L.O.I
Wt%	-	-	-	-	-	-	4.083	<<	5.911

Table 4. Classification of C&D wastes

Type of materials	Materials percent			Mix design name	Cement percent	NMP percent
	Cement wastes	Brick wastes	Gypsum wastes			
Group A	100	0	0	A-1	3	0
	100	0	0	A-2	6	0
	100	0	0	A-3	12	0
	100	0	0	A-4	3	0.3
	100	0	0	A-5	6	0.6
	100	0	0	A-6	12	1.2
Group B	0	100	0	B-1	3	0
	0	100	0	B-2	6	0
	0	100	0	B-3	12	0
	0	100	0	B-4	3	0.3
	0	100	0	B-5	6	0.6
	0	100	0	B-6	12	1.2
Group C	50	50	0	C-1	3	0
	50	50	0	C-2	6	0
	50	50	0	C-3	12	0
	50	50	0	C-4	3	0.3
	50	50	0	C-5	6	0.6
	50	50	0	C-6	12	1.2
Group D	45	45	10	D-1	3	0
	45	45	10	D-2	6	0
	45	45	10	D-3	12	0
	45	45	10	D-4	3	0.3
	45	45	10	D-5	6	0.6
	45	45	10	D-6	12	1.2

cement ingredients, except CL and MgO, but the proportions of ingredients are different. Silicon Oxide is one of the stick agents in cement and its high percentage in NMP materials, makes the mix more adhesive.

2- 1- 4- Aggregate

The used aggregates were classified into three groups: the first group pertains to wastes that contain cement mortar grains collected from cement block workshops in Ardebil; the second group is brick waste (burned clay) which was collected from brick stores; the third group is gypsum waste. The first and second group materials had dimensions less than 1 inch and the third group materials were crushed with labor force and passed through #40 sieve.

2- 2- Conducted Tests on the Materials

In this study, the grading of aggregates was done according to Iran Highway Asphalt paving code No. 234 [25]. The materials were divided into 4 main groups (A, B, C, D) according to the type of their components, then to perform the tests of each of these groups, according to the percentage of cement and polymer, they were divided into sub-branches 1 to 6, as follows: Groups 1 to 3 only have the mentioned percentages of cement and no polymer, and subgroups 4 to 6 have polymer in addition to the percentages of primary cement to determine the effect of the polymer at a ratio of 10 percent by weight of the primary cement, as shown in Table 4. A Standard Proctor-compaction test was conducted on them to determine optimum moisture content. This content of moisture was used to make stabilized samples with cement and NMP. The 7 and 28-day samples undergo compressive strength and indirect tensile tests. Also, some samples undergo 45 cycles of freezing and thawing test according to ASTM C666 [26]. On these samples and control samples, a compressive strength test was conducted to evaluate the effect of NMP during freeze-thaw. A total of 380 samples were made. For each percent of cement and NMP, 6 samples for compressive strength, 6 samples for indirect tensile, and 3 samples for durability test were made. To calculate the optimum moisture content for each group, 5 samples with different percentages of water were made and undergo a proctor-compaction test.

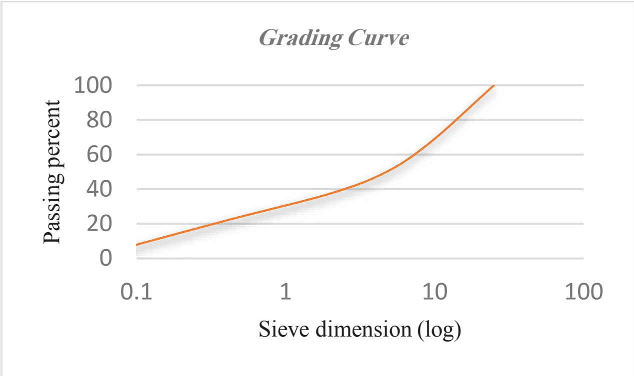


Fig. 2. Grading curve

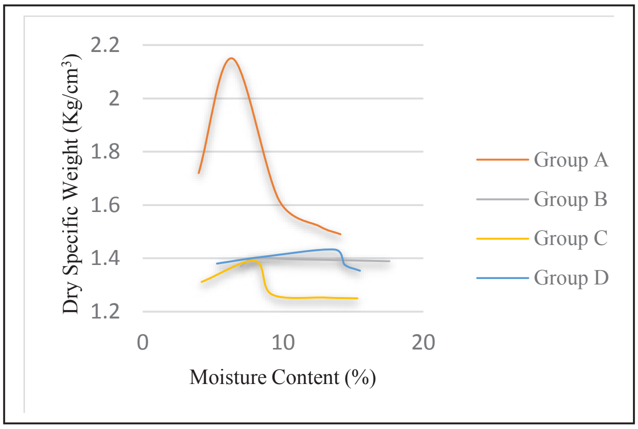


Fig. 3. Specific weight-moisture curve for groups

2- 2- 1- Curing of Samples

The samples for 7 and 28-day compressive tests were kept in plastic bags for 24 hours after mixing to get cured in optimum moisture. Then until the time of testing, they were kept inside the sand and sprayed on the surface. It was done daily. The samples for the freeze-thaw test were kept in a water basin for 14 days and then undergo the freeze-thaw test. Control samples for the freezing and thawing test were kept in water until the test.

2- 2- 2- Grading

According to the NMP producer, we should use aggregates lower than 1 inch. According to Iran Highway Asphalt Paving Code No.234 one group for the base which has been named "IV" is appropriate. The grading curve is shown in Fig. 2.

