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Journal of Civil Engineering and Materials Application Journal home page: http://jcema.com

Received: 24 July 2022 • Accepted: 19 September 2022



doi: 10.22034/jcema.2022.353202.1090

Investigating the Effect of Cement Grading on the Characteristics of Concrete and Standard Mortar

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ABSTRACT

Grading is one of the most important characteristics of cement, which has a great impact on its performance in concrete. The most common methods of monitoring are determination of residues on sieves, Blaine and LD. In this study, introduce the main parameters of cement grading, optimal limits and its effects. Also 204 samples of Portland cement were prepared to determine their physical and mechanical properties and performance of Laboratory concrete mixtures. One of the most important results is the clear effect of increasing the share of 3 - 30μ particles and cement uniformity coefficient on the compressive strength of concrete and mortar and providing relationships. The results of LD- PSD experiments were well correlated with the experiments remaining on the sieve by alpine method. With increasing uniformity or the amount of particles of 3 - 30μ increases (becomes longer); which is not always desirable.

Keywords: grading, PSD, cement, Mortar, concrete.

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1. INTRODUCTION

n order to improve the efficiency of cement and its properties, the effects of cement particle size distribution (PSD) on the hydration process should be considered, and various sources have emphasized the importance of this issue [1-6]. The sieving method [8-7] is not very desirable for cement powder and is the only standard method for measuring PSD cement (turbidimeter or Wagner test) in terms of limited amplitude (smaller than 7.5 microns) [9]. Because there is no standard method that covers a wide range of cement PSDs, the measurement methods in the industry are very different. It is emphasized that the combination of the results of tests to determine the fineness of cement (Blaine) [10], residues on 45 and 90micron sieves, and laser grading is the best option to control the quality of cement wear. It is interesting to note that in forensic medicine, the PSD of very small specimens needs to be accurately determined using a fast and reliable high-resolution method [11]. Laser grading is of special importance in the cement industry, so in the laboratory operations of this paper, we tried to observe the compressive strength of standard mortar and concrete using this method. First, the main characteristics of laser cement grading and its limits are introduced. Particle size between 3 to 30 microns (Δ 3-30): 1-For cement with normal mortar strength: 40-50%; 2- For high strength mortar cement: 55-65%; 3- For cement with very high mortar strength: above 70% has been introduced [12], some other authorities have mentioned at least 50% of this index [13]. According to experimental studies, when the particle size of 3-32 microns in the Portland cement sample increases to 42.5 R, a 13% improvement in 28-day compressive strength is achieved (Figure 1). By decreasing the specific surface area of the cement (Blaine value) and increasing the fraction by 5-20 microns, the initial strength increases due to the improved homogeneity of the particle distribution [14].



Figure1. Comparison of compressive strength of 32-32 micron cement fraction of 42.5R with samples with different grading [14]

The fineness parameter (d') is the sieve index under which 63.2% of the particles are located. If cement's uniformity coefficient (n) is less than 0.9, it indicates a wide and undesirable particle distribution curve, but a uniformity coefficient greater than 0.9 indicates a narrow distribution [15]. The uniformity coefficient is expected to be about 1.2-1.1 in the roller mills and 0.9-0.1 in the bullet mills. In principle, increasing the uniformity coefficient is a positive factor in improving grading, which leads to improved cement strength. It should be noted that operations to achieve large particle size distributions have costs (operating and energy consumption measures) [16]. Increasing the fineness of cement (Blaine) is not always desirable because increasing the fineness of cement increases the need for water consumption (demand) of concrete, and usually, to obtain the smoothness of concrete, the w/c ratio increases, which ultimately increases the strength of concrete despite increasing mortar strength. Does not result [17]. Cement with a narrower grain size curve (less particle size variation) or cement with a higher Blaine (more fineness) has shown the greatest demand. Of course, more water demand in cement also leads to longer setting times [18]. On the other hand, it should be noted that grinding any material that contains two or more different components (in terms of abrasion) (such as clinker, gypsum, pozzolan, lime, and slag in cement) leads to the distribution of two- or multi-phase grading [19]. ASTM Committee C01.25.01 has supported a new method for measuring the PSD of cement [20]. The results of statistical analysis of the collected data on cement pastes produced from the combination of fine cement (SFC) with ordinary Portland cement (OPC) have shown that the PSD of cement paste mixed with SFC is closer to the optimal PSD. The results of bulk density, flow ability, rheology, and strength performance of cement paste mixtures have also shown the improvement of SFC application properties, which brings PSD in cement paste closer to the desired level [21]. Based on the studies of Ferraris et al. (2004), no clear relationship was observed between the measurement time in the new experimental method and the PSD results [22]. Mitrovic (2004) worked on dry and wet grading methods and stated that the PSA 1090 method is an excellent system for combining liquid and dry measurements and cement particle analysis [23]. Frigione & Marra (1976) studied the relationships between PSD, specific surface area, and compressive strength in Portland cement. They showed that when the granulometric range decreases, the volume of the hydrated product increases, resulting in compressive strength. Experimental data have shown that contrary to this hypothesis, the depth of hydration depends more on the size of the particles. However, they proved that in practice, the width of the granulometric range could be minimized, and the mechanical strength of Portland cement in both mortar and concrete could be maximized [24]. According to the studies of Kuhlmann et al. (1985), the specific surface area of cement can be calculated from PSD parameters. The higher the slope of the grading curve, the narrower the distribution, which leads to an increase in cement strength [25]. Osbaeck and Johansen (1985) studied the PSD and the rate of development of Portland cement strength. According to them, the fineness of Portland cement is a key factor in determining the characteristics of its strength development [26]. Aigin et al. (1997) investigated the effect of PSD on cement properties and found that PSD affects porosity and hydration rate; also, the ratio between components mainly depends on bulk density [27]. Aiqin et al. (1999) analyzed the effect of PSD on cement systems on cement properties. They suggested for optimal distribution of cement particles: 1-Wider PSD is useful for increasing bulk density and decreasing water absorption; 2-Thinner PSD is effective in increasing the rate of hydration; 3-In the same water-to-cement ratio, a narrow distribution is useful to reduce the porosity of the cement. In a more practical sense, PSD is optimal when n is equal to 1 [28]. Bentz et al. (1999) The effects of PSD cement on the functional properties of cementitious materials (including setting time, heat dissipation, porosity, permeability, chemical shrinkage, internal shrinkage, internal relative humidity

