Effect of Kerosene and Gasoline on Some Properties of High Performance Concrete

Dr. Nada Mahde Al-Jalawi[1], and Asis.Lec. Dalia Shakir Atwan[2]

1) College of Engineering / University of Baghdad/Email:naljalawi@yahoo.com
2) College of Engineering / Al-Nahrain University/Email:msc.dalia@yahoo.com

ABSTRACT

During the last quarter century, many changes have taken place in the tanks industry and also in the materials that used in its production، while concrete is the most suitable material where concrete tanks has the benefits of strength, long service life and cost effectiveness. So, it is necessary improvement the conventional concrete in order to adapt the severe environment requirements and as a result high performance concrete (HPC) was used. It is not fundamentally different from the concrete used in the past, although it usually contains fly ash, ground granulated blast furnace slag and silica fume, as well as superplasticizer. So, the content of cementitious material is high and the water/cement ratio is low. In this study, the silica fume and superplasticizer were used for obtaining HPC. This paper is an attempt to provide some information about effect kerosene and gasoline on some properties of HPC which can be used as storage tanks for petroleum products. The experimental work in this research including; slump test, weight loss test and compressive strength test were performed. The results of these investigations indicated that the petroleum products have unacceptable effects on the properties of concrete.

Keywords: high performance concrete, kerosene, gasoline, silica fume, superplasticizer, weight loss, compressive strength

الخلاصة

في الربع الاخير من هذا القرن، حدثت العديد من التغييرات في ما يتعلق بصناعة الخزانات وايضا في المواد المستعملة في انتاجها، الا ان الخرسانة تعتبر من افضل المواد المناسبة لهذا الغرض كونها مفيدة من ناحية القوة والعمر الخدمي الاطول اضافة الى الكلفة. لذا كان من الضروري تحسين الخرسانة التقليدية لكي تتكيف مع متطلبات البيئة القاسية وكنتيجة لذلك تم استخدام الخرسانة عالية الاداء. حيث انها لاتختلف كثيرا عن تلك الخرسانة المستخدمة في الماضي بالرغم من احتوائها عادة على مواد بوزولانية فضلا عن الملدنات المتفوقة. وعليه فأن محتوى المواد السمنتية يكون مرتفعا ونسبة الماء الى السمنت تكون منخفضة. في هذا البحث تم استخدام ابخرة السليكا والملدن المتفوق للحصول على الخرسانة عالية الاداء. ويمكن اعتبار هذا البحث كمحاول لتوفير بعض المعلومات عن تأثير النفط الابيض وزيت الغاز على بعض خصائص الخرسانة عالية الاداء التي بالامكان استخدامها كأحواض لخزن تلك المنتجات. تضمن العمل المختبري اجراء فحص الهطول، وفحص فقدان الوزن وفحص مقاومة الانضغاط. واشارت نتائج تلك الفحوصات بان للمنتجات النفطية تأثيرات غير مقبولة على خصائص الخرسانة.

INTRODUCTION

Concrete is the most commonly used material in construction industry. There are a number of reasons for this such as high strength, ease of production, low cost, good compatibility with other materials, especially with steel, durability under aggressive conditions(Hanh, P., 2008). But, when used in the petroleum environment, concrete has some special requirements compared to the conventional concrete. Nowadays, high performance concrete (HPC) is considered to be a major research and development strategy in many countries in the world. If the main requirement of high strength concrete is the value of compressive strength, HPC is required not only the value of compressive strength but also some other special properties as durable life, Low maintenance cost, Variety of structural configuration, Excellent resistance to temperature, Better resistance to fatigue and buckling, Stronger resistance against accidents of missile attack, fire and explosion (Hanh, P., 2008).

The versatility, economy, water-tightness, and long-term durability of HPC make it ideal for environmental structures. Environmental structures are classified as those used for petroleum products storage. HPC can be cast into tanks of any shape required to fit the site or the process. Its higher strength allows for thinner tank floors, walls, and roofs. Furthermore, the high recoating costs that are periodically required for steel tanks are unnecessary when using HPC. Construction joints, particularly those in the tank floor, can be eliminated, ensuring maximum water-tightness. Another benefit is that HPC can be made shrinkage-crack free, which helps protect the conventional reinforcement(Close, S.,2004).

Recently, the addition of silica fume has been used to produce concrete of increased strength and durability. Silica fume increases the strength of concrete due to pozzolanic reactions and increased particle packing density(De Larrad, F., 1994). In addition to higher strength, the addition of silica fume to concrete has been proposed as one method to substantially reduce the permeability of concrete due to reduced pore size(Hooton, R. 1993). Because of these and other advantages, HPC is gaining popularity among owners and engineers who are interested in new solutions to an old problem-leaking, maintenance-laden tanks (Gambhir, M. 1998).

OBJECTIVES AND SCOPE

The oil had and still great importance in all fields of life. It is basic source of energy all over the world. Therefore, the storage of petroleum products in concrete tanks has been offered more benefits compared with other materials such as safety, serviceability and maintenance costs.

The essential objective from this paper is to study the effect of kerosene and gasoline on the properties of HPC until 90 days exposure period. Besides, the research discusses the relationship between that properties.

PERFORMANCE−BASED SPECIFIC-ATIONS FOR HIGH PERFORMANCE CONCRETE

HPC is a concrete in which certain characteristics are developed for a particular application and environment, so that it well give excellent performance in the structure in which it will be placed, in the environment to which it will be exposed, and with the loads to which it will be subjected during its design life. Its includes concrete that provides either substantially improved resistance to environ-mental influences (durability in service) or substantially increased structural capacity while maintaining adequate durability. It may also include concrete, which significantly reduces construction time without compromising long-term serviceability. It is, therefore, not possible to provide a unique definition of HPC without considering the performance requirements of the intended use of the concrete. Examples of characteristics that may be considered critical in an application requiring performance enhancement are; ease of placement and compaction without segregation, early-age strength, long-term mechanical properties, permeability, density, heat of hydration, toughness, volume stability, and long life in severe environments (Gambhir, M. 1998).

