

Evaluation of Cement Content and W/C Influence on Mechanical Behavior of Concrete Pavements

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Abstract

Concrete pavements with zero slump under pressure and high rate vibration has highly attracted the interests of engineers. In this study, fifteen different experimental mix designs with different cement content have been studied to improve the concrete pavement properties. Influence of effective factors on these kinds of concretes has also been considered. Then the relations between cement content and abrasion resistance, flexural and compressive strength, and water absorption have presented. The cement content was found as the most important factor in increasing and decreasing the abrasion and water absorption. Increasing the cement content up to 300 (Kg/m³) not only increased the abrasion resistance but also increases the amounts of cement content do not have always a good effect on a concrete quality and strength.

Introduction

Many studies have been carried out on the abrasion resistance of concrete, these studies show concrete abrasion resistant is mainly depend on compressive strength(Nanni 1989, Cabrera 1985, Sadegzade et al. 1987, Gjorv et al. 1990) of the concrete, surface finishing techniques, curing type, aggregate properties, and testing conditions. (Naik and Hossain 1994, Atis 2002, Naik et al. 1995)

The factors such as concrete strength, aggregate properties, surface finishing, and type of hardeners, noticeably affected on concrete abrasion resistance, the concrete strength influenced by a number of factors including air entrainment, water-to-cement ratio, type of aggregates and their properties, etc. hence, should also affect abrasion resistance. According to ACI Committee 201, concrete subjected to abrasion should have at least 28 Mpa compressive strength. (ACI 201 1977)

There are two type views about the relationship between abrasion resistance and compressive strength Naik (Naik and Hossain 1994) shown that the relationship was linear, however Atis (Atis 2002) indicated that the relation was hyperbolic and Langan (Langan et al. 1990) pointed out that Abrasion resistance tends to increase with compressive strength but not in all the cases.

High abrasion resistance strongly depends on high strength aggregate, surface material and paste should have low porosity and high strength. (Mehta 1986) And type of aggregate affected on mechanical properties of concretes such as flexural and splitting tensile strength (Özturan and Çeçen 1997).

In this work, abrasion resistance of concrete pavements was investigated and comparisons were made with flexural, compressive strength, cement content. And the effect of cement content on flexural strength and water absorption was reported.

Preparation of Samples, Curing Conditions

Three types of aggregates with particle size between 0-3 mm produced by stone broking machine were used. For base concrete, the natural river sand with 3-7 mm and 7-15 mm were applied. All tests on aggregates and fresh and hard concrete and mixtures were designed under (ASTM C192 2007), (ASTM C642 2006) codes.

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After weighing the aggregates and mixing them with cement and water, the concrete transferred to the pavement block producing part. It should be noted that the concrete produced in this part is so dry. Therefore the liquid limit should be obtained by V.B test. As it is shown in Figure 1, after transferring the two kinds of mixtures in to the concrete pavement producer machine, the molded concrete under high pressure and vibration in order to achieve the required thickness. Immediately, the concrete pavement's sample transmitted to the steam room. After 24 hours, samples were transferred to the curing room, and the samples were cured in water with 24°C until test time.



Figure 1. Concrete Pavement Block

Materials and experimental procedure

A total 15 mixtures were produced with 5 different amount of cement content, and 3 different water to cement ratio (Table 1), to obtain the factors affecting the abrasion and flexural resistance achievement. 30 * 30 * 6 cm samples were produced, then the samples with the ages of 7, 14 and 28 days were tested. A number of samples (9, 11, 12, 14 and 15) were not able to be cast because of a little amount of water content in mix designs (No.9, 11, 12, 14 and 15).

Table 1. Mix Designs

Mixtures No	Cement (kg)	Aggregates (kg)	Water	W/C
1	200	2306	50	0.25
2	200	2280	60	0.30
3	200	2254	70	0.35
4	250	2233	63	0.25
5	250	2201	75	0.30
6	250	2168	88	0.35
7	300	2160	75	0.25
8	300	2121	90	0.30
9	300	2082	105	0.35
10	350	2086	88	0.25
11	350	2041	105	0.30
12	350	1995	123	0.35
13	400	2013	100	0.25
14	400	1961	120	0.30
15	400	1909	140	0.35

Cement In this study, the mixtures containing Urmia normal Portland cement Type 1 with a specific gravity of 3.10 gr/cm^3 was selected. The chemical properties listed in Table 2.