..... evolution, and surface transfer microstructure) through computer simulation and several studies Experimental study [29]. Bentz et al. (2001) studied the effect of PSD on cement on initial stressors and initial autogenously Strains in cement pastes with the same water-to-cement ratios for cement with four different finenesses. These researchers used chemical shrinkage to determine the degree of hydration and the development of internal relative humidity; autogenously, deformation and development of specific stress were investigated using a sensor. Their results showed that a small autogenously expansion (probably due to the formation of ettringite) might occur and that cracking at younger ages may be avoided by using coarser cement [30]. Stark and Müller (2003) examined PSD cement and additives. According to them, particle size changes due to the reaction between water and cement in the early hydration period can be observed on site. Although not all the measured effects are clear, the change in PSD and the increase in mean particle size are consistent with the fact that the size of the hydration products is larger than the particle size of the original cement [31]. PSD, uniformity of distribution, and specific surface area (SSA) of cement have a great impact on its properties, especially strength. Accordingly, Celik (2009) conducted studies on the effects of physical parameters on the development of PC 42.5 R cement strength. In order to understand the importance of different particle size ranges in a grain size distribution, he prepared samples with different distributions, including 10, 20, 30, 45, 32-3, and 5-20 microns. According to the results of this PSD researcher, uniformity of distribution and specific surface area (SSA) is very important for the development of cement strength [32]. Binici et al. (2007) investigated the effect of PSD on the properties of mixed cement containing granulated blast furnace slag (GGBFS) and natural pozzolan (NP). They found that samples with cement and additive wear separately were relatively smaller than simultaneous wear samples and had higher compressive and sulfate strengths. Larger separate wear samples had the lowest hydration heat, and smaller separate wear samples had the highest compressive and sulfate resistance. [33]. Hwang et al. (2005) studied the effect of PSD slag cement on its rheological properties and presented similar results [34]. Hassani and Manvarian (2013) designed and optimized the non-uniform granulation of oil well cement in order to achieve the desired properties of cement slurry and stone [35]. Changoi and Zhouhi (2012) proposed a model to simulate the effects of PSD on the cement hydration process [36]. Ferraris & Garboczi (2013) identified and compared improved standard experiments to measure

cement particle size and surface area. The two researchers subjected more than 30 cement samples to Blaine tests, Laser Diffraction (LD) measurement, and residue determination on 45-micron sieves and BET. According to their results, it was difficult to establish the correlation between Blaine, LD-PSD, and compressive strength in cement; however, when the cement properties were investigated, they observed a clear correlation between 28day strength, setting time, and softness [37]. Ghiyasvand et al. (2014) investigated the effect of the milling method and PSD on the properties of Portland-Pozzolan cement. This paper describes the effect of the production method (simultaneous or separate wear) and PSD on the properties of Portland-pozzolanic (PPC) cement. The results of this study showed that the PPC particle size distribution was different for each production method, and the physical properties of cement resulting from simultaneous wear were slightly better than separate wear [38]. Arvantini et al. (2015) studied the PSD, surface area, and shape of cementitious additives (SCMs), including fly ash, grading blast furnace slag, and silica fume, in different ways. They made recommendations for SCM testing using air permeability, sieving, laser diffraction, BET, image analysis, and MIP [39]. Zhang et al. (2017) studied the preparation and application of finely ground cement in cementitious base materials. Their results showed that by adding surface modifiers and MGM, the efficiency of GC preparation could be improved, and the hydration process could be controlled at an early age. Partial replacement of PC with GC, with an optimal dose of 20% GC, can clearly increase the cement performance, resulting in an obvious increase in compressive strength. The degree of hydration, pore structure, and microstructure in ITZ can be improved in the presence of GC compared to a single PC system [40]. Wu et al. (2018) investigated the effects of PSD on the strength-filling properties of cement paste. The CPB resistance parameter model was constructed under the influence of both PSD and finite pressure based on the Mohr-Coulomb criterion. The results of this study showed the effect of optimal PSD on CPB resistance [41]. Kim (2018) investigated the effect of cement granulation on concrete strength development. According to the results of this study: A. The average diameter of cement particles increases with increasing FMC to maintain slump and air; B. With increasing FMC, the setting time is slightly delayed, which is a delay of about 0.42 hours for every 0.1 increase in FMC; C- Formula for estimating compressive strength using FMC and age with high correlation (0.942) as;

$f_{cu}\!\!=\!\!11.177 \!\times\! log D\text{-}11.365 \!\times\! FMC \!+\! 25.146$

Is where f_{cu} is the compressive strength, FMC is the fineness of the cement and D is the age of the specimen in terms of days [42]. The depth of hydration of cement

particles with different sizes is different, which reflects the hydration process. Therefore, knowing and controlling the hydration depth improves the quality of cement materials'

..... quality. Zhang et al. (2021) investigated this issue. They proposed a combined method of electron and stereological images to describe the depth of hydration of cement particles of different sizes in hardened cement materials and measured the depth of hydration of cement particles in hardened cement paste with a water-to-cement ratio of 0.35 at the age of 28 days. They did The results of these researchers showed that cement particles below 2 microns are fully hydrated, and the depth of hydration of cement particles below 10 microns is about 2 microns. This method has good accuracy for cement particles smaller than 16 microns [43]. Younees et al. (2022) investigated the contribution of PSD indices and the shape of cementitious particles in the development of viscosity models of thick suspensions. According to the results of these researchers, kE coefficient and intrinsic viscosity (η) were in good agreement with particle size indices, including the smoothness index (SSA \times Gs) and particle size ratio (d502/SSA) [44]. Considering that more than one-third of electricity consumption in cement factories is consumed in the grinding process in cement mills and grading has a major role in the quality and quantity of cement, Farhadi (2007) is the best granulation range for cement and increased production and optimization of electricity consumption in Studied cement mills. Using laboratory methods, he showed the role of abrasive aid in correcting grading and, after injecting this material in the cement mill, introduced granulation in cement, increased production, and reduced electricity consumption by about

6 kWh per ton of cement [45]. The Rosin-Ramler-Benuet equation shows the effect of PSD on water absorption, degree of hydration, bulk density, and porosity. Accordingly, the effect of PSD on cement properties under different conditions is analyzed [46]. Behfar and Davarfar (1398) designed a laboratory operation to prepare a cement sample with appropriate granulation distribution by abrasion to study the behavior and properties of cement. Then they performed the industrial experiment and its effect on the strength of mortar and concrete. They showed that this sample has better conditions in terms of strength and rheology and can increase the softness and improve the grading distribution by removing very large and very fine particles, the effect of hydration reaction along with increasing concrete efficiency in water and reducing the cost of Cement mills improve [47]. As seen, many studies show that there is not enough information on the effect of cement grading changes on ready-mixed industrial concrete. Therefore, the purpose of this study is to provide some necessary information for cement and concrete producers in the field of optimal selection of cement in concrete. Therefore, specifically, the effect of cement grading changes on the technical characteristics of fresh and hardened concrete (without additives) was investigated in common experiments; So that the working method and details were similar to what often happens in reality in the industry. For this purpose, concrete mixtures with the constant flow (slump) were prepared.