Concretes possessing many of these characteristics often achieve higher strength. Therefore, HPC is often of high strength, but high strength concrete may not necessarily be of high performance. Thus, in practical applications of this type of concrete, the emphasis has in many cases gradually shifted from the compressive strength to other properties of the material, such as a high modulus of elasticity, high density, low permeability, and high resistance to same forms of attacks. The cost and other benefits derived may include less material, light and fewer structural elements, reduced maintenance, extended life cycle and aesthetics (Gambhir, M. 1998).

The replacement of some Portland cement by one or a combination of supplementary cementitious materials is very often beneficial from a rheological point of view when making HPC. Experience shows that sometimes, it is difficult to fully control the rheology of the mixture for 1 h 30 min when using some combinations of pure Portland cement and superplasticizer. In fact, currently, most cement manufacturers optimize the characteristics of their clinker and the gypsum content and fineness of their cement to obtain a high early cube strength at a w/c of about 0.50. Consequently, they favour high C_3A and C_3S content for their clinker and a high fineness for their cement, which is the opposite of what should be done if the objective of their optimization process is to improve the rheological characteristics of low w/b ratio concrete. At the present time, binary, ternary and quaternary binders are commonly used to produce HPC (Aïtcin, P. 1998)

In recent years, the use of pozzolanic materials becomes an important strategy for obtaining HPC. In this study, the use of highly reactive pozzolans, such as silica fume combined with superplasticizer addition, let to prepare HPC.

BACKGROUND OF CONCRETE STORAGE TANKS

Tanks fulfill an important role in supplying mankind with essential products. They are used for storing liquids or solids which may be either intermittently produced but consumed at a fairly uniform rate, or continuously produced at a fairly uniform rate but consumed in an irregular manner. A further important aspect is that the locations of origin and consumption are frequently appreciable distances apart. These circum stances necessitate the provision of appropriate storage capacities. The building of tanks in concrete offers several advantages such as: (VSL International LTD 1983)

a. Concrete tanks are economical to construct and maintain (they require virtually no maintenance). Construction is relatively inexpensive because the basic materials for making concrete are usually locally available and suitable special building methods make rapid construction possible.

b. Concrete tanks are relatively insensitive to mechanical influences, whereas steel tanks, for example, when used for storing environ mentally polluting or dangerous substances have to be surrounded by protective concrete walls to assure the required degree of safety.

c. Concrete tanks are eminently suitable for the storing of a very wide variety of substances; for example, if provided with a suitable liner, they may even be used for low temperature liquefied gases.

Since the turn of this century, concrete tanks have been in use to store crude oil and its products. The critical shortage and cost of steel during the second world war expanded progressively the use of concrete for the construction of oil tanks. Striking development in this field, however, occurred in the early seventies, whenever giant concrete rostrums were built in the north sea for excavating crude oil which including temporary storage for large quantities from crude oil in submerged concrete tanks. Contained this mass rostrums more than 140000 m3 concrete, its weight about 350000 ton and designed to resist the effect of marine waves to height 30 m and winds with speed 250 km/hrs.. The basis of this cells was based on deep reach more than 200m. during 1973-1986, achieved 15 another cells and began of thinking to carry out cells on deeps over than 350m (Moufaq, J. 1998).

In 1975 VSL international LTD. prepared a design for a 20 000 m3 capacity fuel oil tank, consisting of an outer tank in post-tensioned concrete and a double layers, plasticized PVC inner tank. The concrete tank is designed to fulfill two functions: firstly to serve as a support for the PVC tank and secondly as a collecting basin for any leakages which might occur in the inner tank. The tank has an internal diameter of 36.00 m, a wall height of 20.00 m and wall thickness of 250 mm. It has a bottom slab at least 150 mm thick with an edge beam at least 400 mm thick. The roof consists of a reinforced concrete dome with post-tensioned ring beam. The minimum concrete thickness of the roof is 60 mm. There are sliding bearings between the ring beam and the tank wall. As a transition between the bottom slab and the wall, a sliding bearing with an internal seal or a continuous neoprene bearing is installed. To improve the tightness of this joint, a proportion of the vertical tendons of the wall are continued through the joint and anchored in the base slab. This transition between base slab and wall would today be constructed monolithically.

In 1997, Al-Lami investigated the structural behavior of ferrocement exposed to petroleum products. It was observed that the oil soaking does not prevent shrinkage of ferrocement. Also, the results indicated that the final shrinkage of ferrocement depends on their initial drying shrinkage and the shrinkage occurred in during the petroleum soaking period which affected by aggregate content, reinforecement and thichness elements. The ferrocement exposed to petroleum products showed reduction in flexural first cracking, ultimate moments and direct tensile cracking strength ranging from (3.33% to 20.1%), (2.07% to 14.53%) and (5.13% to 16.27%) respectively. Finally, the ferrocement–reinforced brick beams exposed to gas oil demonstrated reduction in first cracking and ultimate moment ranging from (4.75% to 8.75%) and (12.8% to 16%) respectively. Besides, the ferrocement-reinforced concrete beams showed reduction in ultimate moment capacity about 11.9% versus no reduction in the first crack moment.

