REDUCING PERMEABILITY OF CONCRETE EXPOSED TO OIL PRODUCTS BY USING CONCRETE ADMIXTURES[+]

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Abstract:

Oil and its products as one of active sources of energy due to their operating and economic properties, there is a shortage of information about the behavior of concrete under oil effect, most of the recent researches tend to study the possibility of using reinforced concrete has oil products storage as an alternative to the expensive steel storage. This research studied the effect of two products, crude oil and kerosene of concrete and its possibility of reducing this effect by using (1%) of fibers reinforced of total mix volume, (5.5%) by cement weight of superplasticizer type (Melment L_{10}) and (30%) of slag by weight as replacement of sand . The results show a better reducing in permeability of 1% F.R-5.5% HRWR-30%SL concrete . This reduction after 96 hours reaches 14.5% and 28.8% for crude oil and kerosene exposure respectively .

المستخلص:

كون النفط ومشتقاته مصدراً حيوياً للطاقة لخواصه الاقتصادية والتشغيلية ولوجود شحة واضحة في المعلومات لسلوك الخرسانة المعرضة لتأثير مشتقات النفط . اتجهت الأبحاث لدراسة امكانية استخدام الخزانات الخرسانية لخزن المشتقات النفطية كبديل للخزانات الحديدية المكلفة. في بحثي هذا دراسة لتاثير نوعين من المشتقات النفطية هما النفط الخام والابيض على نفاذية الخرسانة وامكانية تقليلها باستخدام مضافات الملدن المتفوقة من نوع (melment L_{10}) ومطابق للمواصفة الامريكية ASTM C494 و ١% من الياف الفايبر بالنسبة الى الحجم الكلي للخلطة الخرسانية اضافة الى (٣٠%) خبث من وزن الرمل وبديلاً عنه ولجميع الخلطات الخرسانية عدا الخلطة المرجعية. تم التوصل الى تحسن كبير في التقليل من نفاذية الخرسانة مع مرور الوقت حيث بلغت نسبة تقليل بعد (٩٦) ساعة عمر الى ١٤,٥%، ٢٨,٨% للخلطة الحاوية على ١% من الياف الفايبر اضافة الى ٥,٥% من الملدن المتفوق ونسبة ٣٠% من الخبث لكل من النفط الخام والابيض على التوالي.

Introduction:

The durability of concrete is one of the most important properties because it is essential concrete that should be capable of standing with the conditions for which it has been designed through out the life of a structure [1]. One method of estimating the durability of concrete by measuring the rate at which a fluid permeates through the

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concrete under a given head pressure, the more quickly a fluid moves through the concrete, higher permeability, and lower the anticipated durability. Similarly, if a fluid moves through the concrete at a very slow rate that means low permeability and a high durability would be expected [2]. Permeability may be defined as the flow of liquid or fluid through porous material or the ease with which a fluid penetrates or seeps through the porous media along its capillary channels, voids, pores of varying sizes and fissures linked by the shrinkage crack [3]. The permeability of concrete is largely dependent upon that of cement paste , because it contains pores of different types such as gel , capillary pores , as well as pores from in complete consolidation [4] .

The Problem :

The facts of concrete storage tank and steel storage tank should be separated . The steel storage tank as a result of the high maintenance costs , scarcity of steel and safety requirement ,has motivated the use of materials other than steel to store and transport oil products but the problem , which limits the use of concrete for storage and transport for oil products , is the concrete permeability that increases by the presence of crack in concrete a result of shrinkage and other deformations .

The Object :

Studying the effect of admixtures on the concrete permeability that is exposed to crude oil and kerosene by using some chemical and mineral admixtures to improve the concrete quality by reducing the concrete permeability to resist deterioration .

Concrete Mixes:

The compressive strength and workability were considered in mix design so that the w/c ratio was determined according to these requirements. The reference concrete mix was designed to have an average 28-day compressive strength of 30 MPa, the cement content was 402.5 kg/m^3 and w/c ratio to attain a slump of (25±5) mm was 0.40 the reference mix proportion used in this research was(1:1.6:3) by weight and other mixes show in Table(1).

Table (1) Percentage of admixtures used in mixes.