2. MATERIALS AND METHODS

In the first step, 204 samples of Portland cement type 2 were prepared from 6 different cement mills. Then, physical and mechanical properties, including determination of residue on sieves, fineness (Blaine), setting time, and compressive strength of standard mortar of cement samples, were measured (Figure 2).



Figure 2. Laboratory cementation and determination of their physical and mechanical characteristics

In the next step, 204 concrete mixtures with cement samples were prepared with the aim of achieving a slump

of 8 ± 0.5 cm. Figure 3 and Table 2 show the characteristics of aggregates used in this study.

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Passing percent of sieve 200	Fracture (%)	ρ (SSD)	Water absorption (%)	fineness modulus (FM)	MSA	Туре								
0.5	45	2.57	1.50	7.2	25	gravel								
44	*	2.53	3,39	7.0	*	sand								

Table 1 Technical specifications of materials used in concrete mix designs



Figure 3. Particle size of sand (right), sand (left) and composition of materials (bottom) used in concrete mixes

In all mixtures, the quality of aggregates and water, weight values of materials, and physical conditions such as temperature, tools used, testers, and processing conditions have been as constant as possible so that the only variable of cement consumption is created under the same conditions (Figure 2). The grade of cement used in all

designs was 350 kg/m3. Mixtures were designed nationally [48]. To prepare this mixture, 65% sand with 35% coarse sand was used (Figure 3). The compressive strength of concrete mixes was measured at 7 and 28 days (Figure 4).



Figure 4. Preparation of concrete mixes and related tests

3. RESULTS AND DISCUSSION

Table 2 summarizes the results of the experiments performed.