In 1999, Al-Geryawee and Al-Rahame studied the permeability characteristics and mechanical properties of concrete exposed to oil products. Six types of liquids were used in this study (water, gas oil, Kuwait crude oil, north sea crude oil, Basrah crude oil and Kirkuk crude oil). It was found that the oil product storage losses per day depended on the coefficient of permeability and type of stored liquid. It was concluded that tanks containing crude oil are more successful more and cost saving than gas oil tanks.

In 2001, Al-Zaidi studied the influence of oil products on the physical and electrical properties of concrete. The work involves reinforced and plain concrete samples. Physical test results revealed an increase in the compressive and tensile strength for specimens after 7 days of exposure to petroleum liquids compared with that cured in water. On the other hand, the exposure to petroleum liquids has produce an increase in permeability and electrical resistance of concrete specimens.

INTERESTS OF USING CONCRETE TANKS

Tanks are available in a wide range of materials including steel, concrete, fiberglass or plastic. All of these materials can be suitable providing the tanks have been manufactured specifically for the storage of petroleum products. But, It has been found that concrete tanks are very well suited to these requirements where concrete tanks offers significant advantages over other materials such as; (VSL International LTD 1983)

- Endless color options
- Minimal shrinkage
- Easily takes any shape
- The lower damage of water
- High durability
- Fire resistance
- Lower thermal conductivity
- Low effect for climate changes
- High safety
- Low maintenance
- No hazardous
- No staining
- Greater resistance to abrasion and impact
- Resistance to leakage
- Corrosion resistance
- Cost effectiveness

EXPERMENTAL WORK

Materials

Cement

Ordinary Portland cement type I used in this work. The percentage oxide composition and physical properties of the cement indicate that the adopted cement conforms to the Iraqi Specification No.5/1984 as illustrated in Tables 1 and 2.

Fine Aggregate

Local sand was used as fine aggregate. The sieve analysis and the grading curve of fine aggregate used conformed to the ASTM C33-03 as shown in Table 3 and Figure 1. The specific gravity and absorption of the fine aggregate were typically 2.62 and 0.72%, respectively as listed in Table 4.

Coarse Aggregate

Crushed gravel with a maximum aggregate size 20 mm was used as coarse aggregate. The sieve analysis and the grading curve of coarse aggregate used corresponds to the ASTM C33-03 as illustrated in Table 5 and Figure 2. The average values of specific gravity and absorption of the coarse aggregate were typically 2.65 and 0.57%, respectively as listed in Table 6.

Silica Fume

As a pozzolainc material, silica fume was used in this study. The chemical analysis of silica fume illustrated in Table 7. The specific gravity of silica fume used was 2.16 as described in Table 8.

Superplasticizer

Superplasticizer combined with a retarding effect was used. Its has a trade name "EUCOBET SUPER VZ" and used to promote good workability for a long period due to retarding effects. The specific gravity of the superplasticizer as given by the supplier is 1.1 and without chloride content as described in Table 9.

Water

For mixing and curing tap water was used.

Composition of Trial Mixes and Their Fresh Properties

In this work, the trial mixes were designed to give minimum compressive strength of 50 and 60 MPa according to ACI Committee 211.1-95 classification and considered by varying the quantity of superplasticizer, while keeping the water content constant. Two trial mixes were prepared by using a fixed contents of binder (cement+silica fume) equal to (562 kg/m^3), sand (750 kg/m^3) and gravel (882 kg/m^3). Two levels of the superplasticizer 3 and 5 L/m^3 were used for preparing and testing. For each trial mix, a constant water content of 174 kg/m^3 of concrete was taken. By using the slump test, the workability of the fresh concrete mixes was measured according to ASTM C143-89. The mix proportions used are provided in Table 10.

Preparation, Compaction and Curing of Test Specimens

All molds were cleaned and oiled in order to prevent their from bonding to concrete. After that, the concrete was placed into the molds and compacted on a vibrating table. Then, the surface of the top layer is leveled. Follows, a polyethylene sheet was used to cover the molds for a period of 24 hours in the laboratory. After 24 hours, the specimens for strength test were removed from the molds and placed in a water tank for curing until measurement dates. Besides, two tanks were prepared, one filled with kerosene and another with gasoline. The specimens for testing durability in petrochemicals materials were placed in these tanks after 28 days curing in water tanks; this was done because the moisture of specimens placed in water tended to acquired strength.

Tests

Weight Loss Test

After 28 days of curing, the initial weight of the cubic specimens of 15x15x15 cm^3 was determined before immerging in the tanks of kerosene and gasoline. Then, the specimens were kept continuously immersed in these tanks for 12 weeks as recommended by ASTM C267-97. During the test period, the cubic specimens were removed weekly from curing tanks, rinsed with tap water, without brushing, and left to dry for 30 min before weighing and visual inspection. The kerosene and gasoline were renewed with each new weighing to maintain constant concentr-ation(ASTM C192-07). Cumulative weight change (WCt) for each specimen was determined as follows:

$$WCt\,\% = [(W_0-W_i)/W_0]*100 \qquad \text{Eq.(1)}$$

Where:

W_0 is the initial weight of saturated surface dry specimen before exposure to petroleum products (kg).

Wi (i=1,2,3, ,12) is the weight after I weeks of exposure to petroleum products (kg).

The percentage of strength change was calculated in the same way as the weight change equation.

Compressive Strength Test

This test was carried out According to B.S.1881: part 116: 1989 at ages of 7, 28 and 90 days on 150mm cubes by using a compression testing machine of 1814.882 kN capacity. For each age three samples were tested and the average of the three test results was reported.

