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EFFECTS OF DIESEL CONTAMINATED MIXING WATER ON CHARACTERISTICS OF CONCRETE BATCHED FOR STREETS AND LOCAL ROADS CONSTRUCTION

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Abstract: The concrete mixing water and the environment at large are polluted with diesel due to oil spillage, pipeline vandalism and explosion of tankers carrying diesel fuel oil. Consequently, the present study focused on the effects of diesel contaminated mixing water on concrete batched for concrete streets and local roads pavement were evaluated. The properties of fine and course aggregates were evaluated and concrete specimens were prepared at mix ratio of 1: 2: 3 with 0%, 5%, 10%, 15%, 20%, 25% and 30% diesel fuel contamination of mixing water. The slump was evaluated immediately after batching. The splitting tensile and flexural strengths were evaluated at 7 day and 28 day age. The compressive strength was evaluated at the 3rd, 7th, 14th, 28th and 56 day age. The results indicate increase in slump value as the percentage contamination of mixing water with diesel increases. The strength properties of the hardened concrete increases with increase in age and decreases with increase in percentage contamination of mixing water with diesel. The research therefore concludes that the use of diesel contaminated mixing water for concrete production should be avoided as much as possible and mixing water for concrete production must conform to the specification of ASTM C192/C192M – 16a (2016).
Keywords: concrete, pavement, compressive strength, diesel, mixing water

1. INTRODUCTION

Concrete is a mixture of cement, water, fine and coarse aggregate which hardens to a stone – like mass. Concrete is used more than any man made materials on earth. The concrete strength is often regarded as the most important property of concrete. Concrete suffers from one major drawback compared with other materials like steel and timber. Its strength cannot be measured prior to it being placed. Factors affecting compressive strength are water cement ratio, mix ratio, degree of compaction, type of cement, the grade of aggregate, design constituent, mixing method, placement, curing method and presence of contaminates (Hashem 2011). According to Ready Mixed Concrete Association of Ontario (RMCAO) 2009, Portland cement concrete (PCC) pavement refers to the rigid concrete layer of the pavement structure that is in direct contact with the traffic. Typical concrete is composed of coarse aggregate (crushed stone and gravel), fine aggregate such as sand, Portland cement, admixtures and water. Concrete can be modified in a number of ways, including the addition of cementitious materials such as Slag or Fly Ash (which are materials that are added to the mixture to enhance the properties of the fresh or hardened concrete) keeping them from landfill sites. Once the concrete has been mixed, it is placed on a prepared base coarse, consolidated and shaped.

Hamad, Rteil, and EL-Fadel, (2003), studied the effects of used engine oil on concrete properties and concrete behavior. The effect of used engine oil on properties of fresh and hardened concrete was investigated. Results indicated that used engine oil acted as an air-entraining agent by improving the slump and fluidity of the concrete mix, and enhancing the air content of fresh concrete. Reductions in the strength properties of hardened concrete due to the incorporation of oil were not as significant as when a commercial chemical air-entraining admixture was used. They found that UEO did not have significant effect on the structural behavior of reinforced concrete elements, where the ultimate load or load deflection diagrams have not been altered due to adding UEO to concrete mix ingredients. Jassim and Jawad (2010) found that oil-exposed concrete showed a decrease in compressive strength over time and the maximum reduction in the strength values of normal and high concrete specimens exposed to crude oil, gas oil and white oil for 120 days are about 25.19% and 12.86% respectively. Ajagbe et.al (2012), investigated the compressive strength of concrete using fine aggregates contaminated with crude oil at different percentages of the weight of the sand used in the mixture. The results showed a slow rate of increase in the strength of concrete and increase in the rate of decrease as the percentage of pollutant increase.