2- 2- 3- Proctor – Compaction Test

Proctor-compaction test was conducted on each of the 4 groups of materials according to ASTM D558 [27]. The grading curve for materials is shown in Fig. 3. The moisture content for A, B, C, and D was 6.5, 8.5, 8, and 13.5 percent respectively. As it is seen, the moisture content of group C is between the moisture contents of A and B, because this group is made by mixing groups A and B. Also, the presence of gypsum in group D leads to more water absorption and increases the optimum moisture content. As can be seen, group A has a considerable dry density compared to other groups, the reason for the high density of these materials is the texture of the aggregates and the existence of the primary granulation of these materials, which is used in the production of building blocks.

2- 2- 4- Compressive Strength Test

This test was conducted according to ASTM C39 [28]. Cylindrical samples were placed between the plates of the machine. Then vertical load was imposed until the fracture of the sample. This test was conducted on 7 and 28-day samples and also freeze-thaw samples.

2- 2- 5- Indirect Tensile Test

This test was conducted according to Iran National Standard No. 6047 [29]. This test aims to determine the tensile strength of samples by splitting off the sample. In this test, a diagonal compressive force is imposed along the length of the cylindrical sample until the fracture. It was conducted on 7 and 28-day samples with different percentages of cement and NMP. Fig. 4 shows the test setup for compressive and indirect tensile strength.

2- 2- 6- Freezing and Thawing test

The samples were kept in a water basin for 14 days according to ASTM C192 [30] standard and then according to ASTM C666 they were placed in the refrigerator for 2 hours and 20 minutes at -18˚ C. Then they were placed in water with 20˚ C temperature to thaw. This process was done for 45 times. The period between freeze and thaw in a cycle should not exceed 10 minutes except when they are testing.

3- Results

The results of compressive and indirect tensile tests are given in Table 5. Table 6 shows the results of the compressive test on 45 cycles of freeze-thaw and control samples.

3- 1- Results of Compressive Strength Test

As it is shown in Figs. 5 and 7, the compressive strength of the samples stabilized with NMP, in all groups is more than samples without NMP in both 7 and 28-day samples, but the percent of increase is different. Fig. 5 shows the effect of using NMP and cement on 7-day compressive strength, as can be seen, for 7-day strength, the maximum increase in strength is for groups A and D, and for the combination of 3% cement with 0.3% NMP. Also, For groups B and C, the maximum increase of strength is for the combination of 6% cement with 0.6% NMP. However, in none of the groups, the sample with 12% cement and 1.2% NMP does not have the