Table 2. Summary of test results

Comp (MPa)	. Strength Concrete	w	/c	Comp. Strength (MPa) Mortar		Setting time Blaine (min) (m2/kg)		Retained on sieve (%)			Laser Diffraction d'		n		Retained on sieve (%) LD		Code	
		28days	7 days	28days	7 down	Final	Initi		30µ	45µ	90µ	3-30µ			30µ	45µ	90µ	
32/1	23/8	0/54	56/4	40/4	260	180	al 302	21	14	2	59	10	25	1/09	31	13	1	1
36/0	27/8	0/55	54/3	40/9	265	185	305	17	10	1	64	11	23	1/10	26	10	0	2
26/5	21/7	0/56	53/2	40/8	230	160	295	22	11	1	62	10	24	1/10	28	8	0	3
27/5	21/5	0/54	42/0	19/7	240	170	293	45	28	6	49	10	32	0/97	51	25	6	5
22/1	18/6	0/54	45/4	36/0	200	140	348	30	20	3	56	11	26	0/98	33	17	1	6
29/0	24/3	0/51	41/5	31/8	190	130	346	32	19	3	55	11	27	0/96	34	18	3	7
30/1	24/2	0/55	51/7	40/6	245	170	299	23	15	3	61	10	23	1/04	29	13	1	9
25/2	19/2	0/54	47/8	33/5	250	155	302	21	12	1	56	17	21/90	0/91	27	13	1	10
29/0	26/8	0/56	55/2	37/1	245	165	302	17	9	1	62	16	20/50	0/99	22	9	0	11
29/6	24/4	0/55	49/5	37/1	255	160	288	20	11	1	55	16	23/30	0/97	23	10	2	12
27/1	20/6	0/52	49/6	36/7	250	165	281	20	12	1	56	17	22/50	0/92	28	14	1	14
29/7	26/7	0/55	58/4	44/2	280	185	309	27	7	2	58	16	21/74	0/94	26	12	2	15
33/5	25/6	0/55	48/6	36/9	300	180	274	26	14	4	60	15	21/30	0/88	26	14	1	10
30/2	24/7	0/55	54/2	40/5	295	205	302	19	9	2	59	16	21/56	0/95	25	11	1	18
28/1	24/4	0/53	53/4	39/4	285	180	288	18	9	2	62	14	21/48	1/01	24	10	1	19
31/4	22/8	0/53	54/3	43/4	280	185	305	18	8	0	58 60	17	21/14	0/92	25	9	0	20
31/7	26/1	0/53	53/2	38/8	295	190	312	20	9	0	60	16	21/28	0/96	25	10	1	22
34/1	24/5	0/54	58/1	37/3	250	180	299	21	11	2	57	17	21/17	0/91	26	11	0	23
29/4	25/6	0/52	53/3	37/4	295	190	302	17	8	2	60	16	21/04	0/96	24	9	1	24
24/3	17/3	0/51	42/2	38/4	285	170	302	30	16	3	50	16	25/44	0/86	33	17	2	26
25/7	17/3	0/55	53/7	33/5	310	235	305	37	25	4	45	18	28/83	0/72	36	25	10	27
28/4	23/5	0/53	47/1 39/5	26/7	285	210	274	20	12	3	50	17	25/44	0/83	29	19	6	28
29/5	21/6	0/53	51/7	34/7	320	250	312	21	12	3	54	16	24/91	0/85	30	17	7	30
30/5	24/4	0/53	49/3	31/0	285	215	302	20	10	1	60	16	21/00	0/96	24	9	0	31
27/9	20/6	0/54	45/8	34/0	270	185	299	23	19	3	49	20	20/14	0/79	22	19	4	32
26/6	17/4	0/54	38/4	32/8	290	210	281	21	12	3	45	13	35/02	0/80	42	29	13	34
26/9	18/7	0/54	47/2	34/2	270	190	305	13	4	3	55	17	23/54	0/88	28	14	2	35
28/4	16/1	0/55	45/4	33/6	295	200	302	32	22	8	55 47	20	22/62	0/88	34	22	7	30
31/1	25/6	0/60	53/6	35/7	290	205	309	19	9	2	60	16	21/70	0/94	24	10	1	38
30/9	25/6	0/55	49/6	34/6	295	210	302	19	9	2	58	16	22/93	0/93	26	12	2	39
31/3	23/5	0/55	58/3	38/0	280	195	315	30	19	4	47	18	27/82	0/80	35	19	3	40
31/5	29/4	0/54	48/5	39/4	270	190	295	18	9	1	55	17	23/42	0/90	28	14	2	42
29/8	25/0	0/56	47/8	34/2	260	170	377	26	21	6	46	22	24/92	0/67	32	22	9	43
32/1	27/4	0/55	53/0	41/9	2/5	195	312	28	7	2	51	17	20/42	0/84	25	11	1	44
30/5	22/4	0/55	59/2	40/4	280	190	295	30	15	1	53	16	25/83	0/88	31	17	3	46
29/2	25/2	0/56	48/5	29/6	150	100	318	30	20	5	47	20	26/08	0/71	33	22	9	47
30/1	22/3	0/54	49/5	35/0	245	155	328	20	10	2	50	18	20/31	0/85	26	11	1	48
32/3	26/1	0/54	53/2	37/5	270	165	309	18	10	1	57	16	23/65	0/88	28	14	5	50
30/3	23/9	0/56	45/1	27/9	270	175	288	23	12	0	55	16	24/42	0/91	29	14	1	51
28/6	24/9	0/54	40/5	32/6	213	140	328	23	18	3	50	17	28/54	0/88	35	17	3	53
31/8	25/0	0/54	50/1	36/3	295	200	305	17	9	2	59	14	24/47	1/01	27	11	1	54
30/7	27/1	0/53	51/0	33/2	285	205	318	17	9	2	59	15	23/68	0/98	26	11	1	55
29/8	26/4	0/56	48/2	32/4	205	145	331	29	22	4	47	16	30/27	0/83	37	23	7	57
26/3	24/5	0/54	46/3	35/8	230	155	352	30	27	3	44	17	31/34	0/80	38	24	6	58
29/8	22/7	0/54	48/7	34/6	255	175	340	17	12	1	58	15	24/09	0/96	27	11	1	59 60
28/9	25/4	0/55	48/2	35/6	240	150	321	19	11	0	55	15	25/38	0/96	30	13	1	61
30/4	28/1	0/53	49/7	41/7	250	170	321	29	21	3	45	17	31/46	0/81	38	24	6	62
27/3	23/4	0/54	57/9	42/0	270	190	305	17	8	1	55	15	25/59	0/95	30	14	3	63 64
29/9	27/6	0/54	49/4	36/3	2/5	195	302	19	11	1	53	15	27/22	0/94	32	16	2	65
30/6	26/2	0/52	46/4	32/5	250	170	288	31	19	3	50	18	26/37	0/80	32	19	5	66
28/4	24/5	0/53	48/2	34/3	260	180	295	27	14	3	47	16	29/91	0/84	37	21	4	67 68
31/0	25/4	0/54	49/5	38/5	265	185	288	18	9	2	57	15	24/27	0/95	28	11	2	69
25/1	24/4	0/53	49/0	39/1	280	195	292	21	10	1	56	15	24/95	0/94	29	13	0	70
27/5	24/4	0/56	47/4	33/7	270	200	295	25	16	4	54	15	25/85	0/91	31	17	4	71
28/1	21/7	0/54	45/2	24/7	320	215	295	32	22	9	50	20	23/06	0/84	39	24	11	73
28/6	24/5	0/54	50/0	34/5	240	185	288	19	9	2	55	14	25/98	0/96	31	15	2	74
25/6	21/6	0/53	42/5	34/8	250	170	312	27	18	5	52	20	22/90	0/79	28	16	2	75
30/2	20/6	0/53	50/5	36/4	225	180	328	20	20	2	59	19	27/34	0/75	26	11	1	76
29/4	22/8	0/53	57/7	44/9	265	190	302	22	10	2	59	16	22/62	0/94	25	11	1	78
29/6	26/5	0/56	45/1	41/2	230	150	277	30	19	3	45	19	28/89	0/75	36	22	6	79
28/5	22/4	0/57	54/6	39/3	205	203	281	19	8	2	59	10	21/93	0/94	23	10	1	81
28/9	25/2	0/54	48/5	38/4	250	170	285	27	15	2	53	21	21/67	0/80	26	13	1	82
28/0	23/0	0/54	51/3 48/4	38/0	260	180	288	19 21	8	1	59	16	22/71	0/96	25	10 12	1	83 84
28/0	23/3	0/53	54/4	38/0	270	200	309	20	8	0	58	18	21/52	0/90	24	10	0	85
29/2	23/1	0/57	52/0	36/1	270	195	285	23	11	2	57	17	22/73	0/89	26	12	1	86
30/7	25/3	0/56	56/7 45/1	37/4	285	210	289	20	11	3	57	17	22/85	0/91	26	11	1	87
28/2	23/6	0/57	57/0	42/6	235	200	281	20	9	0	55	18	23/16	0/88	27	10	1	89
29/2	24/1	0/54	48/7	37/6	270	200	295	23	15	2	55	17	23/67	0/89	28	14	2	90
28/4	21/1 23/0	0/55	50/2 54/3	43/2	265	185	321 302	28	20	2	49 63	21	24/35	0/76	30 23	17	4	91 92
28/6	23/4	0/55	51/5	35/3	260	190	309	16	9	1	60	17	20/95	0/93	23	10	1	93
29/4	25/0	0/56	45/8	34/9	265	190	302	24	10	5	43	20	30/47	0/68	37	26	12	94
29/9	25/4	0/54	42/7	32/2	250	185	321 312	23	14	2	54	18	23/17	0/84	28	16	4	95 96
31/8	25/6	0/54	48/1	35/4	270	200	331	19	10	2	59	14	23/19	0/96	27	13	2	97
28/1	25/3	0/55	49/6 51/8	40/1	240	180	309	22	8	0	57	17	22/92	0/91	27	12	1	98
	40/0	0.54	51/0	5910	275	205	504	17	0	1	00	10		0, 20		10	1	