Abousnina et al (2015), found that concrete made by fine sand contaminated with light crude oil, the cohesion increased significantly up to 1% of oil contamination and then decreased with increasing percentage of crude oil while a slight reduction in frictional angle was observed with oil contamination. The highest compressive strength was obtained for mortar with 1% oil contamination and with only a 18% decrease in strength of

mortar with 10% oil contamination compared to the uncontaminated samples. Osuji and Nwankwo (2015), observed that the presence of crude oil in concrete hinders the bond formation between constituent materials and brings about segregation. Consequently, the presence of crude oil in concrete resulted to variations in workability of the concrete the higher the percentages of crude oil in the fine aggregate, the higher the workability. Also, lower compressive strengths were observed in contaminated concrete cubes when compared with the control cubes. This revealed clearly that crude oil is a compressive strength inhibitor in the production of concrete. The higher the percentages of crude oil in the fine aggregate, the lower the compressive strength obtained. It can be inferred that the optimum crude oil contamination for the achievement of normal compressive strength is as low as 0.3%. Shafiq et al (2011), found that the addition of used engine oil, concrete slump was increased by 18% to 38% and air content by 26% to 58% as compare to the slump of control concrete. Porosity and oxygen permeability of concrete containing used engine oil was also reduced and the compressive strength obtained was approximately same as that of the control mix.
According to BS EN590 (2013) and ASTM D975 – 17 (2017), diesel fuel is any liquid fuel used in diesel engines, originally obtained from crude-oil distillation (petro-diesel), but alternatives are increasingly being developed for partial or total substitution of petro-diesel, such as biodiesel (from vegetal oils), and synthetic diesel (usually from a gas fuel coming from coal reforming or biomass, also named gas to liquid fuels, GTL). In all cases, diesel nowadays must be free of sulfur. According to Girish, et al, (2014), Abdul, et al, (2000) and Ejeh and Uche (2009), spillage of petroleum products adversely affects marine life and environment. Spillage of petroleum on roads leads to cracks and consequently failure of the roads. Petroleum products pose high degree of adverse effects on the properties and performance of concrete thus degrades it.
Ayinimuola, (2009), studied the influence of diesel oil and bitumen contaminated sand on the compressive strength of concrete and concluded that the presence of diesel oil and bitumen of any proportion in sand result in concrete of lesser compressive strengths. This indicates that diesel oil and bitumen are compressive strength inhibitors in concrete production. He also concluded that the 28 day compressive strength of concrete made of contaminated sand of 2% to 10% diesel oil were in the range of 96.8% to 77.4% of uncontaminated sand. Likewise those of bitumen are in the range of 76.2% to 26.2%. He suggested that the higher the percentage of oil in the sand, the lower the compressive strength obtained. According to Mohammed and Walid (2017), penetration of oils to cement hydration products may cause an expansion in the voids of the gel and separation of these products from each other which leads to weak bonds between them, reduction in the cohesion forces on the surface of the gel and increase the possibility of sliding some of them in addition to the increasing of the internal hydraulic pressure as a result of absorption of these liquids.
Although many studies have been conducted on the effect of petroleum products contaminated mixing water on engineering proprieties and behavior of fresh and hardened concrete prepared for pavement construction, the interpretation of their behaviors are still unclear and need further studies. This research aims at providing additional information and on evaluating the effect of diesel contaminated mixing water on characteristics of concrete prepared for street and local road pavements.

2. MATERIALS AND METHODOLOGY

— Materials

≡ Portland cement, Fine and Coarse aggregate

The Portland cement used in this research conform to the specifications of AASHTO M85 (2016), ASTM C150/C150M – 16e1 (2016), ACI 225R (2016) and WSDOT standard practice QC1 (2016) and WSDOT M46 – 01.25 (2016). The fine and coarse aggregates used in this research satisfied the specifications of AASHTO M6 (2013) and AASHTO M80 (2013) respectively. They also satisfied the specifications of ASTM C33/C33M – 16e1, (2016), and WSDOT M46 – 01.26 (2017).

≡ Diesel, mixing water and curing water

The diesel satisfied the specifications of BS EN590 (2013) and ASTM D975 – 17 (2017). The mixing water for 0% contamination of mixing water with diesel fuel oil conform to the specifications of WSDOT M23-50, (2016), FDOT (2010), NCDOT (2012), CDOT (2011) and PCA EB 233 (2005).