a) compressive strength   b) indirect tensile strength

Fig. 4. Loading method in the test

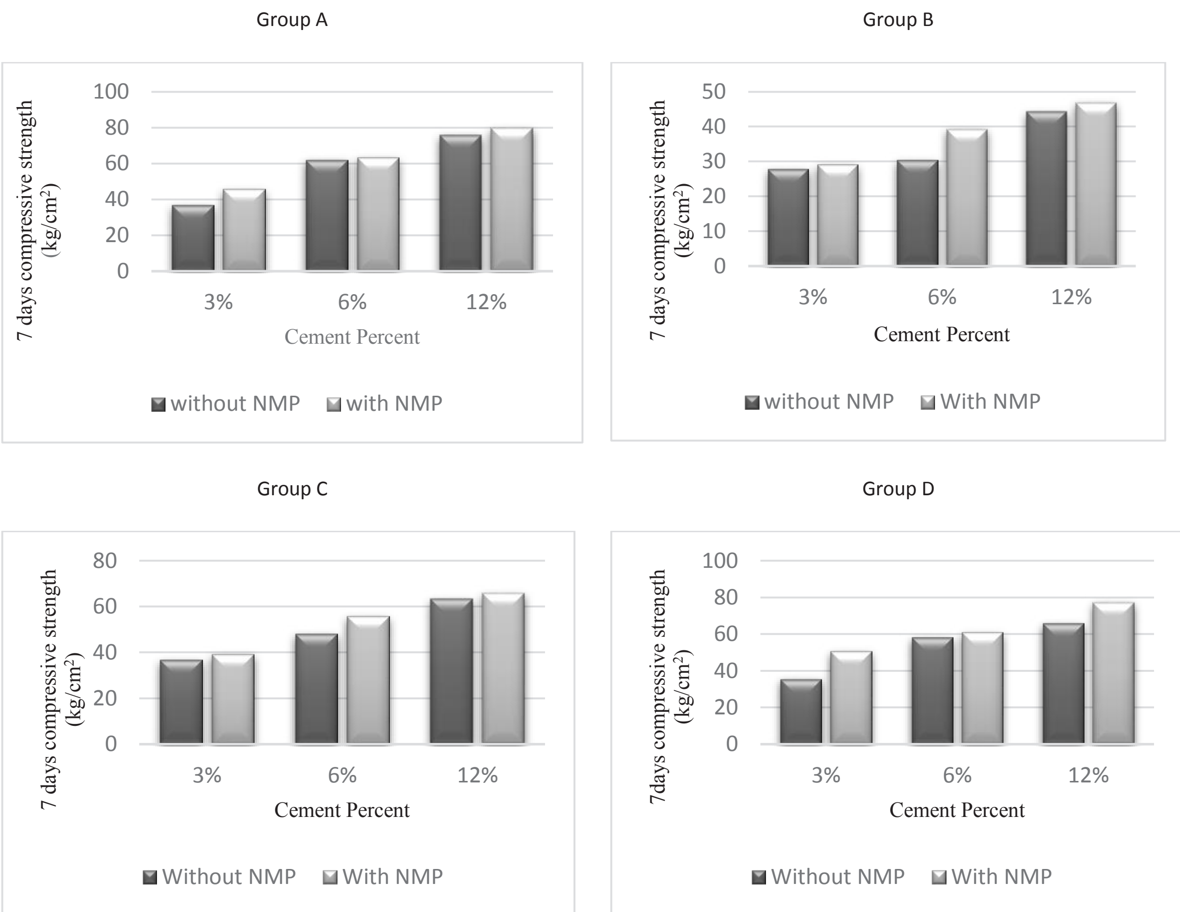


Fig. 5. Results of 7 day Compressive strength for each group of C&D Materials

Table 5. Result of Compressive and Indirect tensile tests

Material Type	**Mix Design Name**	**Compressive Strength**				**Indirect Tensile Test**			
		7 Day		28 Day		7 Day		**28 Day**	
		Mean Compressive Force (Ton)	Mean Compressive Strength (kg/cm^2)	Mean Compressive Force (Ton)	Mean Compressive Strength (kg/cm^2)	Mean Tensile Force (ton)	Mean Tensile Strength kg/cm^2) (	Mean Tensile Force (ton)	**Mean Tensile Strength (kg/cm^2)**
Group A	A-1	2.9	36.7	3.9	49.4	1.1	13.9	1.15	**14.55**
	A-2	4.9	62	6.1	77.25	1.4	17.7	1.4	**17.7**
	A-3	6	75.9	8.2	103.7	1.4	17.47	1.4	**17.7**
	A-4	3.6	45.5	5.4	68.4	1.1	13.9	1.15	**14.55**
	A-5	5	63.3	6.7	84.8	1.4	17.7	1.4	**17.7**
	A-6	6.3	79.7	8.6	108.95	1.4	17.7	1.45	**18.35**
Group B	B-1	2.2	27.8	2.95	37.3	1	12.7	1	**12.7**
	B-2	2.4	30.4	3.45	43.65	1	12.7	1	**12.7**
	B-3	3.5	44.3	4.9	62.05	1.1	13.9	1.1	**13.9**
	B-4	2.3	29.1	3.1	39.25	1	12.7	1.15	**14.55**
	B-5	3.1	39.2	3.8	48.1	1	12.7	1.1	**13.9**
	B-6	3.7	46.8	6.15	77.8	1.1	13.9	1.15	**14.55**
Group C	C-1	2.9	36.7	3.7	46.85	1.1	13.9	1.15	**14.55**
	C-2	3.8	48.1	4.6	58.25	1.1	13.9	1.15	**14.55**
	C-3	5	63.3	5.9	74.6	1.2	15.2	1.5	**19**
	C-4	3.1	39.2	3.8	48.1	1.1	13.9	1.15	**14.55**
	C-5	4.4	55.7	5.8	73.25	1.2	15.2	1.45	**18.35**
	C-6	5.2	65.8	6.05	76.55	1.6	20.3	1.6	**20.3**
Group D	D-1	2.8	35.4	3.85	48.75	1	12.7	1.2	**15.2**
	D-2	4.6	58.2	4.9	62	1.4	17.7	1.5	**19**
	D-3	5.2	65.8	6.35	80.4	1.5	19	1.6	**20.3**
	D-4	4	50.6	4.3	54.45	1.2	15.2	1.4	**17.7**
	D-5	4.8	60.8	6.7	84.8	1.4	17.7	1.5	**19**
	D-6	5.8	77.1	6.75	85.45	1.5	19	1.6	**20.3**

Table 6. Results of compressive test on 45 cycle of freeze-thaw and control samples

Material Type	Mix Design Name	Average compressive strength of samples under freezing and thawing (kg/cm^2)	Compressive strength of control specimens (kg/cm^2)	Material Type	Mix Design Name (kg/cm^2)	Average compressive strength of samples under freezing and thawing (kg/cm^2)	Compressive strength of control specimens (kg/cm^2)
Group A	A-1	41.7	49.4	Group B	B-1	25.55	**34.2**
	A-2	65.85	77.2		B-2	34.2	**48.1**
	A-3	72.8	103.8		B-3	29.75	**51.9**
	A-4	44.95	68.4		B-4	29.1	**38**
	A-5	66.4	84.8		B-5	29.65	**50.6**
	A-6	79.75	108.9		B-6	45.6	**75.9**
Group C	C-1	25.3	49.4	Group D	D-1	23.45	**46.8**
	C-2	27.8	57		D-2	52.4	**63.3**
	C-3	41.75	65.8		D-3	51.9	**97.7**
	C-4	28.5	50.63		D-4	23.45	**57**
	C-5	46.85	59.5		D-5	54.45	**83.6**
	C-6	53.8	92.4		D-6	59.5	**86**