31/2	23/7	0/54	46/3	33/7	290	200	305	18	8	1	57	17	22/25	0/90	25	12	2	100
29/1	22/8	0/54	39/9	28/5	265	185	292	27	17	3	49	21	23/95	0/74	30	18	5	101
28/8	23/3	0/54	37/8	26/3	285	195	318	28	18	3	49	19	25/81	0/78	32	19	5	102
20/0	23/3	0/34	3//0	20/3	203	195	310	20	10	5	49	17	25/01	0/78	34	19		102
29/8	21/9	0/54	46/1	36/0	230	185	318	23	9	U	5/	17	22/18	0/89	26	12	1	103
29/5	24/1	0/53	56/6	41/2	265	195	302	15	6	1	61	15	22/32	0/98	24	10	1	104
30/7	25/4	0/53	54/5	40/8	240	180	309	13	6	1	62	16	21/00	0/98	22	8	0	105
29/1	24/1	0/54	49/9	35/9	245	180	334	26	16	2	50	20	24/21	0/79	29	16	2	106
29/4	25/6	0/53	51/8	38/0	245	180	325	26	16	2	51	19	24/90	0/81	30	17	2	107
31/3	25/7	0/54	45/0	31/9	235	165	299	29	19	4	51	20	24/27	0/80	30	17	2	108
30/3	25/1	0/54	45/1	30/8	220	155	299	25	16	5	50	20	24/08	0/77	30	17	3	109
20/0	20/1	0/54	50/0	40/1	220	195	200	20	10	4	50	20	10/46	0/79	22	11	1	110
29/0	24/0	0/55	30/0	40/1	230	100	309	20	10		54	23	19/40	0/78	23	14	1	110
28/6	24/0	0/53	44/6	33/8	240	180	299	25	17	3	53	20	23/05	0/81	28	14	2	111
31/7	25/7	0/54	52/6	39/8	265	195	309	16	6	2	64	16	20/18	0/99	20	6	0	112
30/8	25/6	0/53	52/0	40/5	260	190	302	14	6	1	61	16	21/52	0/96	23	9	0	113
26/6	22/6	0/54	37/1	31/1	245	170	352	32	23	7	49	19	25/34	0/78	32	20	4	114
28/1	24/9	0/54	48/6	39/9	265	190	295	27	17	3	53	19	23/47	0/82	29	16	2	115
28/6	25/2	0/54	50/6	39/7	270	195	325	24	15	2	50	20	24/25	0/78	30	17	5	116
20/0	20/2	0/54	55/0	40/9	205	220	323	10	5	1	62	17	24/25	0/07	21	7	0	117
30/2	22/1	0/54	53/1	40/0	295	220	321	10		1	02	1/	20/03	0/97	21	11	1	117
30/9	25/6	0/53	53/1	42/1	290	215	299	18	10	2	59	16	22/40	0/94	25	11	1	118
28/0	22/7	0/55	46/6	38/4	285	195	292	18	9	1	57	16	23/78	0/92	28	13	2	119
28/2	24/3	0/55	51/4	38/0	275	195	302	16	9	1	59	16	22/20	0/94	25	11	1	120
28/4	22/4	0/56	47/9	32/2	240	165	305	28	19	6	47	21	25/88	0/75	32	18	3	121
27/9	23/1	0/58	43/7	32/9	230	175	309	26	17	3	50	18	25/48	0/80	32	19	5	122
27/8	21/4	0/56	51/7	39/5	280	195	334	25	12	3	48	19	26/85	0/78	33	20	6	123
27/4	22/8	0/59	44/7	32/8	270	190	299	27	15	3	49	19	25/82	0/80	32	18	2	124
30/1	22/6	0/56	56/3	42/1	295	215	299	12	5	1	62	16	21/24	0/97	22	8	0	125
30/5	23/2	0/56	51/0	36/5	270	190	288	17	7	2	58	16	23/31	0/94	26	12	1	126
27/7	22/3	0/58	13/2	31/5	215	145	300	26	17	-	49	20	24/98	0/77	31	18	3	127
20/1	25/3	0/56	40/2	24/6	215	220	302	20	7	1	4)	16	24/30	0/66	25	10	1	127
30/1	23/2	0/50	49/0	34/0	303	100	302	20	14	1	51	10	22/44	0/00	23	10	1	120
21/5	23/3	0/50	45/5	35/3	260	190	309	26	14	3	51	20	23/70	0/78	29	10	4	129
26/8	23/5	0/56	45/2	34/5	285	210	292	23	13	3	51	18	25/57	0/83	31	17	3	130
30/2	23/6	0/56	53/4	39/1	260	185	302	6	6	1	59	16	22/40	0/94	25	10	0	131
29/0	24/0	0/56	47/4	30/7	275	195	302	17	8	2	54	20	20/00	0/76	26	16	7	132
29/9	25/1	0/56	44/1	31/8	275	195	299	22	8	2	58	16	23/42	0/94	27	12	1	133
27/8	22/7	0/57	50/4	34/4	265	185	318	25	16	4	50	19	25/05	0/81	31	17	2	134
29/8	22/3	0/57	45/8	37/7	270	195	295	20	8	2	58	16	22/74	0/93	25	11	1	135
29/6	25/9	0/54	45/3	24/1	180	120	331	21	12	4	56	18	21/88	0/87	25	12	2	136
28/9	23/5	0/53	47/9	32/0	205	200	334	27	14	4	48	21	25/55	0/76	31	19	4	137
20/0	25/5	0/55	51/5	32/0	275	100	227	27	14	-	40	20	25/55	0/70	31	10	-	137
28/5	25/0	0/54	51/5	39/2	270	190	337	24	12	3	49	20	25/63	0/78	31	18	5	138
31/0	24/5	0/53	49/7	34/8	290	210	295	16	7	2	59	16	22/23	0/93	25	11	1	139
31/0	24/6	0/53	48/9	34/5	305	225	315	20	10	3	55	18	22/56	0/86	27	14	3	140
31/5	25/2	0/54	52/0	38/7	280	205	309	21	8	2	51	22	21/63	0/76	27	16	4	141
30/8	25/4	0/56	55/6	33/4	240	165	309	25	15	6	50	19	25/97	0/81	32	18	3	142
28/7	23/6	0/56	57/3	40/2	265	190	357	20	11	2	50	19	25/47	0/81	31	17	3	143
28/9	23/7	0/54	53/5	32/3	295	215	315	11	4	1	65	16	20/32	1/01	20	6	0	144
31/6	23/9	0/54	55/0	41/1	305	230	309	16	8	2	60	18	20/64	0/92	20	9	1	145
21/1	23/5	0/54	60/8	29/5	200	230	201	15	5	1	63	10	20/04	0/92	22	7	0	145
31/1	24/0	0/50	52/9	30/3	290	213	321	15	3	1	50	1/	20/20	0/90	21	17	2	140
2//8	21/6	0/57	52/8	37/8	285	215	325	25	12	3	50	18	25/51	0/81	31	1/	3	14/
28/6	23/2	0/55	49/8	34/0	305	230	318	21	6	1	61	15	22/26	0/98	24	9	0	148
27/6	20/4	0/57	43/8	28/7	255	180	299	25	13	4	52	19	23/88	0/81	29	15	2	149
26/3	21/7	0/57	47/9	34/8	250	175	318	25	14	4	51	19	25/14	0/81	31	17	2	150
26/1	21/7	0/57	46/4	35/1	275	200	325	21	12	2	52	17	25/25	0/85	31	16	2	151
26/5	22/1	0/57	48/2	36/6	295	215	312	18	7	2	60	17	21/66	0/94	24	10	0	152
28/0	22/5	0/57	48/7	36/5	290	210	362	16	13	7	58	17	22/16	0/92	25	11	1	153
20/0	22/3	0/56	56/7	30/3	255	180	312	20	7	2	50	17	21/93	0/92	20	10	1	154
27/2	24/4	0/50	50/7	39/3	205	175	224	20	12	2	53	10	21/95	0/95	24	10	1	154