— Methods

≡ Aggregate characteristics

The sieve analysis was conducted for the fine and coarse aggregates in accordance with ASTM C136/C126M (2014), AASHTO T27 (2015), WSDOT M46-01.25 (2016). Combined fine and coarse aggregates grading was used in this study to ensure that a satisfactory amount of aggregate with a minimum amount of void spaces is obtained. This will enable the use of a minimum amount of paste (water and cementitious material) in concrete, improving the dimensional stability and the durability. The specific gravity and water absorption of the fine and coarse aggregates were conducted in line with the procedures specified in AASATO T84 (2013) and AASHTO T85 (2014), respectively. The procedure employed also conform to the provisions of WSDOT M46 – 01.26 (2017), ODOT (2017), ASTM C128 (2015) and ASTM C127 (2015) for saturated surface dry density and water absorption. The Los Angeles abrasion value was conducted for coarse aggregate in accordance with ASTM C121/C131M (2016), WSDOT M46 – 01.26 (2017), ODOT (2017) and ACI 121R (2008). The aggregate crushing value was conducted for coarse aggregate in accordance with WSDOT M46-01.26 (2017) and ASTM C131/C131M (2016).

≡ **Mix design. Slump test and curing media**

The test specimens were prepared at 1:2:3 mix ratio of hydraulic cement, fine and coarse aggregate respectively. The batching was by weight in accordance with ASTM C94/C894M – 16b (2016), PCA EB001. 15 (2011), NRMCA version I (2014), ACI 363.2R (2011), and ACI 304R – 00 (2009). The maximum size of coarse aggregate used was 19.00mm. The water cement ratio was maintained at 0.50 and the mixing water used for the control mix conforms to the specifications of ASTM C1602/C1602M (2012). Mixing water for subsequent concrete specimens marked D2, D3, D4, M5, D6, and D7 were contaminated with 5%, 10%, 15%, 20%, 25%, and 30% by weight of diesel fuel oil. The slump test was performed for all the concrete mixes in accordance with ASTM C143/143M – 15a (2015) and WSDOT M46 – 01.26 (2017).

≡ **Compressive strength, splitting tensile strength and flexural strength**

According to NRMCA CIP-16 (2000), the National Ready Mixed Concrete Association (NRMCA) and American Concrete Pavement Association (ACPA) have a policy that compressive strength testing is the preferred method of concrete acceptance. ACI 325, 9R – 15 (2015) and ACI 330R (2008) point to the use of compressive strength as more convenient and reliable to judge the quality of concrete. The compressive strengths of the concrete specimens were evaluated at the 3rd, 7th, 14th, 28th and 56th days. The specimens were of the 150mm diameter by 300mm long.

The compressive strength test was conducted in accordance with ASTM C39/C39M – 16b (2016), WSDOT M46 – 01.25 (2016). IDOT D&E – 2 (2012) and IDOT (2008), and IDOT MAT 13 (2014), TXDOT manual notice (2011). The flexural strength (modulus of rapture) was conducted in accordance with ASTM C78/C78M (2016). The sizes of the beams used were 150mm breath, 150mm depth and 700mm long. The span – overall depth ratio of 4.0 was maintained. The split tensile strength was conducted in accordance with ASTM C496/C496M – 11 (2004). The concrete cylindrical specimens used were of 150mm diameter and 300mm long.

3. RESULTS AND DISCUSSION

— **Properties of diesel used and aggregate**

Table 1 shows the results of the laboratory analysis of the diesel used in this study. The results satisfied the specifications of BS EN590 (2013) and ASTM D975 – 17 (2017). Figure 1, shows the combine sieve analysis result of fine and coarse aggregate. It can be seen that the aggregate used were well graded of 19mm maximum size. The sieve analysis results satisfied the specification of ASTM C136/C136M (2014), AASHTO T27 (2015) and WSDOT M46 – 07.25 (2016).

Table 1: Properties of diesel used.