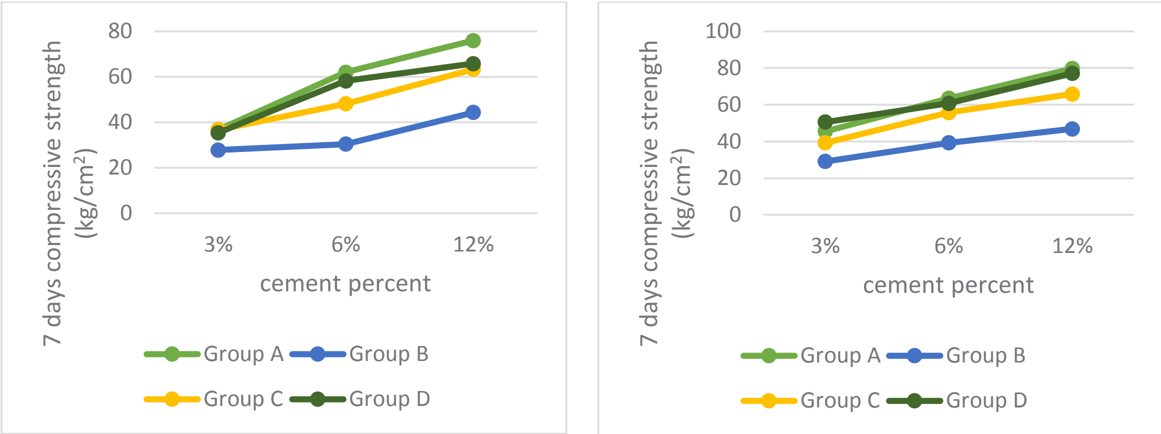
highest percentage increase in strength. Therefore, a high percentage of cement and NMP will not necessarily lead to greater strength. Fig. 6 shows a comparison of the effect of adding cement and NMP separately for each group for the case where only cement is used and for the combination of cement and NMP.

Fig. 7 shows the results of 28-day compressive strength on samples, as can be seen, for the 28-day condition, the highest increase in strength for groups C and D is related to the case where 6% cement is mixed with 0.6% NMP. For group A, the maximum percentage of strength is related to the combination of 3% cement with 0.3% NMP. And for group B, is related to the combination of 12% with 1.2% NMP. Fig. 8 shows the effect of only cement, and cement with NMP on the increase of strength in each group.

3- 1- 1- Comparison of 7-day and 28-day samples strength

The charts below show the increase in strength of the samples from 7 days to 28 days:

According to Fig. 9, the average increase in strength for materials for group A is 36.11%, for group B is 40.25%, for group C is 23.83, and for group D is 20.68. As can be seen, the passage of time improves the resistance of all compounds containing cement and polymer, but these changes have reached their lowest value on average in the case of group D compounds which contain gypsum waste compounds, which can indicate an adverse effect. The presence of gypsum waste due to water absorption has affected the resistance change and reduced its increase. Especially in humidity above 6% where the effect of gypsum is more visible.



a) Stabilized only with cement and without NMP

b) Stabilized with cement and NMP

Fig. 6. Results of the effect of cement, and cement with NMP, on 7-day compressive strength.

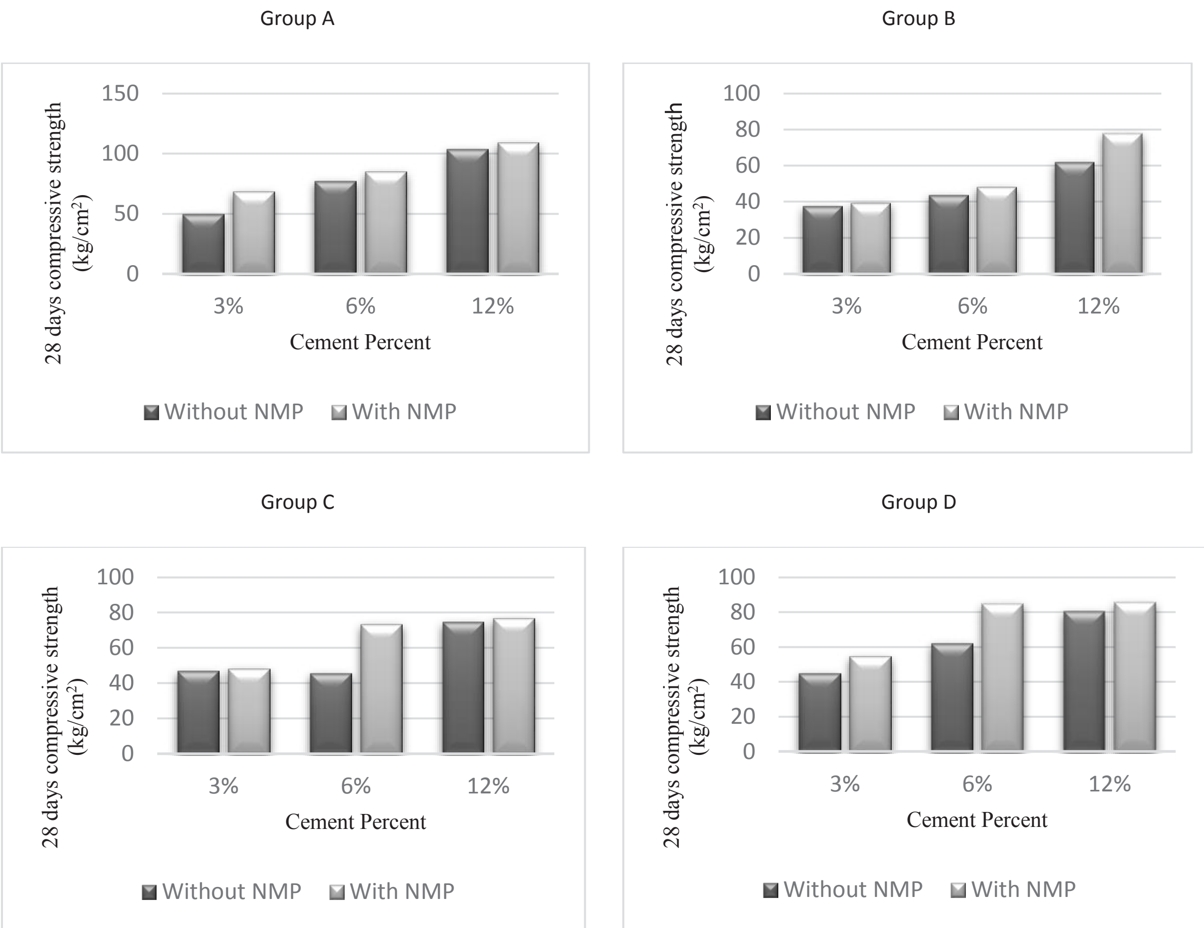
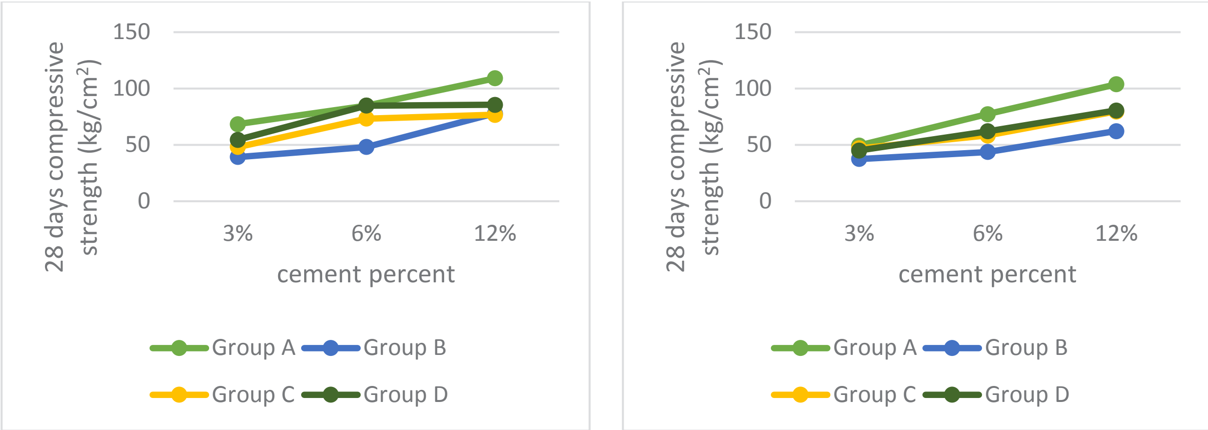


