COMBATING SULPHATE ATTACK WITH WASTE MATERIALS

ATA Olugbenga Ph.D, MNIOB, R.Bldr.

Department of Building, Obafemi Awolowo University, Ile-Ife

Abstract

The menace posed by waste to our built environment and the soaring cost of conventional building materials call for development of alternative cheaper ones from available local materials without prejudice to performance. Of particular interest are agricultural waste that constitute an embarrassing nuisance to our built environment. This paper explores the possibility of mitigating the effect of sulphate attack on concrete with the use of sawdust ash (SDA) as a supplement to Portland cement.

The performance of saw dust ash blended ordinary Portland cement (OPC) concrete in sulphate environment was investigated. 100mm cubes of 1:2:4 mix proportion and 0.75 water/cement ratio were cast. The concrete specimen were exposed to magnesium sulphate solution of 3 and 5% concentrations for 7, 14, 28 and 56days. The compressive strength of the cubes were measured at the end of the exposure periods. The results indicate that the compressive strength of the sawdust ash blended OPC concrete decreased with increasing SDA content and increased with increasing curing age in water. The compressive strength of concrete decreased with increasing $MgSO_4$ concentration, except at 56-day where it was noticed that at 3% $MgSO_4$ concentration, SDA concrete experienced a slight increase in strength. The study concluded that the pozzolanic activity of sawdust ash enhanced the resistance of concrete to sulphate attack at exposure period of not earlier than 56days and that incorporating concrete with waste material like SDA would not only promote the recycling of waste but also provide high sulphate attack resistance.

Keywords: *Sawdust ash, Compressive strength, Sulphate, Concrete*

Introduction

The soaring cost of conventional building materials in general and those used for concrete works in particular calls for development of alternative cheaper ones from available local materials without prejudice to performance. The world needs environmentally friendly construction materials because of the desire to reduce carbon-dioxide emissions, save non-renewable energy resources, provide aesthetically pleasing and healthy surroundings and at the same time minimize waste. Of particular interest are agricultural wastes that constitute an embarrassing nuisance to the built environment. The exploitation of these wastes as sustainable materials will ease pressure on the non-renewable natural resources, reduce the material cost, provide means of waste disposal and thus provide affordable housing.

Concrete, known for its versatility and adaptability is the most widely used construction material. Concrete is a very loyal and dependable construction material. For a long time, concrete was considered to be very durable material requiring a little or no maintenance. The assumption is largely true, except when it is subjected to highly aggressive environments. We build concrete structures in highly polluted urban and industrial areas, aggressive marine environments, harmful sub-soil water in coastal area and many other hostile conditions where other materials of construction are found to be non-durable. Since the use of concrete in recent years, have spread to highly harsh and hostile conditions, the earlier impression that concrete is a very durable material is being threatened, particularly on account of premature failures of number of structures in the recent past. Durability is the ability to last for a long time without significant deterioration. A durable material helps the environment by conserving resources and reducing wastes and the environmental impacts of repair and replacement. Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. It is essential that every concrete structure should continue to perform its intended functions, that is maintain its required strength and serviceability, during the specified or traditionally expected service life. It follows that concrete must be able to withstand the processes of deterioration to which it can be expected to be exposed. Such concrete is said to be durable. Different concretes require different degrees of durability depending on the exposure environment and properties desired; for example, concrete exposed to tidal seawater will have different requirements than an indoor concrete floor. External sulphate attack on cement based materials has been a key durability issue and a subject of extensive investigation for many decades [1] because concrete deterioration due to sulphate attack is the second major durability problem of concrete, after reinforcement corrosion.

Sulphate attack

Sulphate attack is a generic name for a set of complex and overlapping chemical and physical processes caused by reactions of numerous cement components with sulphates originating from external or internal sources [1]. There is some confusion in the literature and the technical community regarding the definition of sulphate attack. For some, sulphate attack is a physical process while others see it as a chemical process. In any case; it can simply be defined as deleterious action involving sulphate ions and the components of hardened concrete, principally the cement paste, caused by exposure of concrete to sulphates and moisture. In other word, an action that does not result in deterioration or in a loss of durability is not an attack [2].