S/N	Properties	Unit	Value	BS EN590 (2013) Standard	
				Lower limit	Upper limit
1.	Appearance	-	Clear and bright, free from visible sediments and water		
2.	Density at 15ºC	Kg/m³	838	820	845
3.	Flash point	ºC	55	Above 55	-
4.	Cetane number		51.0	51	
5.	Cetane index		46.0	46	
6.	Viscosity at 40ºC	mm²/s	3.20	2.0	4.5
7.	Polycyclic Aromatic Hydrocarbons	% (m/m)	8.0		11 (8)
8.	Sulphur Content	mg/kg	10.0		10.0
9.	Carbon Residue : (on 10% Distillation Residue)	% (m/m)	0.30		0.30
10.	Ash Content	% (m/m)	0.01		0.01
11.	Total Contamination	mg/kg	24		24
12.	Water Content	mg/kg	200		200
13.	Distillation: Volume Recovered at 250°C	% (V/V)	55		<60
14.	Distillation: Volume Recovered at 350°C	% (V/V)	85	85	
15.	Distillation: Volume Recovered at 95% Point	ºC	360		360
16.	Fatty Acid Methyl Esters (FAME) Content	% (V/V)	5		7
17.	Lubricity, Corrected Wear Scar Diameter (WSD 1,4) at 60 °C	µm	460		460
18.	Oxidation Stability	g/m³	25		25
19.	Oxidation Stability	h	20	20	
20.	Manganese content	Mg/l	2.0		2.0

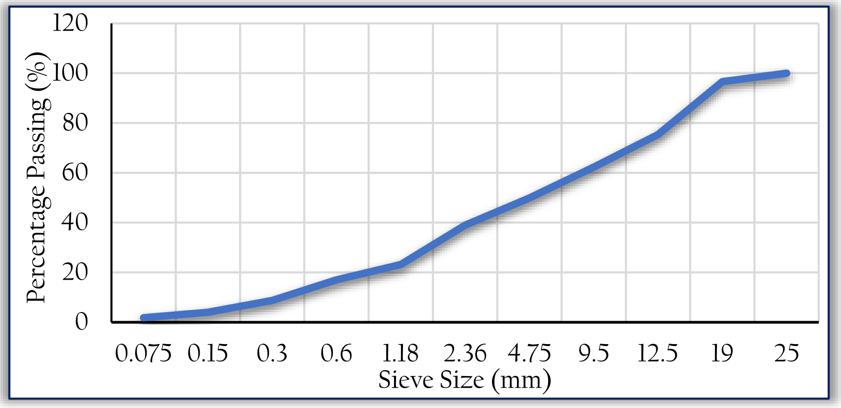

Figure 1. Combined aggregate gradation (fine and coarse aggregate)

Table 2 shows the physical and mechanical properties of the fine aggregate and the coarse aggregate. The values obtained are within the range specified by relevant codes of practice. The results shown in tables 2 and 3 show that the fine and coarse aggregates used in this study satisfied the specifications of ASTM C33/C33M – 16el (2016), ASTM C94/C04M – 16b (2016), WSDOT M41-10 (2017), AASHTO M80 (2013), AASHTO M6 (2013), ACI 363. 2R (2011) and ACI 304 R – 00 (2009).

Table 2: Physical and mechanical properties of fine and coarse aggregate.

Properties	Fine Aggregate	WSDOT M46-07.25 Specifications	Coarse Aggregate	WSDOT M46-07.25 Specifications
Specific gravity	2.61	2.5 – 3.0	2.7	2.5 - 3.0
Water absorption SSD (%)	0.34	0.0 -0.3	0.31	0.0 – 8.0
Loss Angeles abrasion value (%)	-		29	27 - 49
Aggregate crushing value (%)	-		24	20 - 30

— **Mix design**

Table 3: Shows the concrete mix design ratio of 1:2:3 by weight of cement, fine and coarse aggregates respectively and the percentage contamination of mixing water with diesel. The water cement ratio for the control mix (D1) was 0.50 and the diesel contaminated water cement ratio of 0.50 was also kept constant for other specimens. The mixing water used for the control mix (D1) satisfied the specifications of ASTM C1602/C1602M – 12 (2012). The concrete specimens were prepared and cured in accordance with ASTM C192/C192M – 16a (2016), AC1 304R – 00 (2009), ACI 363.2R (2011).

