International Journal of Current Engineering and Technology

ISSN 2277 – 4106

Available at http://inpressco.com/category/ijcet

Research Article

Effect of solid wastes on the characteristics behaviour of petroleum products soaked concrete – A Review

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Abstract

Utilization of industrial solid wastes in concrete would help environmental abatement, in solving solid waste disposal problems. Fly ash and Silica fumes are the wastes from the coal and silica industries and poses serious problems of disposing. This present study focuses on the utilisation of Fly ash and silica fumes in the petroleum products soaked concrete. The effect of using fly ash and silica fumes on sorptivity, water absorption, strength properties, chemical characteristics-XRD, morphological behaviour(SEM) of petroleum products soaked concrete has been carried out. There has been a very comprehensive relation between concrete and petroleum. Concrete tanks are used to store petroleum in petrol bunks. Also petroleum comes in contact with concrete in areas like garages, automobiles servicing stations, storage tanks, etc. The bore hole used in oil extraction may be lined up with concrete. Petroleum poses high degree of adverse affects on concrete and thus degrades it. Petroleum gets penetrated into concrete and thereby flows into underground water. The spillage of petroleum on roads leads to cracking. The study aims at avoiding these effects by mixing concrete with different pozzolans like Fly-ash, Silica fumes. This technique is applied in the construction of roads, garage floorings and petroleum product's storage tanks. In all of the above mentioned instances, petroleum comes in contact with concrete in one way or the other and has a specific impact on its characteristic behaviour. In this study, an attempt has been made to review the literature concerned with petroleum soaked concrete and also its advantages and drawbacks are highlighted.

Keywords: *Petroleum products, concrete, fly ash, silica fumes, sorptivity, water absorption, Compressive strength, Tensile stress, Flexural stress, XRD, SEM analysis.*

Introduction

Oil spills occur due to many reasons and this in turn has many fatal impacts on the environment. An oil spill on land may penetrate underground and move downward reaching eventually the groundwater. However, such vertical movement may be slowed down if prevented by the presence of paved surfaces, natural clay layers or other proper designed concrete. Oil may also move laterally along less permeable layers including surface pavements or with groundwater and surface waters. An oil spill in the underground such as from pipelines or underground storage tank leakage, will likely affect the groundwater since the vertical travelling distance is reduced. Such spill may also result in oil residuals that could be entrapped underground constituting a secondary source for groundwater pollution. Hydrocarbons are made exclusively from carbon and hydrogen atoms which bind together in various ways, resulting in paraffin's, aromatics such as benzene, toluene, ethylene and xylene etc. Other individual compounds that are present in crude oil and oil discharges include sulphur, nitrogen and/or oxygen atoms too. Oil pipeline leakage and accidental oil spills are common problems in petroleum industry resulting into contamination of soil. Toxic heavy metals and petroleum hydrocarbons present in such contaminated soils can leach into the surrounding subsurface and groundwater, posing a threat to the environment and to human health. Petroleum-contaminated soil (PCS) is a mixture of sand, silt, clay and petroleum products (Meegoda and Muller, 1993).

Concrete is one of the essential components used in building materials. Various admixtures are added to it to improve its quality (P. Van den Heede et al, 2012). Utilisation of fly ash and silica fumes in concrete improves mechanical properties and also influences resistance of concrete which is consequence not only of the chemical nature of the hydrated cement paste but also of its microstructure. The durability of concrete structure is determined based on the parameters like strength properties, serviceability over a specified period of time