MIX TYPE	W/C RATIO	% F.R	% HRWR	% SL
REF	0.40	-	-	-
Mix 1	0.33	1	5.5	-
Mix 2	0.315	1	5.5	30

Materials:

Cement:

Ordinary Portland at cement Sabae manufactured by Lebanon factory was used. Tables (2)&(3) show that cement conforms to the Iraqi specification No 5/1984 [5].

Table (2) Percentage oxide composition and main compound of the cement used in this investigation.*

COMPOUND COMPOSITION	ABBREVIATION	PERCENTAGE BY WEIGHT	LIMITS OF IRAQI SPECIFICATION NO 5/1984
Silica	SiO_2	20.38	-
Lime	CaO	63.9	-
Alumina	Al_2O_3	4.99	-
Iron oxide	Fe_2O	3.9	-
Selfate	SO_3	1.82	$\leq 2.8\%$
Magnesia	MgO	1.36	$\leq 5\%$
Loss on ignition	L. O. I	2.48	$\leq 4\%$
Lime saturation factor	L. S. F	0.95	0.66-1.02
Insoluble residue	I. R	1.04	≤ 1.5
Tricalciume silicate (C_3S)		60.88	
Dicalciume silicate (C_2S)		12.58	
Tricalcium aluminate (C_3A)		6.63 > 5	
Tetracalcium aluminate ferrite (C_4AF)		11.85	

* Chemical tests were made by the Central Organization for Standardization and Quality Control.

Table (3) Physical properties of the cement used in this study*

PHYSICAL PROPERTY	TEST RESULTS	LIMITS OF SPECIFICATION NO. 5/1985
Specific surface area (Blaine method) , m^2 / kg	268	230 (min)
Setting time (vicat apparatus)		
Initial , minutes	90	60 (min)
Final , hrs	3.05	10.0 (hrs)
Compressive strength (70.7 mm cub) (N/mm^2)		
3 days	25.59	15 (min)
7 days	31.89	23 (min)
Autoclave expansion %	0.07	0.8%(max)

* Tests were made by the Central Organization for Standardization and Quality Control .

Fine Aggregate:

AL- ukadir region fine aggregate was used, its grading lying in zone two, with specific gravity, absorption and sulfate are 2.63, 0.85%, 0.16% respectively and 2.3 of fineness modulus. Table (4) shows the grading of fine aggregate.

Coarse Aggregate:

It is used irregular shape with maximum size of (10 mm) asseegaile was used, it was brought from Nebaie region specific gravity, absorption and sulfate concrete are 2.65, 0.08% and 0.9% respectively its with 2.45 fineness modulus. Table (5) shows the grading of coarse aggregate.

Table (4) Grading of fine aggregate.

SIEVE SIZE (MM)	CUMULATIVE PASSING%	LIMITS OF IRAQI SPECIFICATION NO. 45/1985
4/75	98	90-100
2.35	82	75-100
1.18	72	55-90
0.6	48	35-59
0.3	17	8-30
0.15	5	0-10
0.075	1.5	0-3
Fineness modulus 2.3		

Table(5) Grading of coarse aggregate.

Sieve size (mm)	Cumulative passing%	Limits of Iraqi specification No. 45/1985
12.5	100	100
9.5	90	85-100
4.75	12	0-25
2.36	3	0-5
Fineness modulus 2.45		

Fibers Reinforcement:

The fiber reinforcement are produced by mechanical factories specialized in steel block industry and this casual products straight or snail of nearly 0.8-1.2 mm thickness,and density of 5600 kg/m^3.

Superplasticizer:

Sulfonated Melamine formaldehyde known as (Melmentl$_{10}$) complying twith the specification of (ASTM C494) was used in this research. The optimum dosage of HRWR required to attain maximum water reduction 17% and 21.25% is 5.5% by weight of cement for concretes reinforced with fiber contents of 1% by volume of concrete mix to obtain the slump of 25±5.

IRAQI Slag:

The Iraqi slag has been used as a casual products of blast furnace of Al-Sumood General company called before for steel industries as Al taji area where it had been brought as a large block and got broken by Jaw breakers to sizes equal to normal gravel and then by using steel ball grinding machine of (5cm) diameter in order to obtain equal to that grains of grading of sand.

The values of water reduction of concrete mixes containing 30% slag as a partial replacement by weigh of sand in conjunction with optimum dosage of HRWR were found to be more than that of concrete mixes containing. HRWR only. This behavior may be attributed to disabsorped of slag particles relative to the sand particles.