Table 2. Cement Chemical Properties

MnO	MgO	K ₂ O	Na ₂ O	CaO	Fe ₂ O ₃	Al ₂ O ₃	SiO ₂	Urmia Cement Type 1
% 0.003	% 1.33	% 0.48	% 0.21	% 65.16	% 0.18	% 4.17	%21.48	

Aggregates The physical properties of aggregates shown in Table 3 natural river sand and crushed stone were used in mix designs. The cumulative percent passing chart and coarseness factor chart of mortar to obtain the best specific gravity and grading of mixed aggregates were presented in Figure 2, 3 and 4, respectively.

Table 3. Physical Properties of aggregates

Aggregates Size	Natural River Aggregates	0-3 mm	3-7 mm	7-15 mm
Specific Gravity SSD	2.51	2.49	2.66	2.67
Water Absorption %	2.5	1.3	0.62	0.6
water % content	2.8	1.5	0.28	0.18

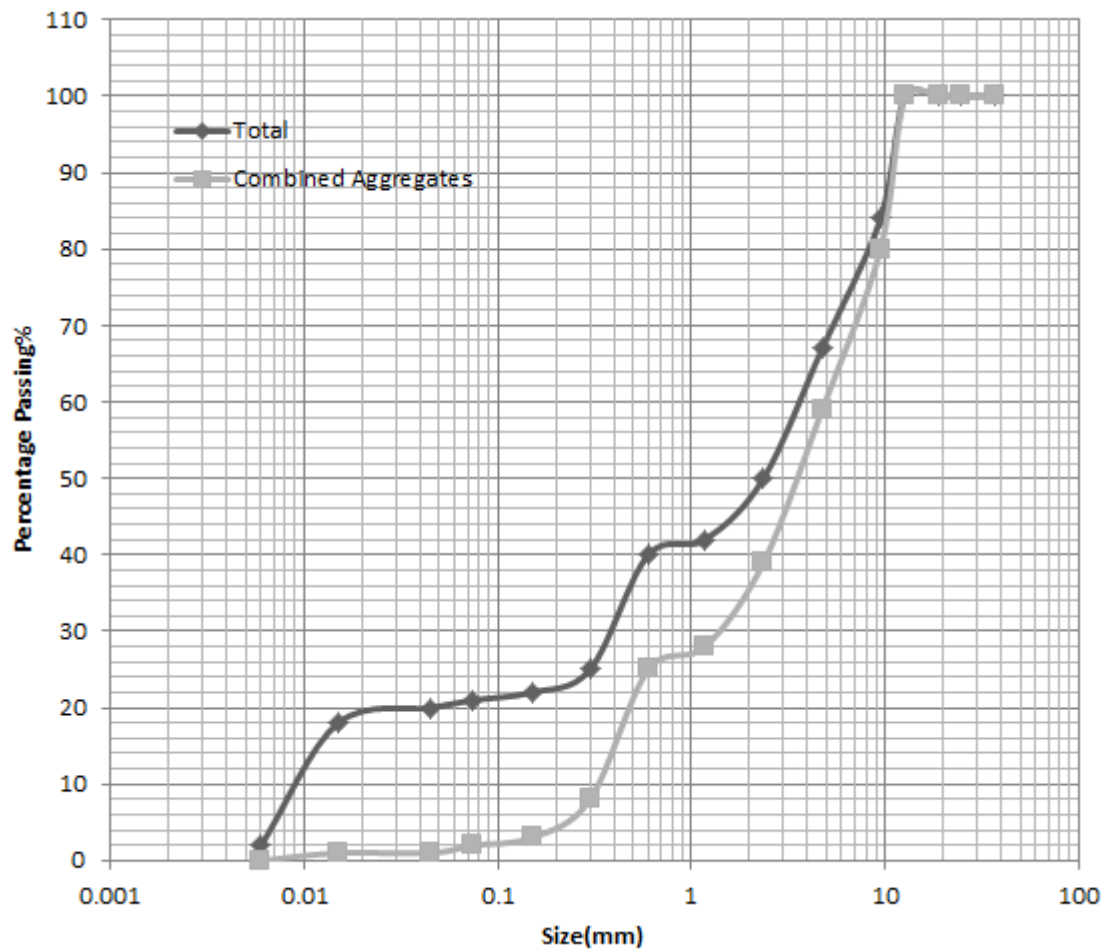


Figure 2. Cumulative Percent Passing Chart

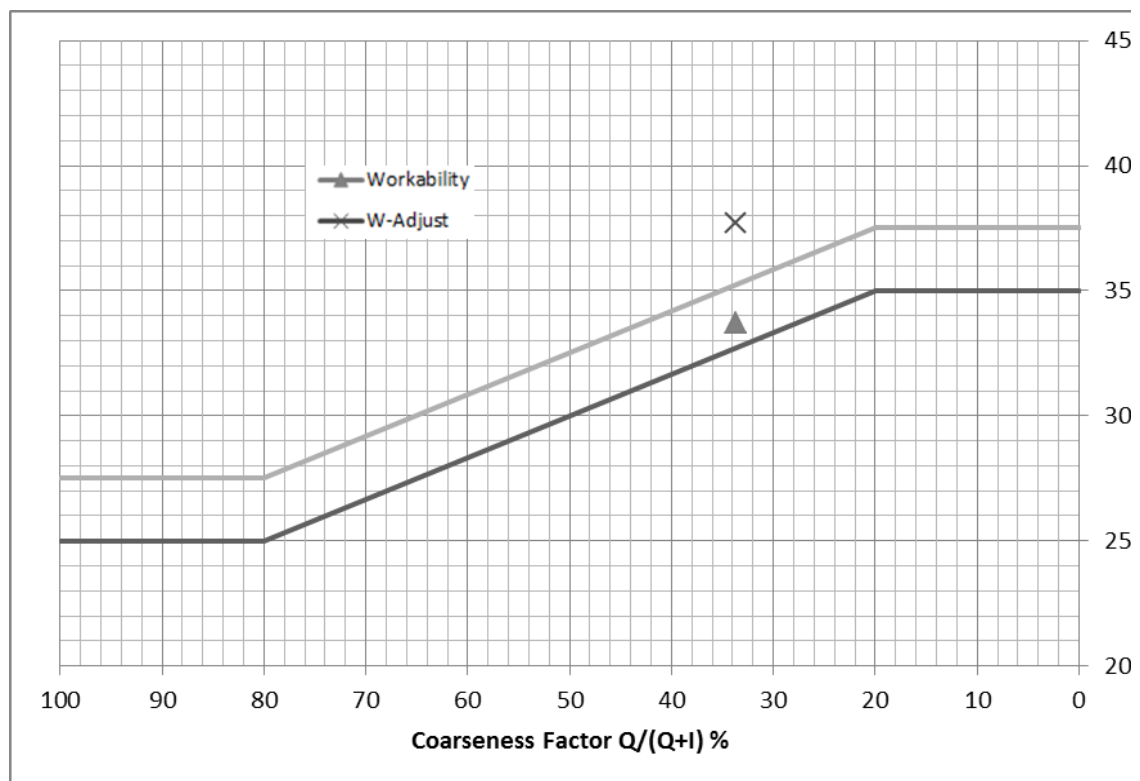


Figure 3. Coarseness Factor Chart

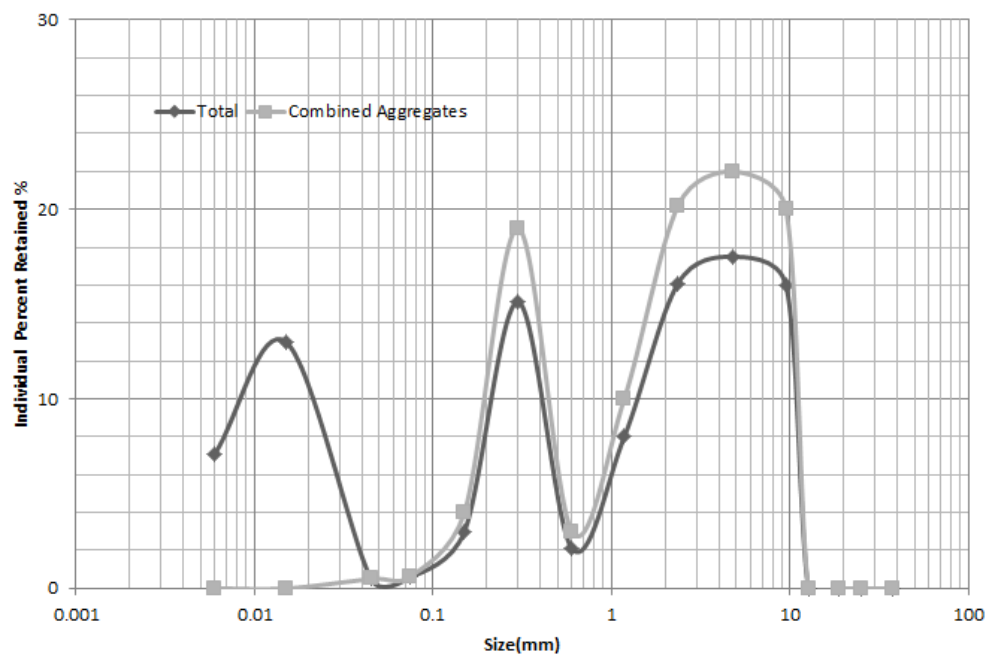


Figure 4. Individual Percent Retained Chart

Water

Water used in these mixtures was well water of phase 3 of Urmia industrial park, which applied after softening and filtering.