RESULTS AND DISCUSSIONS

1. The results of workability test for mixes are shown in Table 10. The data results indicate that the increase of dosage of SP causes an increase in the slump of concrete mix.
2. The results of weight loss for specimens exposed to kerosene and gasoline tanks are shown in Fig. 3, and 4. The specimens with high addition of SP present the greatest weight loss in comparison with reference concretes (3.5% and 2.9% for K5and G5 respectively compared with 1.82 % for K3 and 1.7 % for G3 at 28 days curing age). This was probably due to the fact that the petroleum products as it is known is primarily related to the actual cement contents in these concretes.
3. Compressive strength results shown in Table 11 correspond to the average values obtained on at least three cubes samples 150 mm. The results show increasing in compressive strength with increase of dosage SP added in concrete mix as presented in Fig. 5. The main reason is attributed to that the extra dosage of SP may be caused more dispersion into smaller agglomerates of cement particles which predominate in the cement paste of the concrete mix. As a result to dispersion of cement agglomerates into individual particles; a greater rate of cement hydration can be achieved in the well dispersed system. So that, W5 specimens exhibited increase in compressive strength about 19.50% at 28 curing age compared to their corresponding W3 specimens.
4. The results also demonstrate that the concrete specimens immersed in kerosene and gasoline tanks show reduction in compressive strength compared to their corresponding specimens curing in water as represented in Fig. 6 and 7. The reduction in compressive strength at 28 days were 12.80% and 8.53% for K3 and K5 respectively compared to 9.70 % and 6.47 % for G3 and G5. This due to penetrate those materials into structure construction of cement and caused extending gel pores and spreading solid hydration components which caused weakly adhesion and cohesion forces in cement and easily slip of internal grains. In addition to rise the internal hydraulic pressure. Besides, happen reduction in surface power as a result to absorption these liquids and adhesion on gel surfaces caused reduction in compressive strength (Moufaq, J.1998)
5. The relationships between compressive strength loss and weight loss as a percentage of their initial values before exposure to kerosene and gasoline are illustrate in Fig. 8 and 9. The results reveal that there is not a direct relationship between the compressive strength loss and the weight loss for the concrete specimens immersed in kerosene tanks (Fig. 8). In the same way, for the results of the gasoline tanks, represented in Fig. 9, the external state of the degradation of the samples after exposure to the kerosene is not a good indicator of their compressive strength; in fact, there is a divergence between the loss of weight and the loss of the compressive strength. The observed trend of the compressive strength change after 1 week of exposure to kerosene and gasoline is affected by multiple factors. After exposure to these products, concrete specimens had a softened surface zone underlain by a sound part, which represents the bulk cross-section of specimens. The observed compressive strength reduction after exposure depends on the ratio of deteriorated-to-sound cross-section (Bassuoni M.,2007) Conversely, the occurrence of this zone can increase strength loss results since it has weak mechanical properties, as shown by different studies in the literature (Bernard F.,2008 and Nyugen V.,2007) .

CONCLUTION AND RECOMMEND-ATION

Based on results obtained from the basic investigation on HPC , several conclusions are drawn as follows:

1. Workability of HPC mixes was dependent on the content of SP. Where, the slump was 170 mm at the addition 3 liter from the admixture compared to 186 mm at the addition 5 liter at the same mix proportion.
2. The concrete specimens curing in water exhibited increasing in weight and compressive strength at all ages with rise addition of SP. The percentage increase in weight and compressive strength at 28 day were 0.5 % and 19.50% respectively for W5 specimens compared to their corresponding W3 specimens.
3. The weight loss was more with increasing of dosage of SP for specimens exposed to kerosene and gasoline. The reduction in weight were 1.24% and 0.74% for K5 and G5 respectively

compared to their corresponding K3 and G3 at 28 days.

4. The specimens exposed to kerosene and gasoline showed reducing in compressive strength at all ages with compared to their corresponding reference specimens. The reduction in compressive strength were 12.80% for K3 and 8.53% for K5 compared with 9.70 % and 6.47 % for G3 and G5 respectively at 28 days.
5. The size of the concrete samples was large enough to allow testing of concrete containing large aggregate.
6. The test apparatus and the procedures used for testing were carefully designed in order to provide high precision determination of loss in weight and the compressive strength.
7. In the future, HPC will be specified for characteristics other than its 28-day compressive strength because there are cases where another characteristic is more important for the designer or the owner than the 28-day compressive strength. Consequently, it is becoming imperative to understand better hydration reaction and its consequences as well as the role of the different materials used when making HPC to specify properly the most efficient and economical HPC.

REFERENCES

Aïtcin, P., (1998), High Performance Concrete, E and FN SPON, London, pp.592.

Al-Geryawee, A. and Al-Rahame, A., Properties of Concrete Exposed to Oil Products, Higher Diploma, Thesis, University of Technology, 1999.

Al-Lami, M., Structural Behaviour of Ferrocement Exposed to Petroleum Products, PHD, Thesis, University of Technology, 1997.

Al-Zaidi M., Influence of Oil Products on The Physical and Electrical Properties of Concrete, M.Sc, Thesis, University of Technology, 2001.

American Concrete Institute. ACI Committee 211.1-95, Standard Practice for Selection Proportions for Normal, Heavy Weight and Mass Concrete, ACI Manual of Concrete Practice, Part 1-1995.

ASTM C33-03, Standard Test method for Grading of crushed rock coarse aggregate, Annual Book of ASTM Standard, Vol.04.02.

ASTM C143-89, Standard Test Method for Slump of Hydraulic Cement Concrete, Annual Book of ASTM Standard, Vol.04-02, 1989, pp. 85-86.