Oil Products:

kerosene and crude oil from Al-Daura refinery were used in this research, Tables (6) shows the properties of these oil products.

Table (6) Crude oil properties and Kerosene properties

OIL INSPECTION DATA	CRUDE OIL RESULTS	KEROSENE RESULTS
Moisture content % by volume	0%	0%
Sulfer content % by weight	2.2%	0.13%
Wax content	1.5 – 2.5%	-
PH	-	7.6
Specific gravity gm/cm^2 at		
20 c^o	0.8817	0.784
25 c^o	0.8781	0.708
30 c^o	0.8740	0.707
Viscosity (centipoises) at		
20 c^o	25.953	1.185
25 c^o	20.838	1.092
30 c^o	17.398	1.091

* Oil analyses were made by the laboratory of AL-Daura refinery

Measurement of permeability:

According to the results of mechanical properties, three mixes were chosen to measure the permeability of concrete exposed to crude oil and kerosene, reference mix, 1% F.R-5.5% HRWR mix and 1% F.R-5.5% HRWR-30% SL mix. each mix two small tanks FRONLwere cast cured for 28 days in water and dried in oven at temperature of 70 ± 5 C^0 for 14 days, then one of tanks was exposed to kerosene and other exposed to crude oil for the purpose of measuring permeability, usually permeability of concrete is measured in terms of DIN specification No 1048[6], because specifications. in this test the permeability is expressed as coefficient of permeability (K) given by Darcy equation:-

$$\frac{dq}{dt} = Axk\frac{h}{L}-$$

where $\frac{dq}{dt}$: the rate of flow in cm^3/Sec.

A: the cross sectional area of the specimens subjected to the fluid pressure (cm^2).

$\frac{h}{L}$ =Ratio of drop in hydraulic head through the sample in(cm) to thickness of sample in (cm).

K: the coefficient of permeability cm/sec.

Description of Permeability Apparatus:

A special steel mold whicl consists of three parts shown in Fig (1) & Fig (2) was used described below [8]:-

1. **Top cover:**
   A steel plate of 6mm in thickness and 300 mm in diameter, with steel cylindrical projection of 120mm diameter and 110mm high with slop of 0.005 was used to facilitate the demolding operation, the cover had with small opening to cast the concrete from.

2. **Bottom base:**
   It is a 4mm thick steel circular plate with 300mm diameter and supplied with two steel cramps on its opposite sides to ensure tight interlock with the molds body.

3. **Molds body:**
   A steel cylinder of 10mm thick with two open ends, the upper diameter of 300mm and a slope of 0.005 to facilitate the demolding operation.