Results and Discussion

Abrasion resistance Abrasion resistance test was performed at the ages of 7, 14, and 28 days. For each age, 2 cubic samples with a 7 cm sides were prepared for core testing, then specimens were stored in the oven with 110°C and after 24 hours, the samples were tested. The specimens abrasion testing was according to the Bohme method and TS 2824 standard (TS 2826 1996).

As it has shown in Figure 5, cubic specimens were fixed to rotating circular screens and loaded under 294 N vertical loads. In addition, during the test procedure about 20 gr standard powders were spread on the abrading surface.



Figure 5. Abrasion Strength Testing Machine

After each 22 cycle of rotating, the sample and abrading surface was cleaned. Then the other side of a specimen were abraded. The specimen's thickness was measured in three different points and weighted after each 22*4 revolutions.

According to TS 2824 (TS 2826 1996) standard, the number of cycles can increase up to 22*32 cycles, but in this study 22*16 cycles were evaluated as listed on Table 4.

Based on TS 2824 (TS 2826 1996) standard, total amount of concrete abrasion should be less than 15 cm³ in each 50 cm² of abraded surface. Considering equation 1, the abraded volume was calculated.

$$\Delta V = \Delta m / \rho \quad (1)$$

Where,

ΔV = Change in Volume (cm³)

ρ = Density of Specimen (gr/cm³)

Δm = Mass change

Mixtures No	Abrasion Layer Loss After 22*16 Revolutions (cm ³)				
	Cement Content (kg)	W/C	Days 7 Strength	Days 14 Strength	Days 28 Strength
1	200	0.25	24.1	27.6	31.2
2	200	0.3	18.8	27	28
3	200	0.35	22.7	27.3	30.8
4	250	0.25	20.5	26.5	25.9
5	250	0.3	28.2	22.9	25
6	250	0.35	22.6	28.1	28.3
7	300	0.25	24.3	20.3	25.2
8	300	0.3	16.5	22.4	21.8
10	350	0.25	23.8	23.5	23.1
13	400	0.25	24.3	21.1	24

Table 4. Abrasion Resistance Test

Flexural Strength Flexural resistance of specimens was determined at the ages of 7, 14 and 28 days. At each age six samples were tested. Figure 6 reveals that two ends of specimens were fixed between tow clamps. Then vertical loading applied on the middle of the sample, as shown in Figure 6 and the results were listed on Table 5.