Fig. 7. Results of 28-day Compressive strength for each group of C&D Materials



a) Stabilized only with cement and without NMP

b) Stabilized with cement and NMP

Fig. 8. Results of the effect of cement, and cement with NMP, on 28-day compressive strength

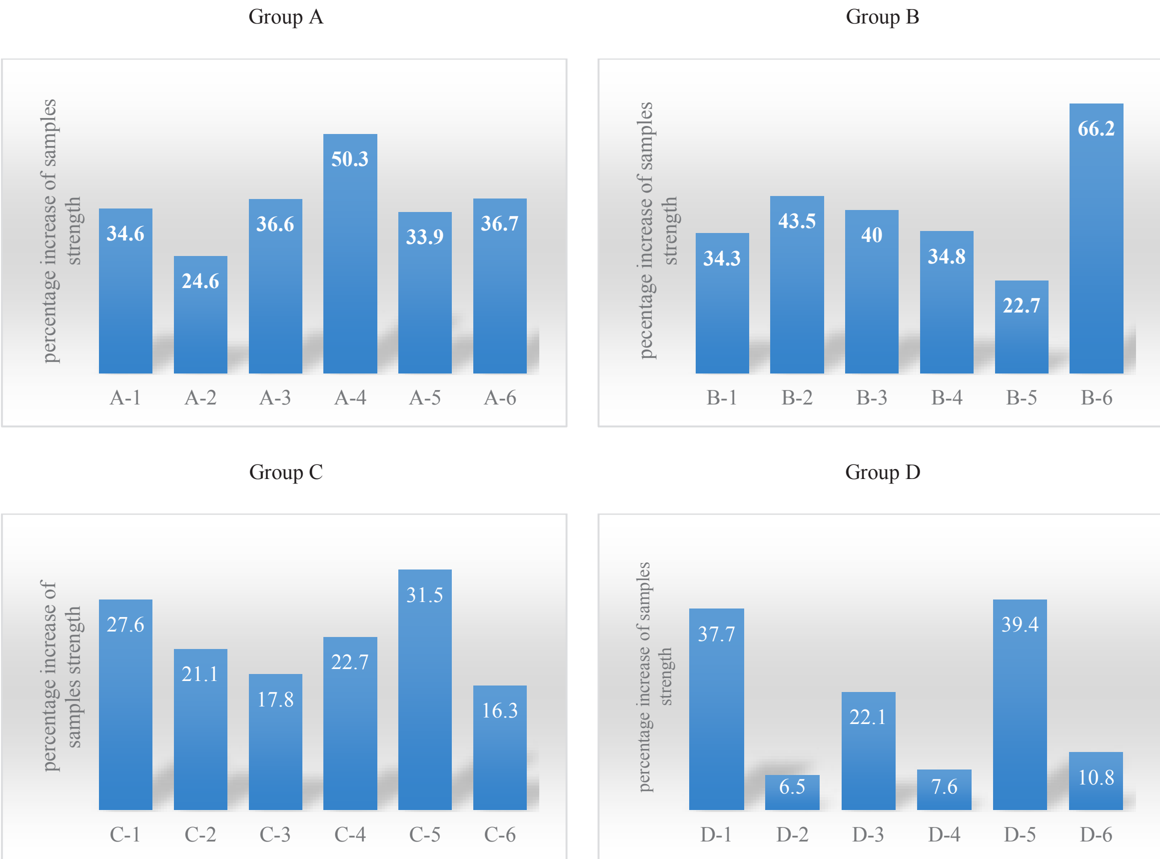
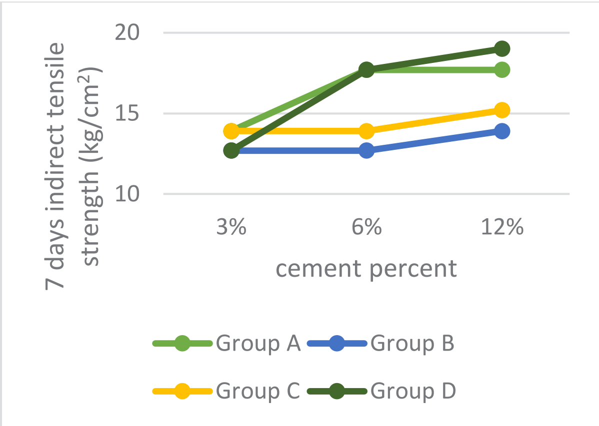
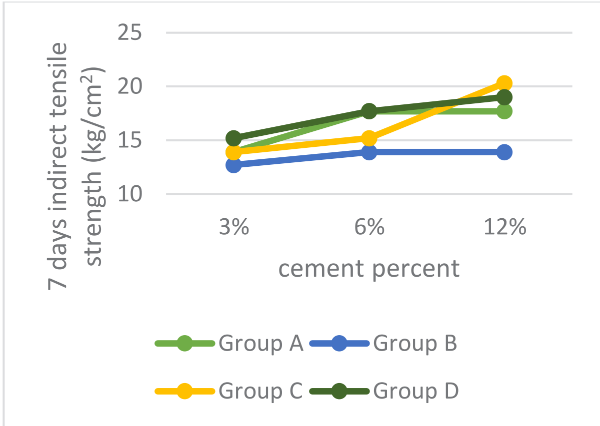