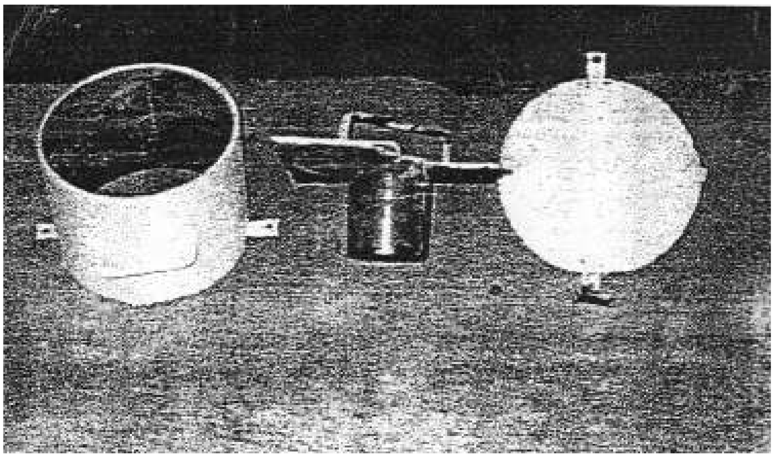


Fig (1) mold parts

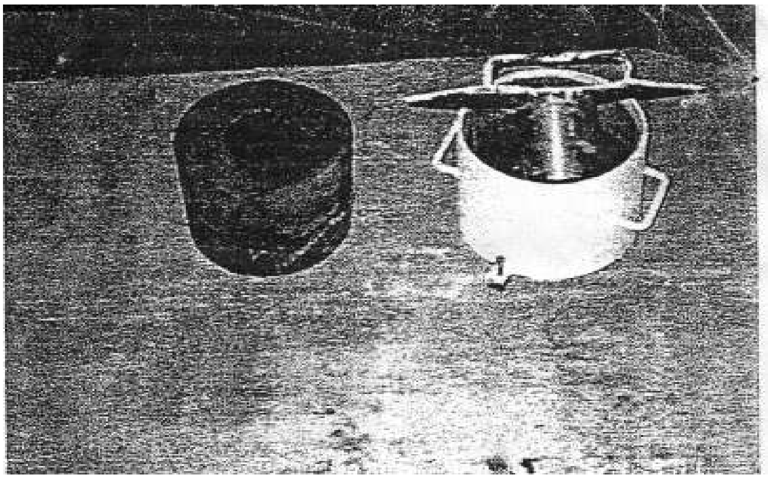


Fig (2) Cast concrete tank model

Results and Discussion:

According to the results of mechanical properties which the author [7] shows 30% SL by weight and replacement of sand were better than that of (10% , 20%) SL added to the same reference concrete mix- proportion in this research , though for three mixes were chosen to measure the permeability of concrete exposed to crude oil and kerosene . These mixes were reference mix, 1% steel fiber with 5.5% HRWR admixture mix (mix_1) and 1% steel fiber , 5.5% HRWR with 30% SL admixture mix (mix_2) . For each mix two small tank were cast , cured for 28days in water and dried in oven at temperature of 70 c^o for two weeks . One of two tank was exposed to kerosene and the other was exposed to crude oil for the purpose of measuring permeability with head pressure of (8)m height . The permeability results of concrete specimens exposed to kerosene and crude oil are presented in Table (7) and plotted in figs (3 to 8) . The test results indicate the following .

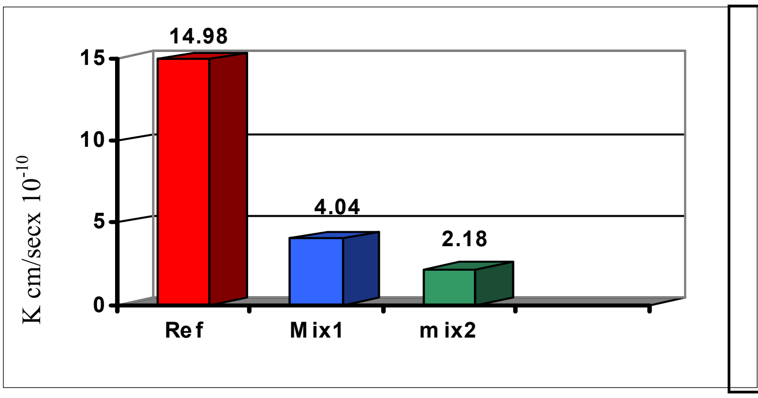
1- Table (7) shows that coefficient of permeability decreases with time for all specimens , until they reach a steady state condition after about 96 hours for both crude oil and kerosene permeability . The test results begin with 378 , 276 and 261 x 10^{-10} (cm / sec) for reference mix , mix_1 , mix_2 respectively . Then they were 14.98 , 4.04 and 2.18 x 10^{-10} (cm / sec) respectively after 96 hours at the end of crude oil exposure test . While for kerosene it is 582 , 454 and 416 x 10^{-10} (cm / sec) for reference mix , mix_1 and mix_2 respectively , at the beginning of the test . Then they were reduced to 18 , 6.3 and 5.2 x 10^{-10} (cm / sec) for reference mix , mix_1 and mix_2 respectively after duration test of 96 hours . This reduction may be due to the clogging of some voids or pores of concrete by depositing of the heavier fraction in crude oil during the liquids [8] .

2- The coefficient of permeability (K) of the concrete specimens to crude oil was lower than the coefficient of permeability to kerosene for all tested concrete specimens . For example the permeability coefficient to crude oil and kerosene for 1% F.R – 5.5% HRWR was 4.04 , 6.3 x 10^{-10} respectively . This variation in coefficient of permeability between crude oil and kerosene might be attributed to the viscosity of the fluid which resists the flow and another reason for the reduction of the crude oil permeability is the wax content .