American Society for Testing and Materials, Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory, ASTM International, West Conshohocken, PA, USA. ASTM C 192, 2007.

American Society for Testing and Materials, Standard Test Methods for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacings and Polymer Concretes, ASTM International, West Conshohocken, PA, USA, ASTM C 267, 1997.

Bassuoni, M. and Nehdi, M., Resistance of Self-Consolidating Concrete to Sulfuric Acid Attack with Consecutive pH Reduction, Cement and Concrete Research, 2007, pp. 1070–1084.

Bernard, F., Kamali, S. and Prince, W. ,3D Multi-Scale Modelling of Mechanical Behaviour of Sound and Leached Mortar, Cement and Concrete Research, 2008, pp. 449–458.

B.S.1881, Part 116, 1989, Method for Determination of Compressive Strength of Concrete Cubes, British Standard Institution, pp.3.

Close, S. and Gangliu, Z., Concrete for Environmental Structures, Concrete International, April 2004.

De Larrad, F., Acker, P., and Le Roy, R. "Chapter 3- Shrinkage Creep and thermal Properties" in High Performance Concrete and Applications, ed. Shah, S.P., and Ahmad, S.H., Edward Arnold, Great Britain, 1994, pp. 65-114.

Gambhir, M., Concrete technology, Third Edition, Civil Engineering Series, 2004.

Hanh, P. and Tuan, N., High Performance Concrete Used for Marine Gravity Concrete Works, The 3rd ACF International Conference ACF/VCA 2008.

Hooton, R., Influence of Silica Fume Replacement on Physical Properties and Resistance to Sulfate Attack, Freezing and Thawing, and Alkali-Silica Reactivity, ACI Materials Journal, Vol. 90, No. 2, March-April 1993, pp. 143-151.

المواصفة القياسية العراقية رقم (٥) لسنة ١٩٨٤ "الاسمنت البورتلاندي"الجهاز المركزي للتقييس والسيطرة النوعية.

Moufaq, J., Effects of Petroleum Products on Civil Engineering Structures, Editor, National Center for Construction Labs, July 1998.

Nyugen, V., Colina, H., Torrenti,J., Baulay, C.and Nedjer, B., Chemo-Mechanical Coupling of Leached Concrete Part 1: Experimental Results, Nuclear Engineering and Design, 2007, pp. 2083–2089.

VSL International LTD, Concrete Storage Structures, Berne/ Switzerland,use of the VSL special construction methods, may 1983.

Table 1 Chemical composition of cement

Physical properties	Fineness (m^2/Kg)	Setting time (hrs:min)		Compressive strength (MPa)		Expansion (%)
		Initial set.	Final set.	3 days	7 days	
Test result	341	2:35	4:45	18.8	23.3	0.03
Limits of I.S. No.5/1984	≥ 230	≥ 00:45	≤ 10:00	≥ 15.00	≥ 23.00	≤ 0.8

Table 2 Physical properties of cement

Oxide composition	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	I.R	L.O.I	L.S.F	C_3S	C_2S	C_3A	C_4AF
% by weight	60.78	20.54	5.88	3.28	1.93	1.87	0.15	3.31	0.89	41.74	27.48	10.04	9.97
Limits of I.S. No. 5/1984					≤ 5.0	≤ 2.8	≤ 1.5	≤ 4.0	0.66-1.02				

Table 3 Sieve analysis of sand

Sieve size (mm)	10	5	2.36	1.18	0.60	0.30	0.15
Cumulative % passing	100	97.44	91.65	78.37	37.21	19.08	3..01
ASTM C33-03	100	95-100	80-100	50-85	25-60	10-30	2-10

Table 4 Physical properties of sand

Physical properties	Specific gravity	Sulfate content	Absorption
Test results	2.64	0.05%	0.80%
Limits of I.S. No.45/1984	-	≤ 0.5%	-

Table 5 Sieve analysis of gravel

Sieve size (mm)	25	20	10	5	2.36
Cumulative % passing	100	94.26	37.35	2.87	1.12
ASTM C33-03	100	90-100	20-55	0-10	0-5

Table 6 Physical properties of gravel

Physical properties	Specific gravity	Sulfate content	Absorption
Test results	2.65	0.1%	0.72%
Limits of I.S. No.45/1984	-	≤ 0.1%	-

Table 7 Chemical analysis of silica fume

Oxide composition	Oxide content %	ASTM C1240-03
SiO_2	88.3	≥ 85%
Al_2O_3	0.35	
Fe_2O_3	1.17	
MgO	2.4	
CaO	1.25	
SO_3	0.91	
Na_2O	1.37	
L.O.I	3.78	≤ 6%

Table 8 Physical properties of silica fume

Property	Result
Specific gravity	2. 16
Fineness	16 m^2/g
Physical form	powder
Colour	grey

Table 9 Technical description of superplasticizer

Appearance	Liquid
Colour	Brown
Specific gravity	1.1
Chloride content	nil
Air entraining	Does not entrain air
Compatibility with cement	all types of Portland cement
Shelf life	Up to 2 years

Table 10 Mix proportions used

Symbol Mix	W/B (%)	Unit Weight (Kg/m^3)					SP (L/m^3)	Slump (mm)
		Water	Binder		Fine Aggregate	Coarse Aggregate		
			Cement	Silica Fume				
HPC3	31	174	533.9	28.1	750	882	3	170
HPC5	31	174	533.9	28.1	750	882	5	186