Table 3: Concrete mix design of 1: 2: 3

specimens mark	Percentage contamination of mixing water with diesel (%)	Mixing water (Kg/m^3)	Diesel (Kg/m^3)	Water -cement ratio/diesel contaminated water - cement ratio	Cement (Kg/m^3)	Aggregates (Kg/m^3)	
						Fine	Coarse
D1	0	220	-	0.50	400	800	1200
D2	5	209	11	0.50	400	800	1200
D3	10	198	22	0.50	400	800	1200
D4	15	187	33	0.50	400	800	1200
D5	20	176	44	0.50	400	800	1200
D6	25	165	55	0.50	400	800	1200
D7	30	154	66	0.50	400	800	1200

The design mix satisfied the minimum cement content of 300kg/m^3 – 360 kg/m^3 for standard and high performance concrete pavement as specified by NCDOT (2012), INDOT (2014), WSDOT M41-01.27 (2017), WSDOT M46-01.25 (2016), WSDOT M41-10 (2017), TXDOT (2011), ACI 325.9R (2015), IDOT (2008), IDOT D&E-2 (2012), PCA EB 001.15 (2011), ODOT (2017), and PCA EB (2005).

— **Concrete characteristics**

Table 4 shows the slump, and compressive strength of concrete made with different percentage contamination of mixing water with diesel fuel oil. The slump increases with increase in percentage contamination of mixing water with diesel as shown in Table 4 and Figure 4. From Table 4 and figure 2, it can be observed that the compressive strength decreases with increase in diesel contamination of the mixing water. The compressive strength of all the concrete specimens increased with increase in age irrespective of the increase in contamination of mixing water with diesel. It is observed that 5% contamination of mixing water with diesel caused 15.64% decrease in 28th day compressive strength.

Table 4: Slump, density and compressive strength of concrete.

Concrete cylindrical specimens mark	Percentage contamination of mixing water with diesel (%)	Slump (mm)	Compressive strength (N/mm^2)				
			3 day Age	7 day Age	14 day Age	28 day Age	56 day Age
D1	0.0	83	24.08	28.81	31.17	36.11	42.41
D2	5.0	110	20.48	23.11	26.08	30.46	33.91
D3	10.0	118	16.11	20.81	23.08	27.82	30.81
D4	15.0	125	13.60	17.61	20.81	24.18	27.01
D5	20.0	138	10.60	13.72	17.51	20.19	24.61
D6	25.0	147	7.80	10.81	14.14	17.11	20.21
D7	30.0	153	6.81	9.11	12.21	15.88	17.88

Table 5: 7days and 28 day split tensile and flexural strengths of concrete

Concrete cylindrical specimen mark	Percentage contamination of mixing water with diesel (%)	Split tensile strength (N/mm^2)		Flexural strength (N/mm^2)	
		7 day	28 day	7 day	28 day
D1	0	4.00	4.62	4.41	4.80
D2	5.0	3.11	3.21	3.31	3.48
D3	10.0	2.82	3.01	3.02	3.34
D4	15.5	2.51	2.08	2.81	3.17
D5	20.0	2.31	2.63	2.51	3.03
D6	25.0	2.20	2.38	2.37	2.88
D7	30.0	2.03	2.11	2.12	2.40