3- There is a significant effect on the coefficient of permeability of the concrete specimens due to using of admixtures with concrete mixes . It is noticed that the is a significant reduction in the coefficient of permeability when the admixture is used . The coefficient of permeability to crude oil of concrete specimens is reduced by about 27 and 31% for the 1% . F.R 5.5 % HRWR and 1% FR. 5.5 % HRWR 30% SL admixtures concrete respectively at the beginning of exposure compared with the value of the reference concrete specimens. On the other hand the coefficient of permeability of concrete exposed to kerosene is reduced by about 22 and 28.5% respectively . These reductions are relative to the reference concrete at the same hydrostatic pressure . The reason may be attributed to admixtures ability to reducw/c , as where most of previous researches , agree in that [9] . The reduction depends on the type of admixtures , and type of exposure .

Table (7) Coefficient of permeability $Kx10^{-10}$ for mixes exposed to crude oil and kerosene.

DURATION (HOURS)	COEFFICIENT OF PERMEABILITY $KX10^{-10}$ OF MIXES EXPOSED TO CRUDE OIL			COEFFICIENT OF PERMEABILITY $KX10^{-10}$ OF MIXES EXPOSED TO KEROSENE		
	Reference mix	1% F.R.-5.5% HRWR	1% F.R.-5.5% HRWR-30% SL	Reference mix	1% F.R.-5.5% HRWR	1% F.R.-5.5% HRWR-30% SL
1	378	276	261	582	454	416
2	176	134	124	302	247	220.5
4	92	72	65.5	167	138	120.9
6	66	49	46	115	90	80.7
8	42	29.8	27	86	66	58.8
12	31.5	21.7	20	48	36.4	32.6
24	23	9.7	9.1	32.5	23.4	21.7
36	17.8	7.21	6.3	25.4	17.3	16.5
48	15.8	4.4	2.49	23.2	12.6	9.7
72	15	4.1	2.22	18.1	6.4	5.3
96	14.98	4.04	2.18	18	6.3	5.2



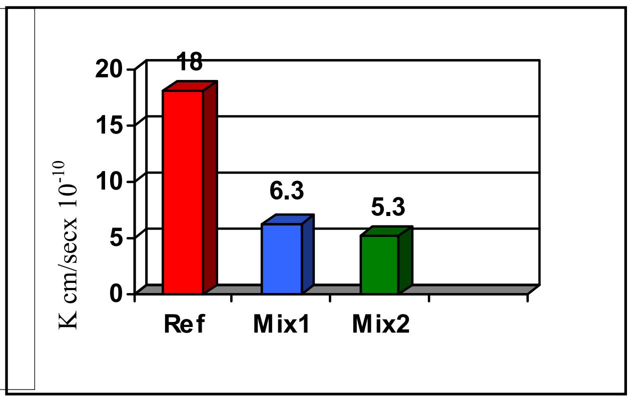
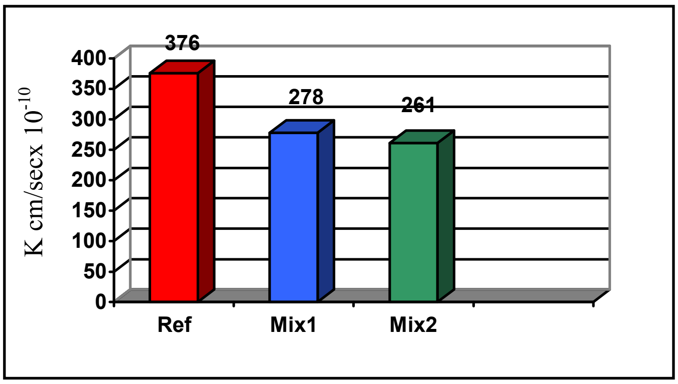