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(A.M. Neville, 2000). The cracking and deterioration of concrete due to spillage of petroleum products has been an area of interest in research. Spillage of petroleum products adversely affects marine life and environment (S.P.Ejeh, et al, 2009). Though concrete storage tanks have been used for more than 80 years, even then, there is lack of knowledge regarding the impact of petroleum products on concrete. Concrete tanks are used to store petroleum products and this is a century old technique. The usage of concrete in this context has led to many economic benefits and has paved way to enhance further study into the use of concrete on a comparatively larger scale (A.M. Matti, 1976). It is highly essential that every concrete structure should carry out its intended functions such as strength and serviceability during its specified service life. It follows that concrete must be able to withstand the processes of deterioration to which it can be expected to get exposed. Such concrete is said to be durable. Compressive strength analysis is vital in determining whether the concrete mixture meets the requirements of the specified strength (CIP 35-Testing Compressive Strength of Concrete, NRMCA.). In automobile service stations petroleum products regularly comes in contact with the surface flooring, water gets contaminated with petroleum products, which percolates through ground and thus contaminates underground water. Because of spillage of petroleum products the surface may crack, it creates water pollution, it may affect marine animals. These are all few adverse effects which may lead to deterioration of concrete. Hence the present study proposes techniques to provide proper designed concrete which can resolve these adverse effects and also minimizes the losses. To improve the strength properties the pozzolanic materials like Fly ash and silica fumes are used. Fly ash and silica fumes are cheaply available hazardous wastes from thermal stations and silica industries which improves the workability of concrete and also reduces the hydration reaction at early stages. These pozzolans when added enable the concrete to react with $Ca(OH)_2$ to form additional calcium silicate hydrate which increases the density , fill the pores properly, refine the pore structure and the permeability which leads to the better durability (Folagbade et al.,2012). Fly ash concrete and silica fume concrete shows comparatively poor characteristics at premature ages, but its pozzolanic reaction improves with curing age and it also provides good resistance in aggressive media in concrete (T.R Naik et al,1998; R.Dhir et al,1999; S..K,Antiohos et al, 2003; K.Hassan et al,2000; LamL et al, 1998). Fly ash has become one of the primary constituents in blended cements because of its availability, its low cost, fineness and quality control. Fly ash, silica fumes are cheaply available, low in cost and hence can be used in concrete which improves the strength properties and can be treated as good pozzolans (T.R. Naik et al,1998; Taywood Engineering Ltd, 1993; M. Ahmaruzzaman, 2010; Ahmad Shamshad et al, 2012). The improvements in combustion technology, usage of gas fired boilers will lead to increased generation and availability of fly ash for future requirements in concrete industry. Fly ash and silica fumes act as best packing material hence reduces porosity and permeability (Taywood Engineering Ltd., 1993.Wikipedia free Encyclopedia;,A.Sinha et al (2012) ;C.Hall,1981; Kwangryul Hwang et al ,2004). It is convenient to use fly ash pozzolanic mineral admixture to replace a large quantity of cement in concrete. It not only enhances the quality of concrete but it also helps in preservation of many resources as well as it is eco-friendly. Cement shows high compressive strength without fly ash in the early stages. But though initially the fly ash mixed concrete shows lower compressive strength values, but it increases with time later (Rafat Siddique, 2003). Various percentages of fly ash have varying effect on the nature of concrete. 30% of cement can be replaced by fly ash as it bestows optimum results (Marta Kosior Kazberuk et al , 2007). Similarly various admixtures in concrete play a vital role in affecting its compressive strength (Jen Chei Liu et al, 2009; Jean Michel Mechling et al, 2009). So this study has used fly ash and silica fumes in this regard, (Kwangryul Hwanga et al,2004) and has developed a mathematical equation to predict the compressive strengths of concrete with time. This study has also led to the generation of equation through regression analysis which satisfactorily gives us the compressive strengths over period of time. Statistical models can easily be employed to accomplish this (Cláudius S. Barbosa; Samia Hannachi et al, 2012; CIP 35-Testing Compressive Strength of Concrete, NRMCA; A.N. Beal; Mahmoud Sayed-Ahmed 2012; S. Silvestri1 et al ,2008; Jen-Chei Liu et al, 2009)

The environmental impacts associated with operations and marketing of petroleum products in Nigeria have become significant in recent times. This might be due to the increasing awareness among the people, the dangers of continued environmental degradation caused by spills of crude oil and its refined products. Pollution from spent engine oil is one of the environmental problems in Nigeria and is more widespread than crude oil pollution (Odjegba and Sadiq 2002). The effects of discharged engine oil on the environment are poorly understood as only limited data exists and these are not readily available. Spills occur at all stages of production, transportation and handling of the product. This could be as a result of pipeline rupture, accidents and dumping of waste engine oil (Oyibo and Agboola, 1983). The local consumption of engine oil in Nigeria is increasing at a very high rate in recent times due to the upsurge in the number of vehicles and other machines that makes use of this lubricant. This directly affects the rate at which the spent lubricant enters and pollutes the environment. Disposal of the spent lubricant into gutters, water drains and vacant plots is a common practice among various automobile mechanics. The existing mode of indiscriminate disposal of this waste oil increases pollution incidents in the environment. Odjegba and Idowu (2002) reported that germination of Amaranthus hybridus seeds was significantly affected in spent engine oil-polluted soil. During the growth of the seedlings, chlorophyll and protein contents were seriously affected (Odjegba and Sadiq ,2002).