27/8	23/1	0/57	54/6	30/2	255	1/5	334	25	12	3	55	18	24/10	0/84	29	15	2	155
2//9	1///	0/58	40/7	28/6	215	140	33/	31	20	8	46	18	29/80	0/75	3/	24	9	150
28/9	22/2	0/55	44/2	30/9	280	205	285	32	13	3	46	17	30/03	0/82	31	21	5	157
25/9	22/9	0/55	40/6	30/2	270	200	309	31	12	3	47	16	30/13	0/84	37	22	5	158
26/7	23/2	0/55	50/6	34/2	285	210	321	30	12	2	48	17	28/37	0/82	35	20	5	159
28/5	22/8	0/55	47/2	32/7	280	205	313	20	7	2	59	16	22/76	0/94	25	10	1	160
28/3	23/0	0/55	47/2	35/1	290	215	317	19	6	2	60	17	21/50	0/94	23	9	0	161
29/6	23/3	0/56				200	293	22	0	3	58	16	23/02	0/94	26	10	2	162
27/9	22/0		50/3	36/0	280	200										12		
22/5		0/56	50/3 50/9	36/0 36/4	280	195	305	30	15	3	49	17	27/85	0/82	34	20	5	163
31/4	16/1	0/56 0/56	50/3 50/9 43/4	36/0 36/4 30/8	280 270 220	195 145	305 321	30 25	15 13	3	49 49	17	27/85 26/39	0/82 0/80	34 32	12 20 19	5	163 164
	16/1 25/2	0/56 0/56 0/56	50/3 50/9 43/4 47/4	36/0 36/4 30/8 32/1	280 270 220 230	195 145 155	305 321 305	30 25 25	15 13 14	3 5 4	49 49 50	17 18 19	27/85 26/39 25/61	0/82 0/80 0/81	34 32 31	12 20 19 16	5 5 2	163 164 165
31/1	16/1 25/2 21/8	0/56 0/56 0/56 0/57	50/3 50/9 43/4 47/4 43/4	36/0 36/4 30/8 32/1 28/5	280 270 220 230 290	195 145 155 210	305 321 305 293	30 25 25 27	15 13 14 16	3 5 4 4	49 49 50 48	17 18 19 17	27/85 26/39 25/61 28/45	0/82 0/80 0/81 0/83	34 32 31 35	12 20 19 16 20	5 5 2 3	163 164 165 166
31/1 30/2	16/1 25/2 21/8 20/2	0/56 0/56 0/56 0/57 0/56	50/3 50/9 43/4 47/4 43/4 41/0	36/0 36/4 30/8 32/1 28/5 27/8	280 270 220 230 290 270	195 145 155 210	305 321 305 293 293	30 25 25 27 26	15 13 14 16	3 5 4 4 4	49 49 50 48 50	17 18 19 17 17	27/85 26/39 25/61 28/45 27/29	0/82 0/80 0/81 0/83 0/84	34 32 31 35 33	12 20 19 16 20	5 5 2 3 2	163 164 165 166 167
31/1 30/2 34/6	16/1 25/2 21/8 20/2 23/3	0/56 0/56 0/57 0/56 0/56	50/3 50/9 43/4 47/4 43/4 41/0 49/8	36/0 36/4 30/8 32/1 28/5 27/8 32/1	280 270 220 230 290 270 200	195 145 155 210 190 215	305 321 305 293 293 293	30 25 25 27 26 11	15 13 14 16 16	3 5 4 4 4 4	49 49 50 48 50 61	17 18 19 17 17 17	27/85 26/39 25/61 28/45 27/29 22/54	0/82 0/80 0/81 0/83 0/84	34 32 31 35 33 24	12 20 19 16 20 18	5 5 2 3 2	163 164 165 166 167 168
31/1 30/2 34/6	16/1 25/2 21/8 20/2 23/3	0/56 0/56 0/57 0/56 0/56 0/56	50/3 50/9 43/4 47/4 43/4 41/0 49/8 48/6	36/0 36/4 30/8 32/1 28/5 27/8 32/1 21/0	280 270 220 230 290 270 290	200 195 145 155 210 190 215 260	305 321 305 293 293 285 297	30 25 25 27 26 11	15 13 14 16 16 5	3 5 4 4 4 1	49 49 50 48 50 61	17 18 19 17 17 17 15	27/85 26/39 25/61 28/45 27/29 22/54	0/82 0/80 0/81 0/83 0/84 1/00	34 32 31 35 33 24	12 20 19 16 20 18 9	5 5 2 3 2 0	163 164 165 166 167 168
31/1 30/2 34/6 29/7	16/1 25/2 21/8 20/2 23/3 23/6 20/2	0/56 0/56 0/57 0/56 0/56 0/56 0/56	50/3 50/9 43/4 47/4 43/4 41/0 49/8 48/6 43/2	36/0 36/4 30/8 32/1 28/5 27/8 32/1 31/0 28%	280 270 220 230 290 270 290 340 250	195 145 155 210 190 215 260	305 321 305 293 293 285 297 203	30 25 25 27 26 11 11 11	15 13 14 16 16 5 5	3 5 4 4 4 1 1 5	49 49 50 48 50 61 54	17 18 19 17 17 17 15 17	27/85 26/39 25/61 28/45 27/29 22/54 22/14	0/82 0/80 0/81 0/83 0/84 1/00 0/75 0/80	34 32 31 35 33 24 28 35	12 20 19 16 20 18 9 19	2 5 5 2 3 2 0 10	163 164 165 166 167 168 169
31/1 30/2 34/6 29/7 28/7	16/1 25/2 21/8 20/2 23/3 23/6 20/2	0/56 0/56 0/57 0/56 0/56 0/56 0/56 0/57	50/3 50/9 43/4 47/4 43/4 41/0 49/8 48/6 43/3 52/9	36/0 36/4 30/8 32/1 28/5 27/8 32/1 31/0 28/6 28/5	280 270 220 230 290 270 290 340 250	200 195 145 155 210 190 215 260 130	305 321 305 293 293 285 297 293 203	30 25 25 27 26 11 11 30	15 13 14 16 5 5 19	3 5 4 4 4 1 1 6	49 49 50 48 50 61 54 48	17 18 19 17 17 17 15 17 18	27/85 26/39 25/61 28/45 27/29 22/54 22/14 28/32 21/26	0/82 0/80 0/81 0/83 0/84 1/00 0/75 0/80	34 32 31 35 33 24 28 35 22	12 20 19 16 20 18 9 19 21	5 5 2 3 2 0 10 3	163 164 165 166 167 168 169 170
31/1 30/2 34/6 29/7 28/7 32/3	16/1 25/2 21/8 20/2 23/3 23/6 20/2 25/3	0/56 0/56 0/57 0/56 0/56 0/56 0/56 0/57 0/56	50/3 50/9 43/4 47/4 43/4 41/0 49/8 48/6 43/3 53/8	36/0 36/4 30/8 32/1 28/5 27/8 32/1 31/0 28/6 38/5	280 270 220 230 290 270 290 340 250 280	200 195 145 155 210 190 215 260 130 200	305 321 305 293 293 285 297 293 301	30 25 25 27 26 11 11 30 15	15 13 14 16 16 5 5 19 6	3 5 4 4 4 1 1 6 1	49 49 50 48 50 61 54 48 62	17 18 19 17 17 15 17 15 17 18 16	27/85 26/39 25/61 28/45 27/29 22/54 22/14 28/32 21/06	0/82 0/80 0/81 0/83 0/84 1/00 0/75 0/80 0/97	34 32 31 35 33 24 28 35 22	12 20 19 16 20 18 9 19 21 8	5 5 2 3 2 0 10 3 0	163 164 165 166 167 168 169 170 171