Fig. (3) The coefficient of permeability after 96 hours exposure to crude oil

Fig. (4) The coefficient of permeability after 96 hours exposure to kerosene



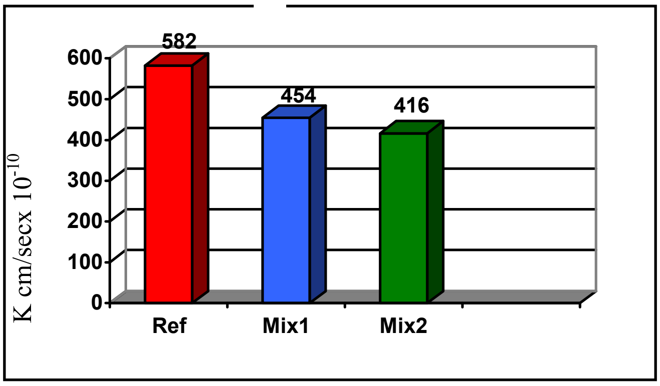


Fig. (5) The coefficient of permeability after 1 hour exposure to crude oil

Fig. (6) The coefficient of permeability after 1 hour exposure to kerosene

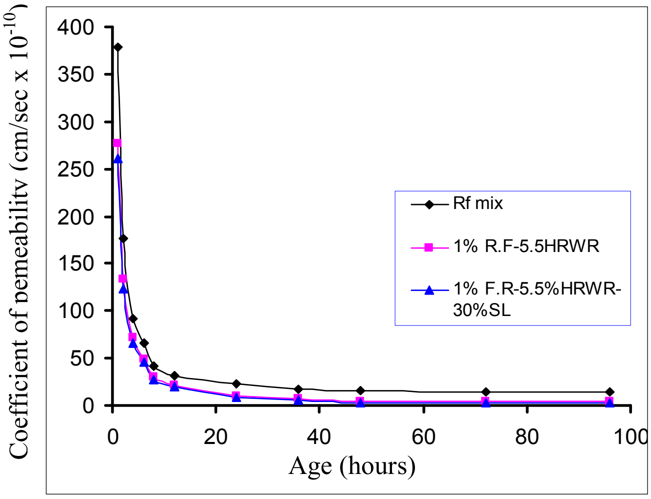


Fig. (7): Coefficient of permeability (K) (cm/sec x 10^{-10}) with different exposure time for crude oil.

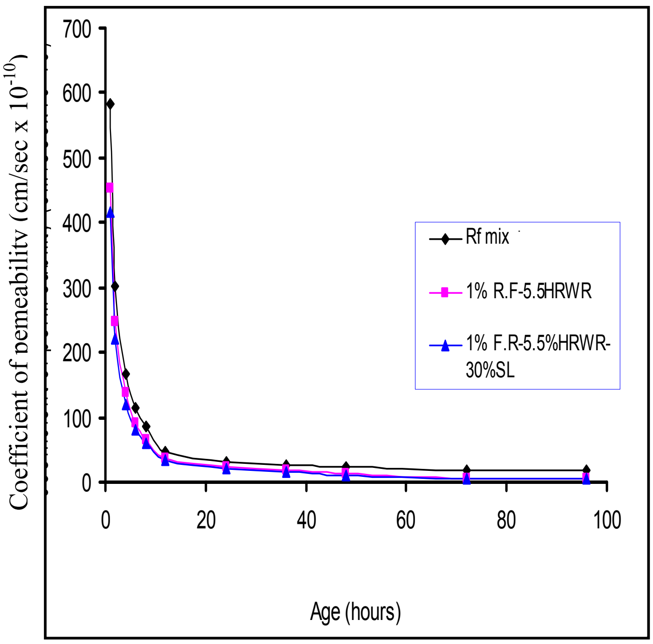


Fig. (8): Coefficient of permeability (k) cm/sec$x10^{-10}$) with different exposure times for Kerosene

Conclusions

Form to the tests results the following conclusion can be drawn :-

1- The coefficient of permeability decreases for all specimens with the exposure time
increases .

2- The coefficient of permeability of the concrete specimens soaked in crude oil is lower than the coefficient of permeability to kerosene for all tested specimens .

3-There is a significant reduction in the permeability depending on the type of admixture and type of exposure .

4-The permeability coefficient increases with the increase in w/c of the concrete specimens for all mixes .

5-The improvement in permeability depends on the amount of reduction in mixing water.

Recommendations :

Based on the present work , further studies are recommended in several lines

1-The relationship between mechanical and permeability properties.

2-The effect of using this admixtures on the shrinkage and creep characteristics of oil soaked concrete .

3-The long term behavior for durability and compressive strength to the oil soaked concrete by using present work admixtures.

4-The behavior of steel fiber reinforced concrete exposed to oil products under dynamic and impact loading for different periods of exposure should be sludised.

5-The economic studies on should be made the steel fiber reinforced concrete construction to store and transport oil .

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