Objectives

- To study the deterioration of concrete when it comes in contact with petroleum products as well as the mechanical behaviour of petroleum products soaked concrete.
- To study the chemical characteristics of petroleum products soaked concrete by XRD and SEM analysis.
- The main purpose of this study is to study the effect of solid wastes on characteristic behaviour of petroleum products soaked concrete.
- To study the durability of mixed petroleum products soaked concrete.

Literature Review

Few related papers are reviewed here and how this study is differing from the others is reported. The effect of petroleum products on concrete and its impact on natural environment and its degradation, including marine life, has remained a green area in literature. Research has shown that concrete deterioration and cracking in marine environment is more severe than in any other terrestrial environment. Hence this has elicited more investigations on the causes of concrete deterioration in similar environment.

The effect of oil soaking on the dynamic modulus of elasticity of concrete was investigated to study deterioration rate due to concrete contact with crude oil (M.A.Matti ,1983). Over a period of 3 years, this parameter was analysed for concrete specimens at various stages. He has conducted experiments where concrete specimens were soaked in crude oil and few specimens were continuously kept in water and others in a controlled environment of constant temperature 16 + 0.5°C and relative humidity of 60 + 2%. By this study it has been found that the dynamic modulus of concrete increased by 8-10% due to oil soaking, while water saturated specimens showed an increase of 10-15%. He has also studied the shrinkage of oil soaked concrete. He has found that the volume of concrete decreases when it comes in contact with crude oil (M.A Matti, 1982).

The properties of Grease-Soaked Concrete in Containment Building were studied and also its physical and chemical properties of grease soaked concrete were determined under temperature and pressure conditions. (Young-Seung Ham et al, 1999). His studies revealed that the tensile strength, compressive strength, and static elastic modulus tend to increase when immersed in grease for a deterministic period of 180 days. This paved the direct proportionality of fluidity and grease penetration with respect to temperature.

(Ramzi B.Abdul et al, 2000) analysed the compressive and tensile strength of concrete loaded and soaked in crude oil. Based on short and long term loading, the effect of crude oil on compressive, splitting tensile and flexural tensile strength of concrete was investigated. He found that the rate of crude oil absorption is high at early stage of soaking, but later on, the rate decreases. This shows the reduction in the absorption by 30 to 40 % strength in specimens under loading versus unloaded specimens.

(F. I. Faiyadh, 1985), investigated the bond characteristics of oil saturated concrete. The average bond strength of oil soaked specimens decreased with the soaking period. This reduction was between 15.5 and 21% for the mild round steel bar and 8.5 and 9.5% for the deformed bar after a soaking period of 750 days compared to that of 120 days oil soaked bond strength. The bond strength of oil saturated concrete is compared to those cured in water or sealed dry as control specimens. Concentric cylindrical pull-out specimens reinforced with one central bar were tested after different oil soaking periods. A modified pull-out test was also used to measure the bond stress distribution along a plain bar in concrete prisms saturated with crude oil.

(H. Abdul Razak, 1992) studied the attack of palm diesel on cement-based materials. He concluded that the mortar samples containing ordinary Portland cement (OPC) exhibited the highest degree of deterioration while the epoxy-coated and magnesium phosphate samples were least affected, and also the degree of deterioration was dependent on the curing regime. The principal cause of the deterioration was attributed to saponification by the free lime present in the set cement, forming calcium soap. He analysed that surface treatment with epoxy or other suitable materials chemically resistant to palm diesel may inhibit the deterioration on the concrete. Furthermore, by using a different kind of cement that contains a substantially smaller amount of calcium than OPC, the attack of the palm diesel may be reduced or prevented.

(Ahmad Jamrah et al, 2007) investigated the petroleum contaminated soil in Oman, by conducting bioremediation treatment and the method is used in hot asphalt mix concrete. He evaluated the leaching characteristics of petroleum contaminated soils as well as their application in hot mix asphalt concrete. The results of his study shows that the clean soils present in the vicinity of contaminated sites contain heavy metals in the following decreasing order: nickel (Ni), followed by chromium (Cr), zinc (Zn), copper (Cu), lead (Pb), and vanadium (V). Their current treatment practice employed for remediation of the contaminated soil reduces the concentrations of nickel and chromium, but increases the concentrations of all remaining heavy metals.

(Ejeh, S.P, et al,2009) studied the Effect of Crude Oil Spill on Compressive Strength of Concrete Materials. He reported that the effect of crude oil spillage on the strength properties of concrete made with ordinary Portland cement (OPC) used in construction in Nigeria showed that the ordinary Portland cement concrete is susceptible to different aggressiveness of the solutions of crude oil concentrations as they led to low rates of strength development of concrete specimens. It is also represented that the entire media including the control medium led to increase in strength of concrete specimens after two months of immersion but the rate of compressive strength development is low in the crude oil and crude oil/water mix.