31/1 31/1 30/2 34/6 29/7 28/7 32/3 29/1	16/1 25/2 21/8 20/2 23/3 23/6 20/2 25/3 23/9 25/3	0/56 0/56 0/56 0/57 0/56 0/56 0/56 0/56 0/57 0/56 0/56	50/3 50/9 43/4 47/4 43/4 41/0 49/8 48/6 43/3 53/8 52/7	36/0 36/4 30/8 32/1 28/5 27/8 32/1 31/0 28/6 38/5 35/1	280 270 220 230 290 270 290 340 250 280 270	200 195 145 155 210 190 215 260 130 200 190	305 321 305 293 293 285 297 293 301 293	30 25 25 27 26 11 11 30 15 25	15 13 14 16 16 5 5 19 6 14	3 5 4 4 4 1 1 6 1 3 3	49 49 50 48 50 61 54 48 62 52	17 18 19 17 17 15 17 18 16 17	27/85 26/39 25/61 28/45 27/29 22/54 22/14 28/32 21/06 26/12	0/82 0/80 0/81 0/83 0/84 1/00 0/75 0/80 0/97 0/86	34 32 31 35 33 24 28 35 22 32	12 20 19 16 20 18 9 19 21 8 17	5 5 2 3 2 0 10 3 0 2	163 164 165 166 167 168 169 170 171 171
31/1 30/2 34/6 29/7 28/7 32/3 29/1 34/0	16/1 25/2 21/8 20/2 23/3 23/6 20/2 25/3 23/9 25/7	0/56 0/56 0/57 0/56 0/56 0/56 0/56 0/57 0/56 0/56 0/56	50/3 50/9 43/4 47/4 43/4 41/0 49/8 48/6 43/3 53/8 52/7 42/8	36/0 36/4 30/8 32/1 28/5 27/8 32/1 31/0 28/6 38/5 35/1 29/1	280 270 220 230 290 270 290 340 250 280 270 245	200 195 145 155 210 190 215 260 130 200 190 170	305 321 305 293 293 285 297 293 301 293 316	30 25 25 27 26 11 11 30 15 25 27	15 13 14 16 5 5 19 6 14 18	3 5 4 4 1 1 6 1 3 5	49 49 50 48 50 61 54 48 62 52 48	17 18 19 17 17 15 17 18 16 17 19	27/85 26/39 25/61 28/45 27/29 22/54 22/14 28/32 21/06 26/12 26/82	0/82 0/80 0/81 0/83 0/84 1/00 0/75 0/80 0/97 0/86 0/79	34 32 31 35 33 24 28 35 22 32 33	12 20 19 16 20 18 9 19 21 8 17 19	2 5 2 3 2 0 10 3 0 2 3 3	163 164 165 166 167 168 169 170 171 172 173
31/1 30/2 34/6 29/7 28/7 32/3 29/1 34/0 29/1	16/1 25/2 21/8 20/2 23/3 23/6 20/2 25/3 23/9 25/7 23/1	0/56 0/56 0/57 0/56 0/56 0/56 0/57 0/56 0/57 0/56 0/55	50/3 50/9 43/4 47/4 43/4 41/0 49/8 48/6 43/3 53/8 52/7 42/8 47/1	36/0 36/4 30/8 32/1 28/5 27/8 32/1 31/0 28/6 38/5 35/1 29/1 30/9	280 270 220 230 290 270 290 340 250 250 280 270 245 270	200 195 145 155 210 190 215 260 130 200 190 170	305 321 305 293 293 297 293 301 293 316 327	30 25 25 27 26 11 11 30 15 25 27 26	15 13 14 16 5 5 19 6 14 18 16	3 5 4 4 4 4 1 1 6 1 3 5 4	49 49 50 48 50 61 54 48 62 52 48 52	17 18 19 17 17 15 17 18 16 17 19 17	27/85 26/39 25/61 28/45 27/29 22/54 22/14 28/32 21/06 26/12 26/82 25/51	0/82 0/80 0/81 0/83 0/84 1/00 0/75 0/80 0/97 0/86 0/79 0/86	34 32 31 35 33 24 28 35 22 32 32 33 31	12 20 19 16 20 18 9 19 21 8 17 19 17	2 5 5 2 3 2 0 10 3 0 2 3 2	163 164 165 166 167 168 169 170 171 172 173 174
31/1 30/2 34/6 29/7 28/7 32/3 29/1 34/0 29/1 33/0	16/1 25/2 21/8 20/2 23/3 23/6 20/2 25/3 23/9 25/7 23/1 24/2	0/56 0/56 0/57 0/56 0/56 0/56 0/56 0/57 0/56 0/56 0/55 0/55	50/3 50/9 43/4 47/4 43/4 41/0 49/8 48/6 43/3 53/8 52/7 42/8 47/1 38/9	36/0 36/4 30/8 32/1 28/5 27/8 32/1 31/0 28/6 38/5 33/1 29/1 30/9 26/9	280 270 220 230 290 270 290 340 250 280 270 245 270 245 270 260	200 195 145 155 210 190 215 260 130 200 190 170 190 180	305 321 305 293 293 285 297 293 301 293 316 327 323	30 25 25 27 26 11 11 30 15 25 27 26 20	15 13 14 16 5 5 19 6 14 18 16 12	3 3 5 4 4 4 4 1 1 6 1 3 5 4 3	49 49 50 48 50 61 54 48 62 52 52 52	17 18 19 17 17 15 17 18 16 17 19 17 18	27/85 26/39 25/61 28/45 27/29 22/54 22/14 28/32 21/06 26/12 26/82 25/51 24/60	0/82 0/80 0/81 0/83 0/84 1/00 0/75 0/80 0/97 0/86 0/79 0/86 0/83	34 32 31 35 33 24 28 35 22 32 32 33 31 30	12 20 19 16 20 18 9 9 19 21 8 17 19 17 17	2 5 5 2 3 2 0 10 3 0 2 3 2 2 4	163 164 165 166 167 168 169 170 171 172 173 174
31/1 30/2 34/6 29/7 32/3 29/1 34/0 29/1 33/0 33/0	16/1 25/2 21/8 20/2 23/3 23/6 20/2 25/3 23/9 25/7 23/1 24/2 22/7	0/56 0/56 0/57 0/56 0/56 0/56 0/56 0/56 0/56 0/56 0/55 0/55	50/3 50/9 43/4 47/4 43/4 41/0 49/8 48/6 43/3 53/8 52/7 42/8 47/1 38/9 51/0	36/0 36/4 30/8 32/1 28/5 27/8 32/1 31/0 28/6 38/5 35/1 29/1 30/9 26/9 34/4	280 270 220 230 290 270 290 250 250 280 270 245 270 260 270	200 195 145 155 210 190 215 260 130 200 190 170 190 190 190 195	305 321 305 293 293 285 297 293 301 293 316 327 323 289	30 25 25 27 26 11 11 11 30 15 25 27 26 20 10	15 13 14 16 5 5 19 6 14 18 16 12 4	3 3 5 4 4 4 4 1 1 6 1 3 5 4 3 1	49 49 50 48 50 61 54 48 62 52 48 52 48 52 62 52 62	17 18 19 17 17 15 15 17 18 16 17 19 17 18 15	27/85 26/39 25/61 28/45 27/29 22/54 22/14 28/32 21/06 26/12 26/82 25/51 24/60 21/87	0/82 0/80 0/81 0/83 0/84 1/00 0/75 0/80 0/97 0/86 0/79 0/86 0/83 0/99	34 32 31 35 33 24 28 35 22 32 32 33 31 30 23	12 20 19 16 20 18 9 19 21 8 17 19 17 17 8	2 5 5 2 3 2 0 10 3 0 2 3 2 2 4 4 0	163 164 165 166 167 168 169 170 171 172 173 174 175 176
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In the first stage, the effect of the amount of particles between 3 to 30 microns on the compressive strength of 7