According to equation 2, 3 flexural resistance was calculated:

$$T = 0.637 * k * P / S \quad (2)$$

$$k = 1.3 - 30 * (0.18 - t / 1000)^2 \quad (3)$$

Where,

T= Splitting Strength (Mpa)

P= Load at Failure (N)

S= Area of Failure (mm²)

t= Thickness



Figure 6. Flexural Strength Testing Machine

Mixtures No	Flexural Strength (Mpa)				
	Cement Content (kg)	W/C	Days7 Strength	Days14 Strength	Days28 Strength
1	200	0.25	1.3	1.4	1.8
2	200	0.3	1.7	1.8	1.8
3	200	0.35	2.1	2.1	2.2
4	250	0.25	2.8	2.3	2.2
5	250	0.3	2.8	1.9	2.5
6	250	0.35	2	2.4	2.6
7	300	0.25	2.7	3	3
8	300	0.3	1.8	2.2	2.7
10	350	0.25	2.7	2.4	2.2
13	400	0.25	2.3	3.1	2.2

Table 5. Flexural Strength

Water Absorption and Compressive Strength All information about water absorption and compressive strength were observed on Table 6 and 7. All cubic concrete specimens (15*15*15 cm) were used for testing.

Mixtures No	Compressive Strength (Mpa)				
	Cement Content (kg)	W/C	Days 7 Strength	Days 14 Strength	Days 28 Strength
1	200	0.25	20.1	26.9	26.9
2	200	0.3	33.8	33.6	33.5
3	200	0.35	33.5	33.8	35.3
4	250	0.25	32.9	38.4	44.6
5	250	0.3	35.7	39.2	39.2
6	250	0.35	29.6	32.6	34.1
7	300	0.25	39.9	44.8	42.5
8	300	0.3	35	39.4	40.2
10	350	0.25	40.7	43.7	46.5
13	400	0.25	38.9	42.8	46.1

Table 6. Compressive Strength

Mixtures No	Absorption %				
	Cement Content (kg)	W/C	Days 7 Strength	Days 14 Strength	Days 28 Strength
1	200	0.25	5.09	4.25	4.18
2	200	0.3	4.27	4.35	4.21
3	200	0.35	4.47	4.26	4.16
4	250	0.25	4.17	4.03	3.87
5	250	0.3	4.05	4	3.9
6	250	0.35	4.97	4.38	4.18
7	300	0.25	4.32	3.45	3.58
8	300	0.3	4.05	3.59	3.44
10	350	0.25	4.2	3.42	3.39
13	400	0.25	4.26	3.51	3.52

Table 7. Concrete Water Absorption

Diagrams In general, for finding the relation between variants, the effect of cement content on compressive, abrasion, flexure strength and water absorption were assessed. It was observed in Figure 7, by increasing flexural strength the amount of abrasion loss was decreased. It means that the abrasion resistance was increased. Figure 8 shows the relation between cement content and compressive strength. When cement content increase from 200 to 250 at the water cement ratio of 0.25, the compressive strength was increased suddenly.

Accordingly, for each water cement ratio after achieve the optimum ratio; increase the cement content had not always a positive effect on compressive strength. The relation between cement content and abrasion factor was evidenced from Figure 9. As a result by increasing cement content the abrasion loss was reduced. Furthermore, it was observed that by increasing water cement ratio from 0.25 to 0.3 at cement content of 200 the abrasion was decreased. It was the same as cement content

of 250 and 300, but when the water cement ratio was increased from 0.3 to 0.35, the abrasion was increased for both cement content of 200 and 250. Figure 10 shows the direct relation between increasing flexural strength by increase cement content at a different water cement ratio. However, over cement content of 300 for the water cement ratio of 0.25, the flexural strength was a sudden reduction by the increase the amount of cement. Moreover, decreasing water absorption was happened by raising the cement content, for a water cement ratio of 0.25. When cement content was over 350, by increasing cement content the water absorption was increased. As it shown in Figure 11, when the compressive strength was increased, abrasion resistance was increased.