Table 11 Results of weight and compressive strength test for concrete specimens

Mix	Symbol	Weight (Kg)			Compressive strength (MPa)		
		7 days	28 days	90 days	7 days	28 days	90 days
HPC3	W3	8.07	8.26	8.35	44.46	51.91	59.53
	K3	7.92	8.11	8.14	41.34	45.27	48.11
	G3	7.98	8.12	8.19	42.25	46.88	49.60
HPC5	W5	8.13	8.30	8.42	56.56	62.02	69.70
	K5	7.79	8.01	8.15	52.21	56.73	59.79
	G5	7.96	8.06	8.16	54.97	58.01	60.08

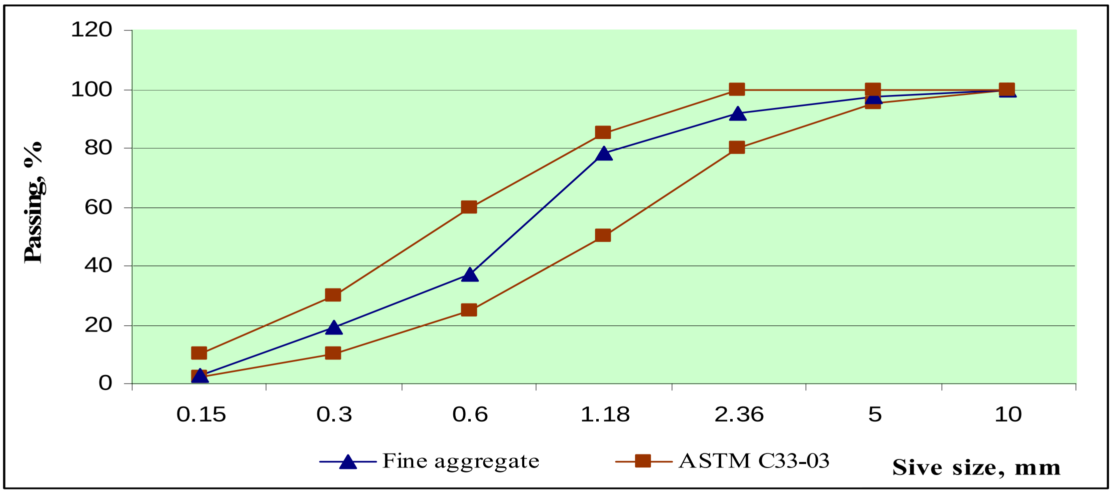

Fig.1 Grading curve for fine aggregate

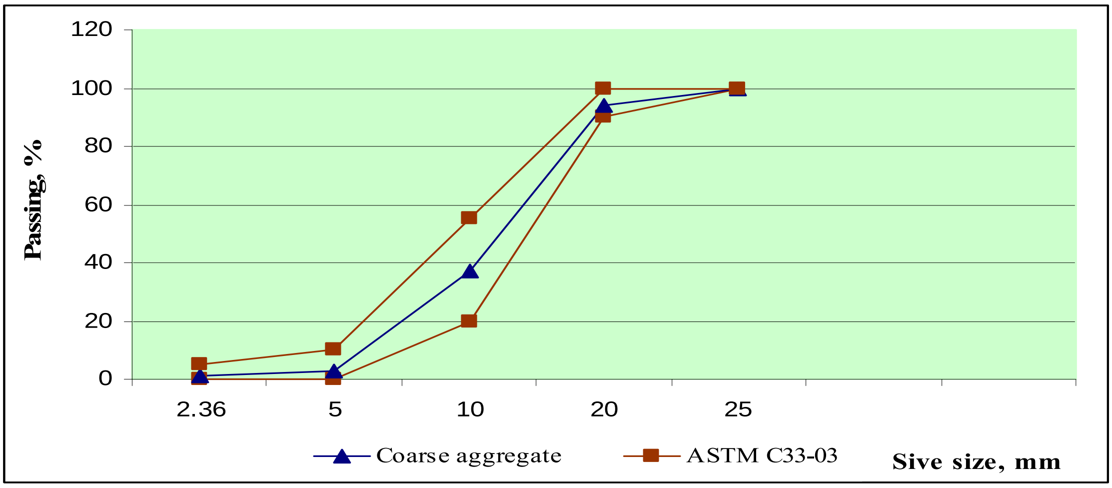

Fig.2 Grading curve for coarse aggregate

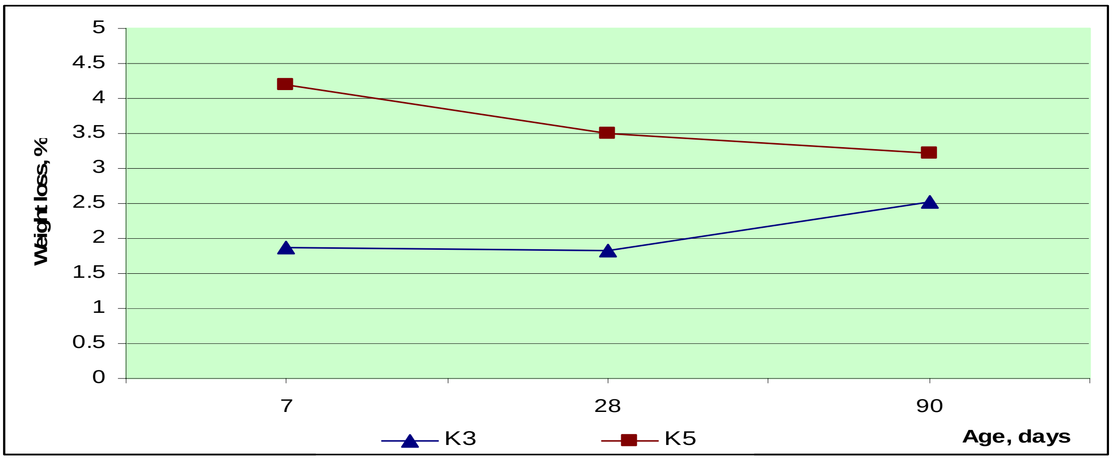

Fig. 3 Weight loss of concrete specimens immersed in kerosene as a percent to their corresponding specimens cured in water