Fig. 9. samples strength increases from 7 days to 28 days for each group of materials

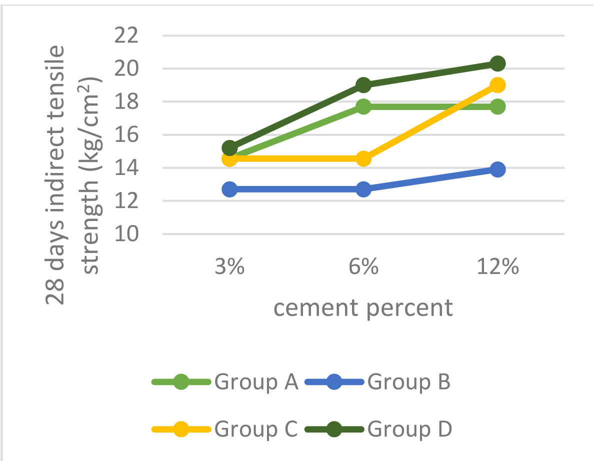


a) Stabilized only with cement and without NMP

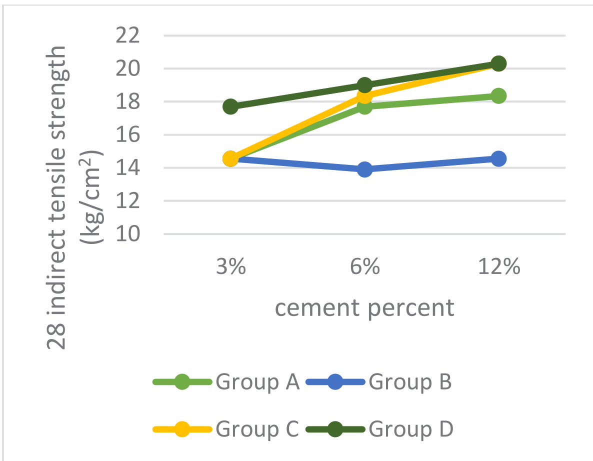


b) Stabilized with cement and NMP

Fig. 10. Results of 7 day Indirect Tensile Strength (Kg/cm2)



a) Stabilized only with cement and without NMP



b) Stabilized with cement and NMP

Fig. 11. Results of 28 day Indirect Tensile Strength (Kg/cm2)

3- 2- Results of Indirect Tensile strength

Fig. 10 shows the effect of NMP on 7-day indirect tensile strength separately for different groups. It can be seen that NMP did not change in most samples. However, in some cases, it has improved the tensile strength. NMP polymer for groups A and B did not change the tensile strength, or the effect was so small that it could not be recorded by the device. The maximum percentage of increase in tensile strength in samples is 33.5% relating to group C.

Fig. 11 shows the effect of cement and polymer on 28-day tensile strength. As can be seen, the 28-day tensile strength of group B has the lowest value in all percentages. The addition of Nicoflok polymer has increased the position of group C materials to a higher strength than group A. Also, group D materials have the highest tensile strength, which can be the effect of the presence of gypsum in these materials.