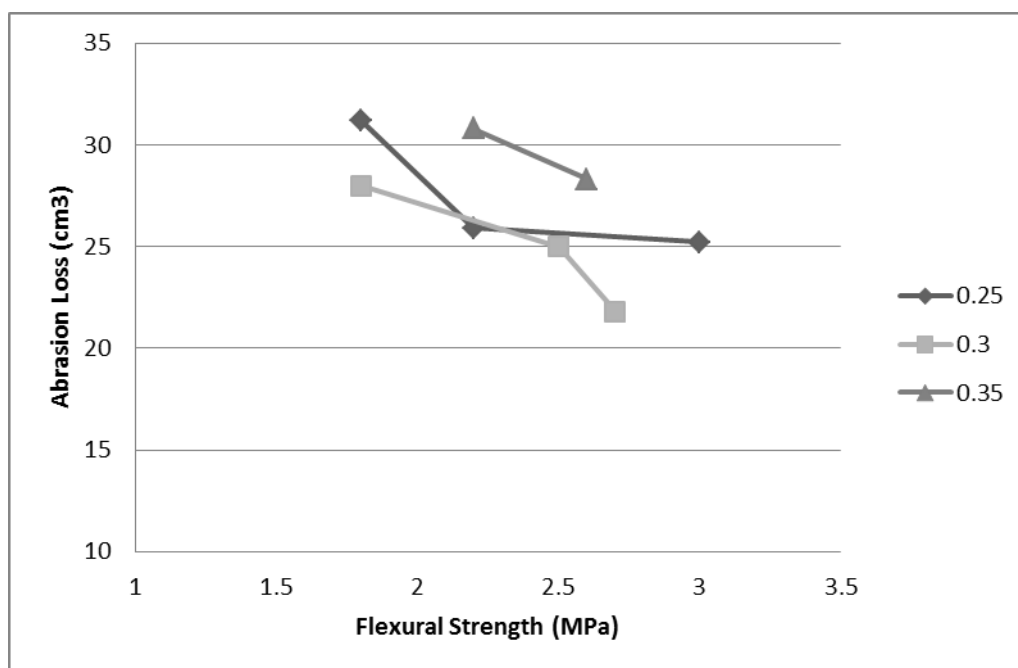


Figure 7. Abrasion loss vs. Flexural Strength

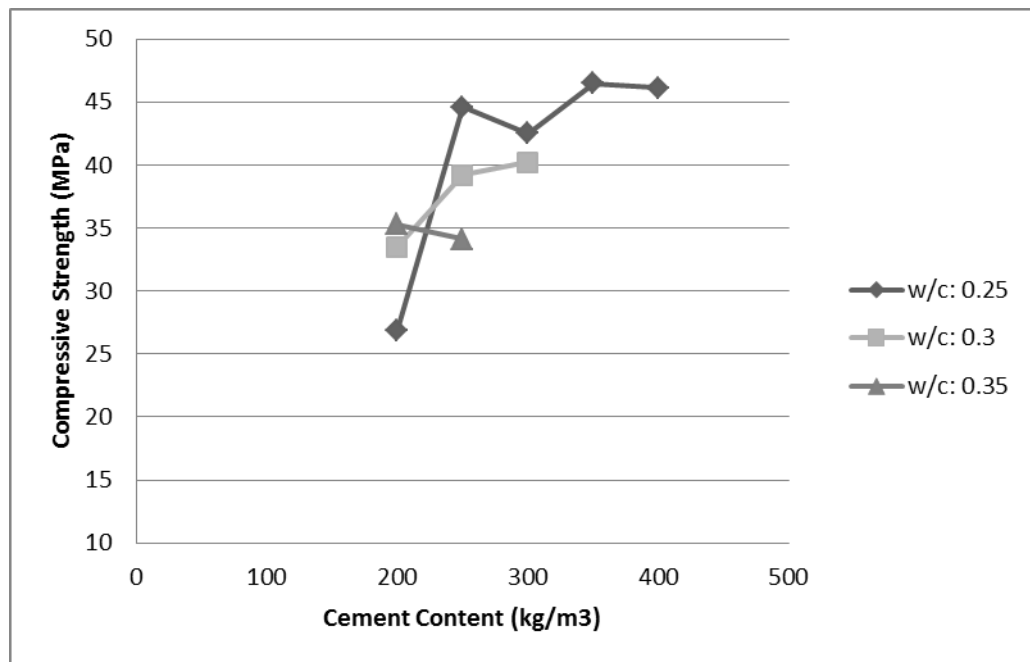


Figure 8. Compressive Strength vs. Cement Content

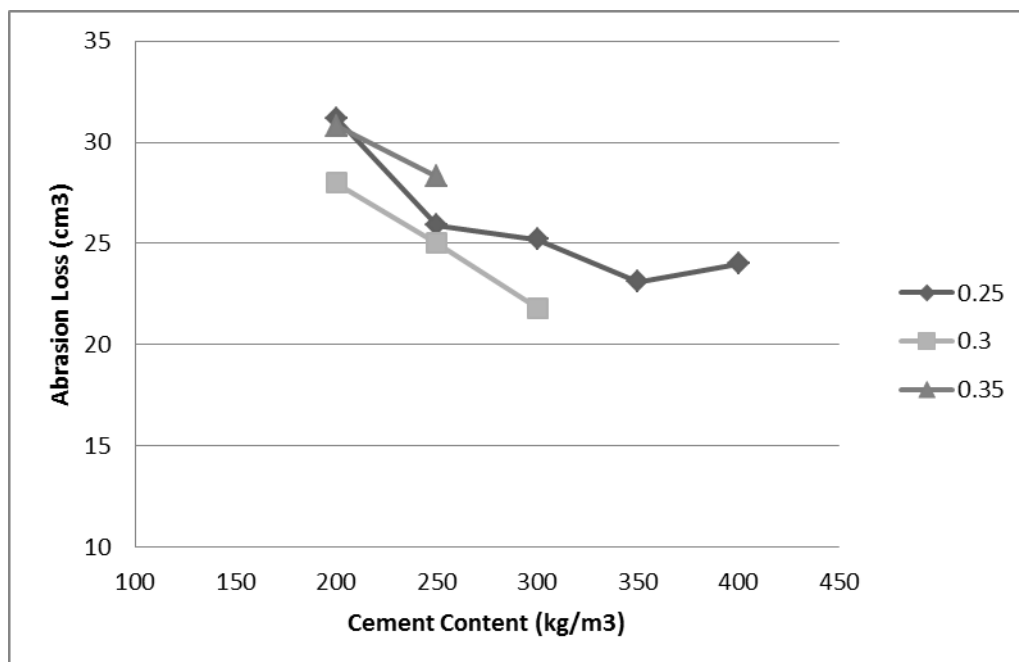


Figure 9. Abrasion Loss vs. Cement Content

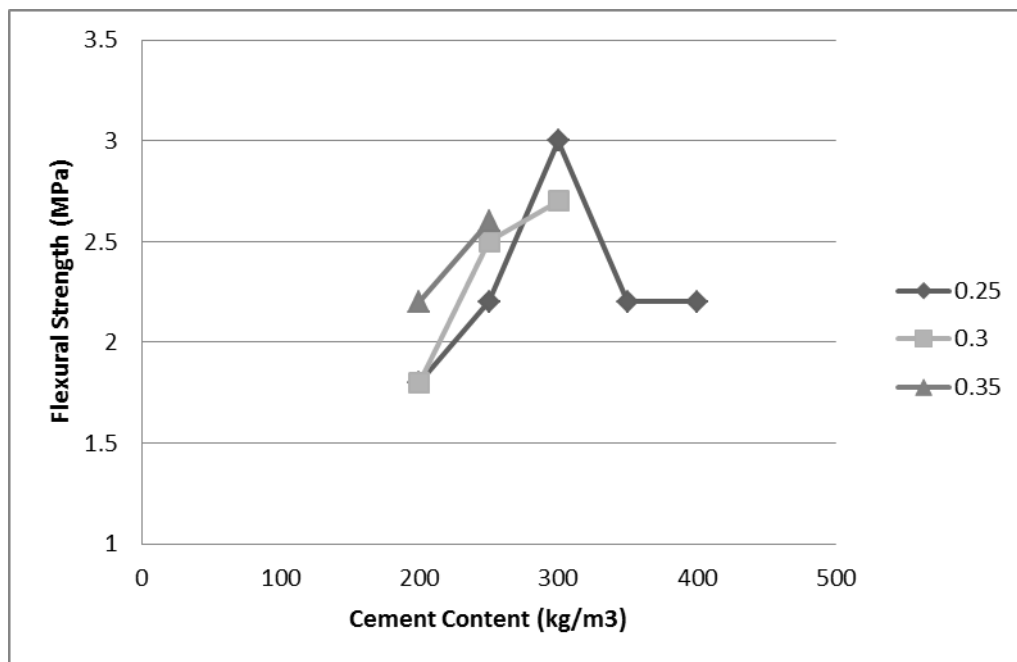


Figure 10. Flexural Strength vs. Cement Content

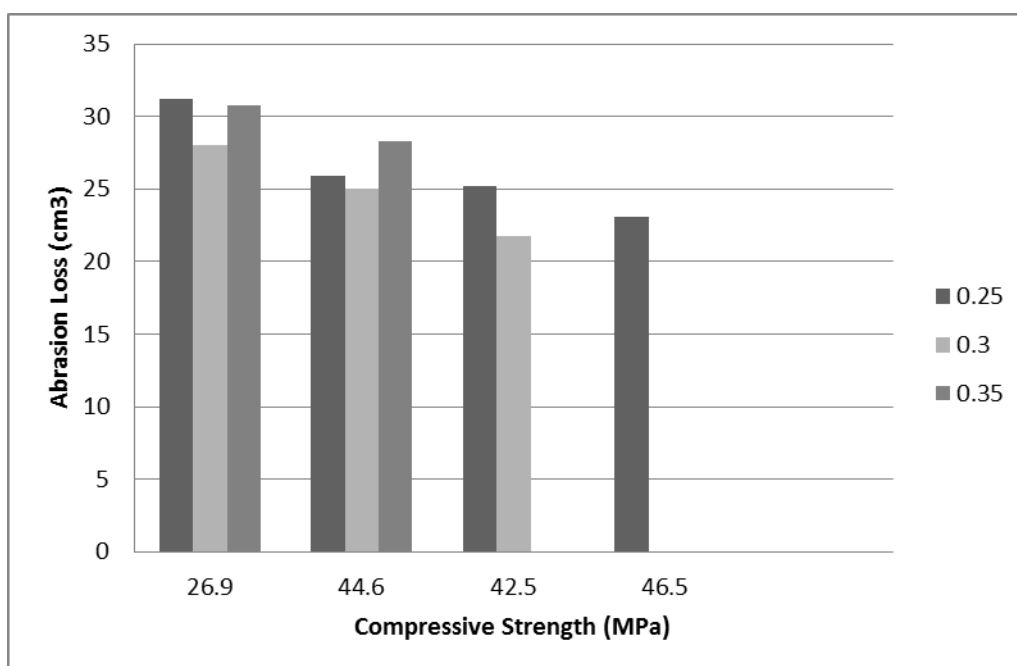


Figure 11. Abrasion Loss vs. Compressive Strength

Conclusions

Base on the results of tests, the following conclusions are drawn:

1. For the same water content ratio, by increasing cement content up to 300 (Kg/m³) the flexural strength increases, therefore the abrasion resistance increases, because there is a direct relation between abrasion resistance and flexural strength.
2. Raising the amount of cement content does not have always a good effect on a concrete quality and strength.
3. The most important factor on increasing or decreasing the abrasion factor and water absorption of concrete used in concrete pavement is the amount of cement content. Hence, the water absorption and the lost weight caused by abrading are reduced by increasing the amount of cement at the constant water cement ratio.
4. There is a direct relation between raising a compressive strength and reduction percentage of the abrasion factor. So by increasing the strength, the percentages of volume reduction due to pavement's abrasion are decreased.
5. Concrete pavements have to be made in two different concrete layers. The surface layer is made by more amounts of cement and fewer water cement ratio as well as high abrasion resistance aggregates.
6. One of the most important factors to estimate the concrete properties is specific gravity that can show the concrete quality.
7. To decrease the cement content and improve the production quality, the optimum curing ways is suggested.
8. Up to cement content of 300 (Kg/m³), there is a direct relation between flexural strength and cement content. However, by increasing the amount of cement content up to 300-400 (Kg/m³) strength decreases, and then it will be constant.

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