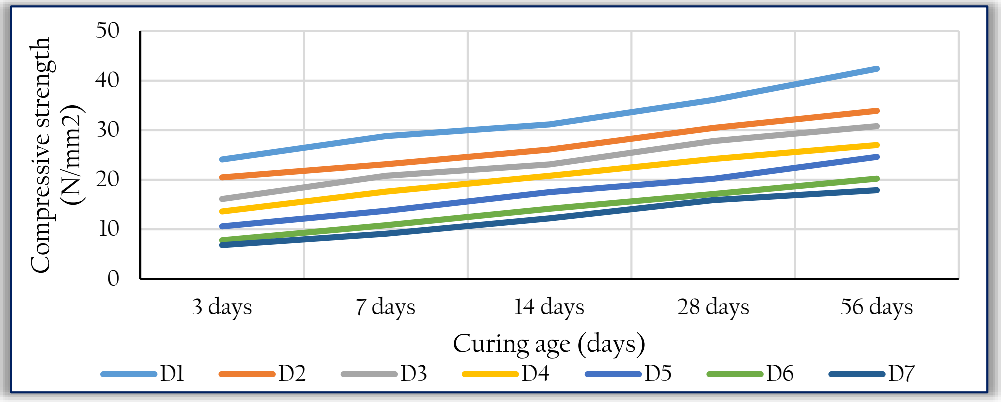

Figure 2. Relationship between the compressive strengths and curing age

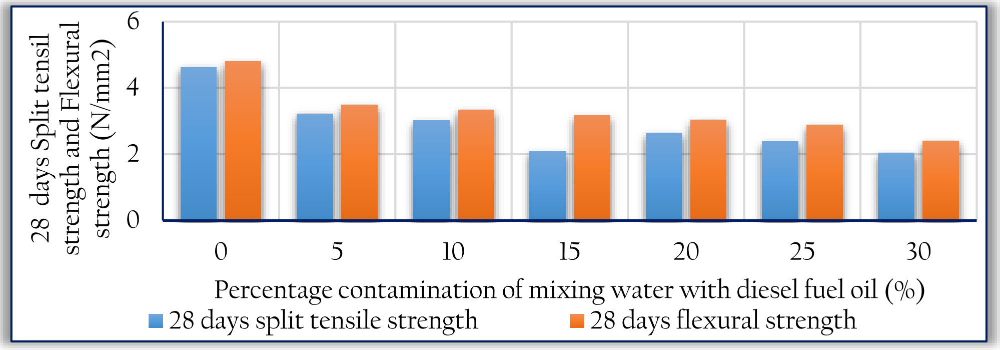

Figure 3. Relationship between percentage contamination of mixing water with diesel and 28 days split tensile strength and flexural strength

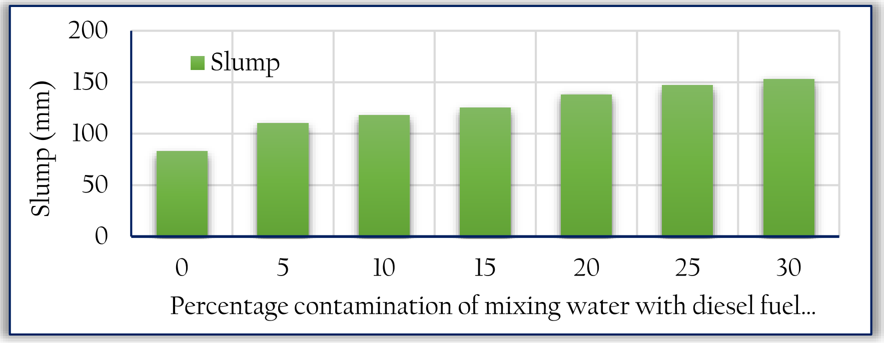

Figure 4. Relationship between percentage contamination of mixing water with diesel and slump

From figure 3 and Table 5 it can be observed that the 28 days split tensile strengths and the 28 days flexural strengths of the concrete decreases with increase in the percentage contamination of mixing water with diesel. Both the split tensile and flexural strengths increased with increase in age.

4. CONCLUSIONS

The following conclusions were made at the end of this research.

a) Increase in diesel contamination of mixing water decreases the strength characteristics of concrete pavement made with diesel contaminated mixing water.
b) Strength properties of concrete pavements made with diesel contamination mixing water increases with age irrespective of the degree of contamination.
c) Concrete mixing water should be free from diesel oil contamination.
d) Mixing water for concrete pavement must conform to the specifications of ASTM C192/C192M – 16a (2016), WSDOT M41 – 10 (2017), ASTM C1602/C1602M (2012).

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