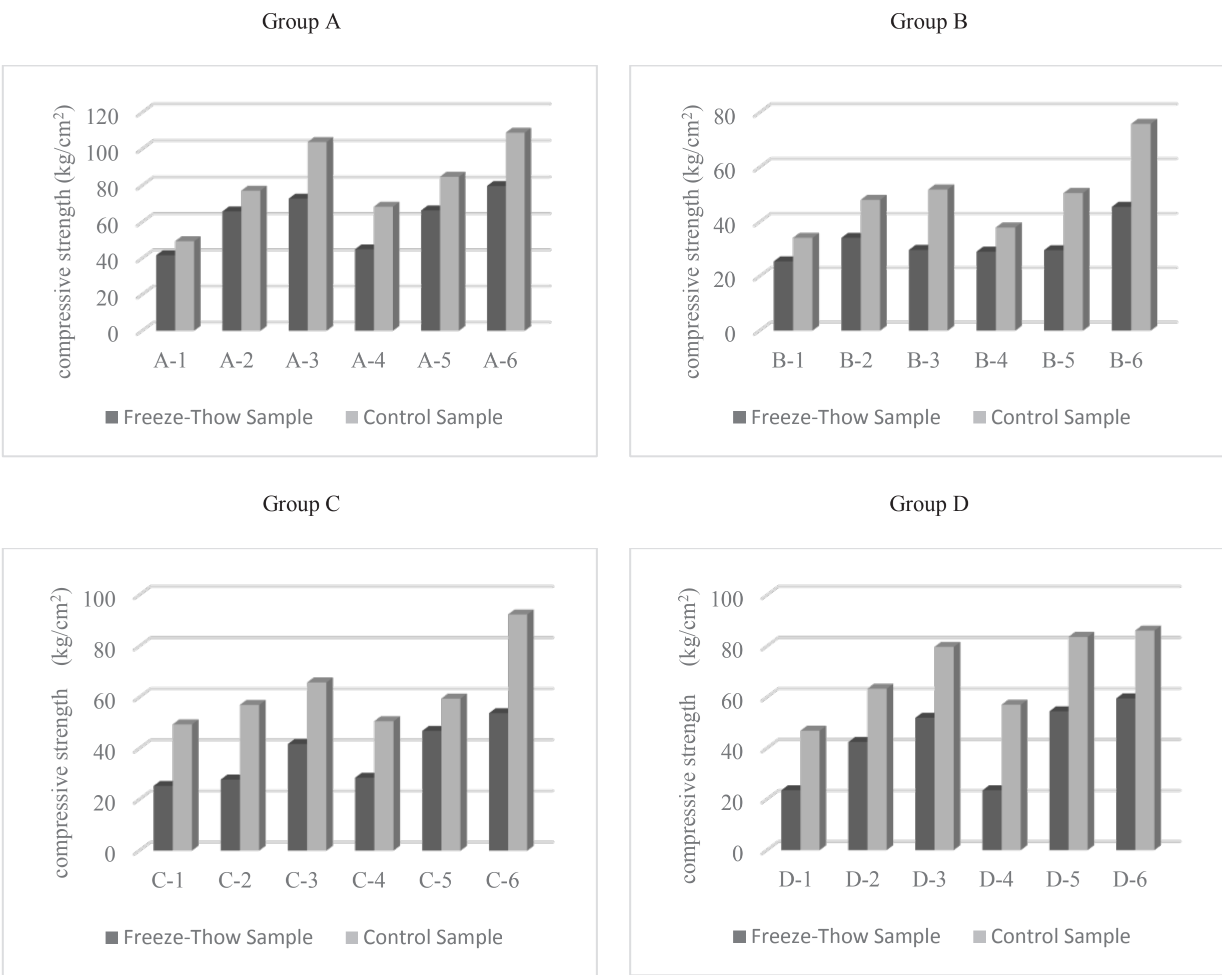


Fig. 12. Results of compressive test on samples with 45 cycles of freeze-thaw and also control samples

3- 3- Results of 45 cycles of freezing and thawing test

The samples made for the freezing and thawing test were subjected to 45 cycles of thawing and freezing after being cured in water for 14 days. According to Figs. 12 and 13, the process of changing the compressive strength due to freezing and thawing tests for different materials and different percentages of cement and NMP is different. The lowest drop in strength is related to group A with 6% of cement. Also, the maximum drop in strength is related to group D with 3% cement and 0.3% NMP. The lack of cement and polymer, which are among the materials, and the presence of gypsum waste, which is the most effective in reducing resistance during the time of melting and freezing, can be the reason for this decrease in resistance. In general, group A materials have more resistance against freezing and thawing.

4- Conclusions

In this research, compacted samples of C&D wastes with 3, 6, and 12 percent cement and also samples with the same percentage of cement and 10% cement from NMP polymer were studied. Compressive, indirect tensile, and freezing and thawing tests were performed on these samples. The results of the research are as follows:

• Considering the compaction curve, it can be concluded that materials of group A which contains cement and pieces of block and mortar, have more potential for compaction. The materials of group B have the lowest dry density at the same compaction energy.