and 28 days mortar and concrete was investigated (Figure 5).



Figure 5. Diagrams of the effect of particle size between 3 to 30 microns on the compressive strength of 7 and 28 day mortar and concrete

Figure 5 Diagrams of the effect of particle size between 3 to 30 microns on the compressive strength of 7 and 28 day mortar and concrete As can be seen in the diagram, the

compressive strength of standard mortar and concrete also increases with increasing the share of 3-30 micron particles, which is as follows:

(1) Compressive strength of mortar-28days (MPa) = $0/4978 (\Delta 3-30\mu \%) + 22/334$

(2) Compressive strength of concrete-28days (MPa) = $0/1581 (\Delta 3-30\mu \%) + 20/847$

Due to the fact that in concrete mixtures to achieve smoothness and slump, the amount of water and consequently the ratio of water to cement (w/c) varied, so the changes w/c of concrete mixtures relative to fine cement particles (3-0 microns) Checked out. Accordingly, with increasing the portion of fine cement particles, the

demand for concrete increases, which leads to a decrease in the strength of concrete (Figure 6). On the other hand, with increasing the portion of fine cement particles, the amount of particles of 30-30 microns decreases, which leads to a decrease in strength.



Figure 6. Graph of changes in the amount of 3-0 micron particles of cement in relation to w/c and 28-day compressive strength of concrete mixtures

Figure 7 shows the desired effect of increasing the uniformity coefficient (n) on the compressive strength of mortar and 7 and 28-day concrete. According to previous

studies, with increasing the uniformity coefficient, the rate of hydration of cement increases, and as a result, the compressive strength also increases.





Figure 7. Diagrams of the effect of uniformity coefficient (n) on the compressive strength of mortar and concrete for 7 and 28 days

Also, with increasing the uniformity coefficient (n), the setting time of cement paste increases. The relationship between the amount of 3-30 micron particles and the



setting time was also directly observed (Figure 8). It should be noted that in some cases, increasing the setting time of cement is undesirable.



Figure 8. Diagrams of the effect of uniformity coefficient (n) on compressive strength of 7 and 28 day mortar and concrete

In the next step, the results on the 90-micron sieve by manual method and the residue on the 45 and 30-micron sieves by the alpine method were compared with the results of determining the percentage of material on the 90, 45, and 30 sieves by laser granulation method (figure 9).

As expected, the correlation between the results in both alpine and laser methods was relatively high (R2=0.63), but between the results of manual and laser methods, this correlation was lower (R2=0.34).



Figure 9. Diagram of the results of the parameters remaining on the sieve by alpine, manual and laser grading methods

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4. CONCLUSION

According to the results of this study: 1. The compressive strength of standard mortar and concrete also increased with the increase of the share of 3-30 micron particles, which were presented; 2. The results of LD-PSD experiments were well correlated with the experiments remaining on the sieve by the alpine method; 3. The favorable effect of increasing the uniformity coefficient on the compressive strength of mortar and concrete for 7 and 28 days was observed; 4. With increasing uniformity or the number of particles of 3-30 microns, the setting time of cement paste increases (becomes longer);

FUNDING/SUPPORT

Not mentioned any Funding/Support by authors.

ACKNOWLEDGMENT

Many thanks to the managers, experts and technicians of Tehran Cement Company.

AUTHORS CONTRIBUTION

This work was carried out in collaboration among all authors.

CONFLICT OF INTEREST

The author (s) declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

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