(Nuruddin M.F.,et al, 2008) studied the effect of Used Engine Oil on MIHRA Concrete. This study is to overcome the disposal problem of used engine oil. These materials can cause damage to the environment if no proper disposal is implemented. In MIHRA concrete, the used engine oil acted as a best super plasticizer and performed better concrete than MIHRA concrete mix.

(Onabolu O.A,1989) Some Properties of Crude Oil Soaked concrete-I Exposure at Ambient Temperature, investigated that the variations in compressive strength, length change and absorption characteristics of typical offshore concrete exposed to crude oil for 365 days. This paper presents the mechanical properties of concrete cured in sea water and then exposed to the crude oil at ambient temperature of about 20^{o} C. He analysed the strength properties of oven dried concrete specimens as well as moisture saturated concrete. He concluded that oven dried concrete specimens absorbs crude oil and strength decreases where as moisture saturated concrete specimens absorbs very slowly and strength is more comparatively. Similarly in the same year, he studied Some Properties of Crude Oil Soaked concrete-II Exposure at Elevated Temperatures, in part-II the effect of exposure to crude oil at elevated temperatures of 45,60 and 80^{0} C, superimposed on the conditions of curing, has been studied and was found to affect the measured properties significantly. The results presented in part-I and part-II have shown that the mechanical properties of concrete exposed to hot crude oil were affected by such conditions as mode of curing, moisture condition at the time of exposure, and exposure temperature. Deterioration of concrete properties was more severe for oven dried specimens than for moisture saturated specimens. Exposure to elevated storage temperatures was highly significant, and exposure at 80^{0}C was critical, causes strength losses and severe changes.

Ground Water Contamination by Crude Oil near Bemidji, Minnesota. USGS (science for changing world). This article says that ground-water contamination by crude oil, and other petroleum-based liquids, is a widespread problem. An average of 83 crude-oil spills occurred per year during 1994-96 in the United States, each spilling about 50,000 barrels of crude oil (U.S. Office of Pipeline Safety, electronic commun., 1997). An understanding of the fate of organic contaminants (such as oil and gasoline) in the subsurface is needed to design innovative and cost-effective remedial solutions at contaminated sites. This article says that ground water gets contaminated with petroleum products. According to U.S.Geological survey, 10,700 barrels of crude oil was spilled due to the bursting of pipe line at Bemidji, Minnesota. Thus, it is evident that a variety of sources for oil spill and a variety of ways the oil could be spilled exist. A sudden oil spill involving large amounts of spillage (thousands or even millions of gallons - such as that from an oil tanker failure or due to accidents in offshore drilling) could have disastrous effects due to the high concentrations of released contaminants and the difficulty to remediate such big spills. At the same time, an oil spill involving small but continuous releases such as those from leaking pipelines or road runoffs may have little visible effect (they are naturally attenuated usually due to microbial degradation as well as due to many chemical-physical processes). But even small leaks can add up to big problems. A tank leaking one drop every 10 seconds could release 60 gallons per year.

Industry and transport activities, are the source of aggressive media threatening the service life of concrete structures. Among them, the aggressive organic compounds are occurring in the growing extent. Concrete structures may exposed to the action of the media containing some organic compounds which may be dangerous causing their deterioration.(Vladimı´r Zˇ ivica,2006)

Conclusions and discussions

It is evident from the above reviewed papers that studies have focussed more on elastic behaviour of normal concrete rather than mechanical and chemical like modulus of elasticity, dynamic modulus, bond characteristics, shrinking effects, curing days, temperature and pressure effects. The proposed study puts light on usage of solid waste materials in concrete for achieving good mechanical and chemical properties. To obtain clear picture about the structural, morphological and chemical characteristics of pozzolan mixed petroleum products soaked concrete, complex and reliable tests like Scanning Electron Microscope (SEM) and X-Ray Diffraction (XRD) were carried out which prove to be a convenient approach in this regard. To gain a deeper sense of petroleum-concrete relationship effect, more research is highly inevitable which can efficiently determine the degree of deterioration, amount of soroptivity and in turn the resulting strength properties of concrete.

Acknowledgements

The authors gratefully acknowledge the support and facility provided by Shivaji University, Kolhapur, Maharashtra and Civil Engineering Department, KLE Society's college of Engineering and Technology, Belgaum, Karnataka.

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