• Adding gypsum to brick and cement waste causes an increase in the moisture content without decreasing dry density, which indicates that gypsum makes the mix absorb

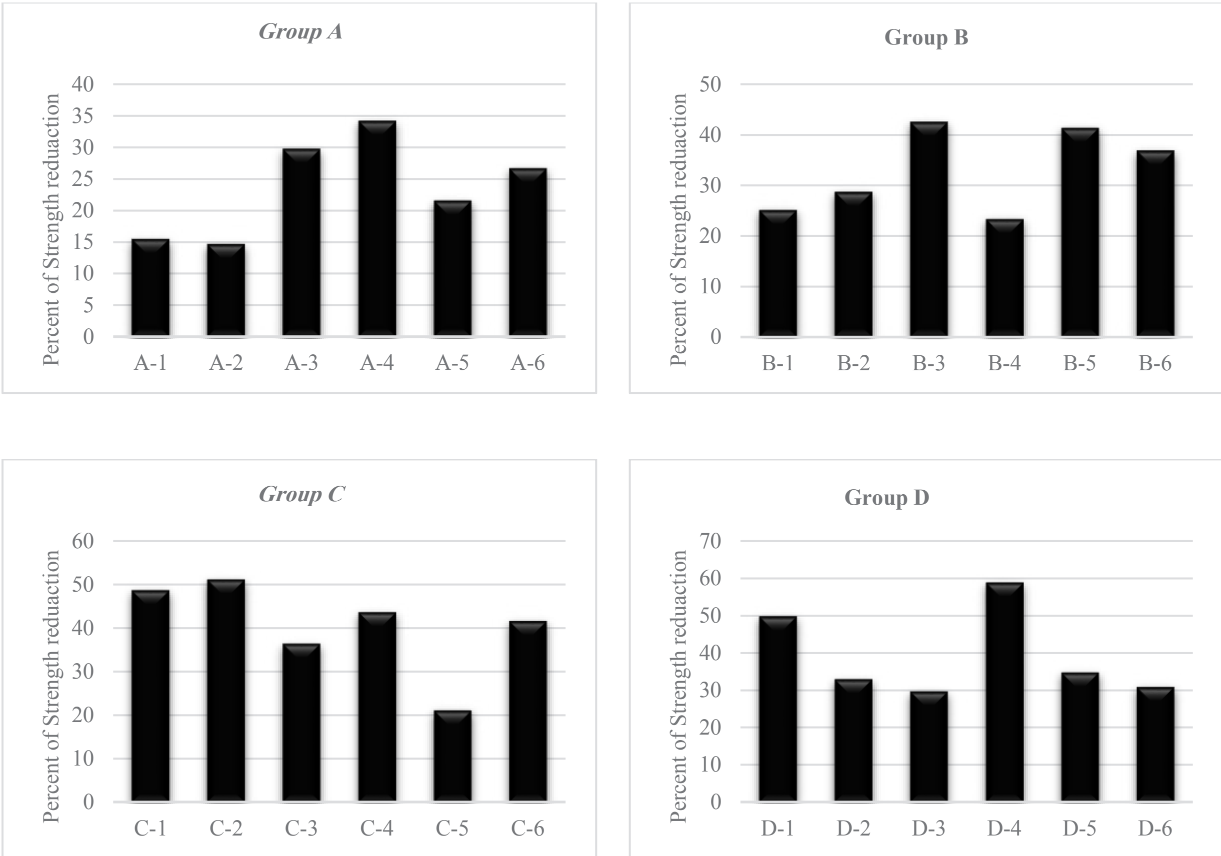


Fig. 13. Percent of strength reduction due to 45 cycles of freeze-thaw for each group of C&D materials

more water and that's why the dry density of group D is more than group C's.

• Adding NMP causes an increase in the strength of 7-day samples of all groups and all percent. This increase from 2 to 42.9% is different for different percent. It can be said that it has increased the 7-day strength of samples by 13.3% on average.

• It was seen that NMP was most effective in 3 and 6 percent of cement. In none of the groups samples with 12% cement have more increase in strength. this shows that only using a lot of polymer and cement will not improve the condition.

• The greatest increase in 7-day strength in group C pertains to the C-5 sample which contains 6% cement and 0.6% NMP. Adding gypsum waste causes the most increase in strength in group D pertaining to D-4, i.e., for samples with 3% cement and 0.3% NMP indicating the positive effect of adding gypsum waste.

• Generally, it can be said that for 7-day samples, increasing cement and the NMP polymer weaken the effect of NMP.

• For the 28-day samples, in all percentages, the compressive strength of group B is lower than other groups, and the resistance of group C is between group A and B. The use of gypsum waste has improved the 28-day strength, but anyway, the strength of group A is higher than others.

• The average increase in 28-day sample strength which was the result of using NMP, was about 18.6%.

• For samples with 28 days of curing, in all groups except B, samples with 3 and 6 percent cement have the highest increase in compressive strength due to the use of NMP. The percent of the increase in strength of samples with 28 days of curing was 18.6% on average.

• In many 7-day samples NMP did not have any effect in increasing the strength in the indirect tensile test or its effect was as low as that the machine was not able to record it. The average increase of 7-day strength for all groups is 6%.

• 7-day tensile strength of group B material has the lowest value. The tensile strength of group C materials is between A and B in most cases. Adding gypsum to materials of group C increases the tensile strength.

• The presence of aggregates and primary granulation in group A materials has caused a high resistance in them, and the presence of cement even in cementation conditions has also had an effect in creating this resistance.

• Generally, by increasing cement and NMP, their effect on 28-day strength decreases.

• The addition of gypsum wastes to the composition of group A and B scum has increased the percentage of moisture without reducing the dry specific weight, which can indicate that gypsum has absorbed more water in the composition, but because it is in the form of fine-grained material, it has caused the pores between the grains to be filled and increased the specific dry weight compared to sample C.

• Increasing tensile strength due to the use of NMP means that using this polymer can decrease tensile cracks in pavements.

• Considering the obtained results, it can be seen that cement waste materials have usually better results in comparison to other wastes. But construction waste is commonly a combination of the aforementioned waste, mixing the materials according to group D will be the optimum state for pavement construction. Also, the optimum percentage for using NMP is 6 percent cement and 0.6% NMP.

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