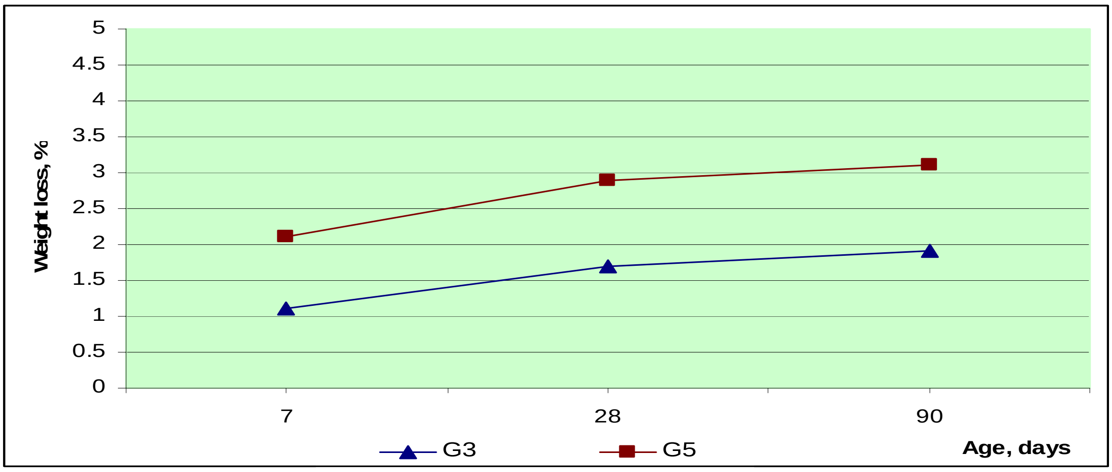

Fig. 4 Weight loss of concrete specimens immersed in gasoline as a percent to their corresponding specimens cured in water

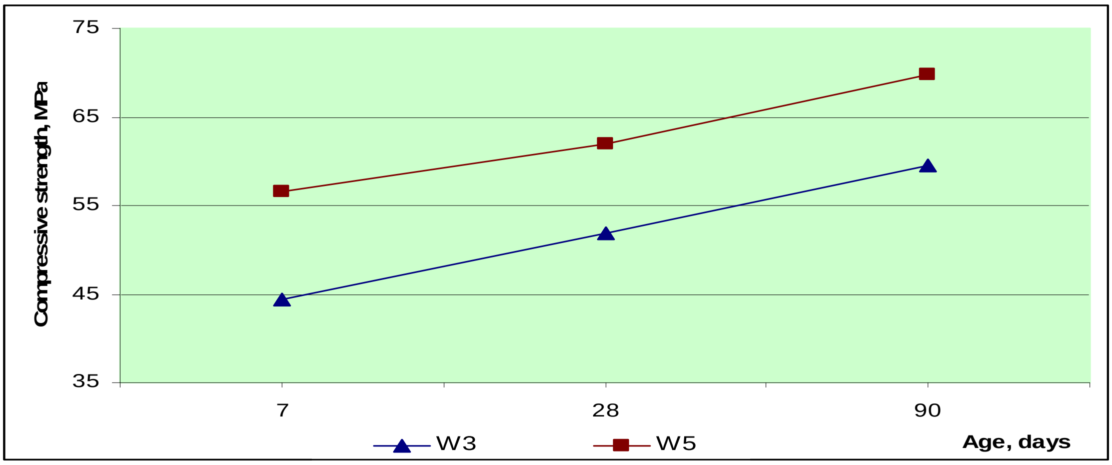

Fig. 5 Effect of SP on compressive strength of concrete specimens cured in water

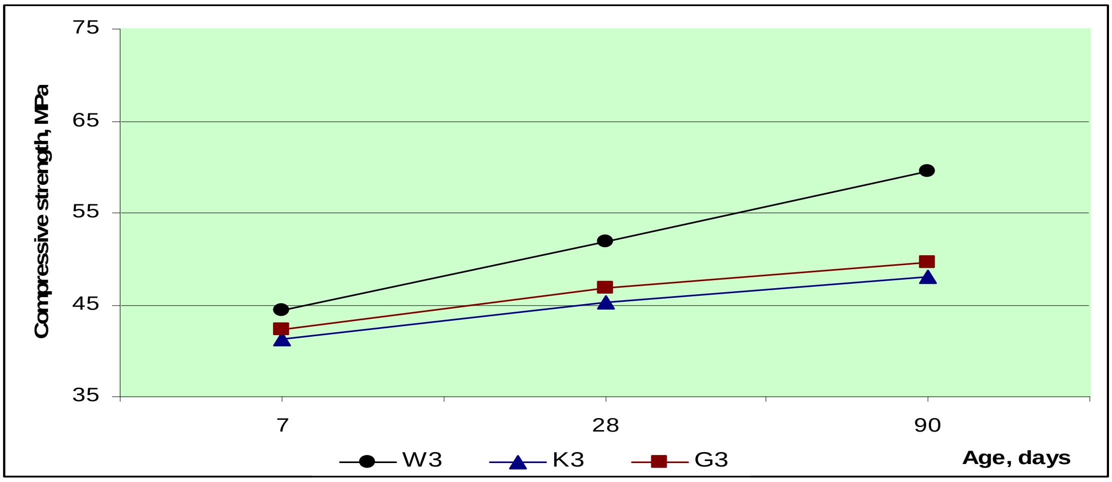

Fig. 6 Effect of kerosene and gasoline on compressive strength of HPC3

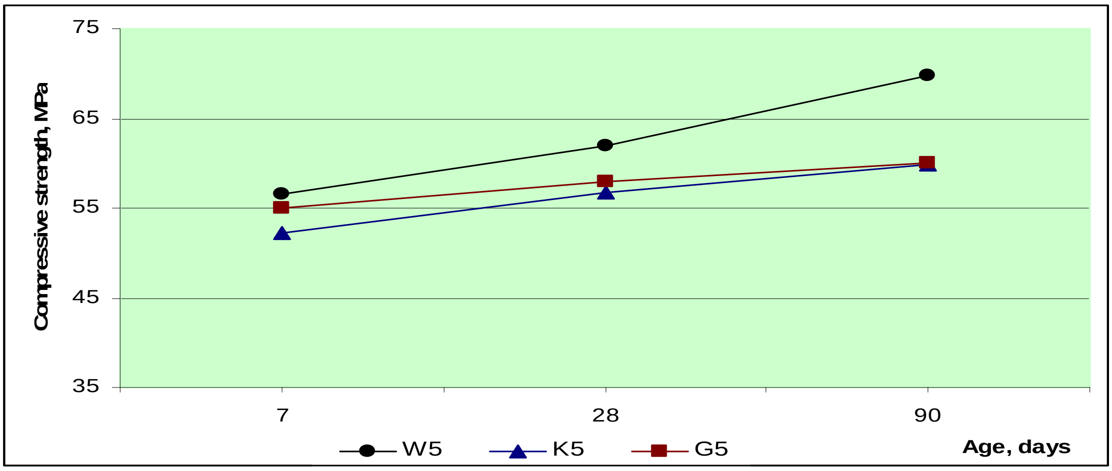

Fig. 7 Effect of kerosene and gasoline on compressive strength of HPC5

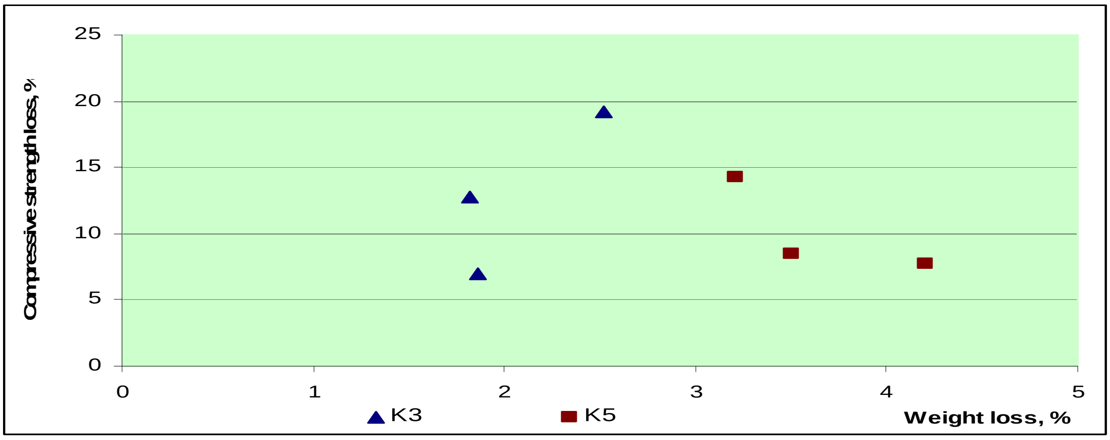

Fig. 8 Compressive strength loss versus weight loss after 12 weeks of exposure to kerosene as a percent to their corresponding specimens cured in water

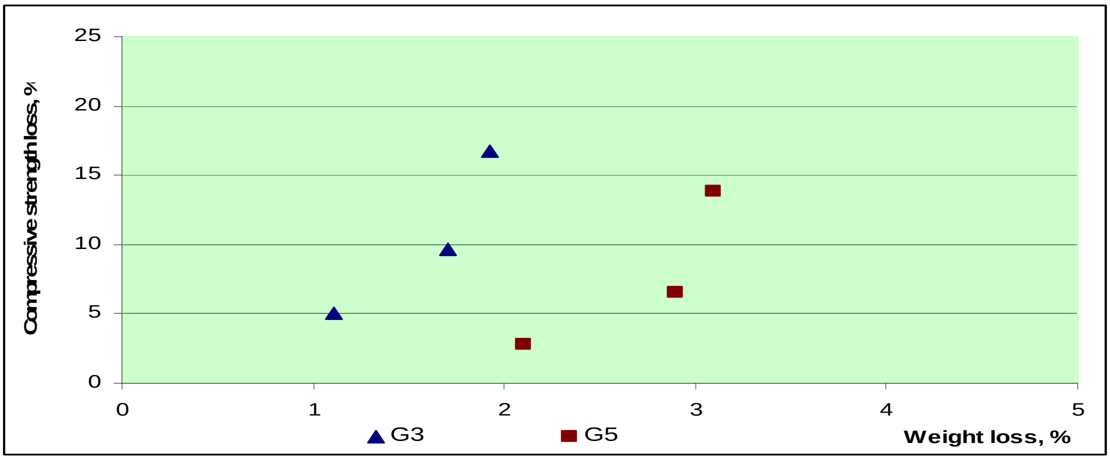

Fig. 9 Compressive strength loss versus weight loss after 12 weeks of exposure to gasoline as a percent to their corresponding specimens cured in wate