Deterioration of concrete due to sulphate attack, according to [3], manifests itself in three forms. The first mode of deterioration is akin to eating away of the hydrated cement paste and progressively reducing it to cohesionless granular mass leaving the aggregates exposed. This type of deterioration may lead to reduction in the cross-sectional area of the structural component (i.e. loss in weight of concrete) and decrease in strength. This mode of failure is attributed mainly to the formation of gypsum, and is known as the acidic type of sulphate attack. The second mode of deterioration, which is normally characterized by expansion and cracking, takes place when the reactive hydrated aluminated phases, present insufficient quantities, are attacked by sulphate ions, thereby forming tricalcium-sulfo-aluminate hydrate, also called ettringite or Candlot's salt. This expansive type of reaction is ascribable to the formation of a colloidal form of ettringite in high pH media. The third mode of sulphate attack is the onion-peeling type that is characterized by scaling or shelling of the surface in successive layers in the form of delamination. This mode of concrete deterioration due to sulphate attack is the least reported in the literature and was observed in the plane and fly ash-blended cement paste cement specimens exposed to mixed sulphate environments.

Different types of sulphate resisting cements are being used to mitigate the effect of sulphate attack on concrete e.g. types II and V cement. But these cements are too expensive for the common man and thus not popular in use in Nigeria. Any attempt in the direction of looking alternatives to these conventional will be a welcome development.

Attempts have been made to produce and use pozzolanic agricultural by-product and industrial waste pozzolans such as fly ash (FA) and silica fume (SF), sawdust ash (SDA), rice husk ash (RHA) to improve the quality of concrete [4-7]. Sawdust ash as a pozzolanic material for producing concrete either in binary combination with ordinary Portland cement or in ternary combination with one other industrial byproduct pozzolan such as rice husk ash increases the strength of concrete.

In attempts to protect concrete in aggressive environments, efforts have been made in sourcing for local materials that could be used as partial replacement or supplement to ordinary Portland cement (OPC) in civil engineering and building works [8-10]. Calcium silicate hydrates (C-S-H) and

Calcium hydroxide [$Ca(OH)_2$] are the hydration products of OPC. The strength of concrete depends on the amount of gel (the C-S-H which is the essential cementing compound) in the cement paste. The amount of gel produced at any given time also depends on the type of cement because different cements require a different length of time to produce the same quantity of gel. When blended with Portland cement, a pozzolanic material reacts with the $Ca(OH)_2$ to produce additional calcium-silicate-hydrate (C-S-H), which is the main cementing component. Thus, the pozzolanic material serves to reduce the quantity of the deleterious $Ca(OH)_2$ and increases the quantity of the beneficial C-S-H. Therefore, the cementing quality is enhanced if a good pozzolanic material is blended in suitable quantity with OPC.
Sawdust ash as a pozzolanic material for producing concrete either in binary combination with ordinary Portland cement or in ternary combination with one other industrial byproduct pozzolan such as rice husk ash increases the strength of concrete [10].

Sawdust ash is a solid residue of the combustion of sawdust or wood in air and is composed of carbonates and oxides of metals, e.g. calcium and potassium, originally compounded in the plant's woody tissues that are present in the residue. The major elements in sawdust ash are calcium, potassium and magnesium all in various proportions while sulphur, phosphorus and manganese are present at around 1% and iron, aluminium, copper, zinc, sodium, silicon and boron are present in relatively smaller amounts. The chemical compositions of sawdust ash are mainly carbonates and oxides of the alkali metals, namely $CaCO_3$, $K_2Ca(CO_3)_2$, $Ca(OH)_2$, MgO, $Ca_4Mn_3O_{10}$, K_2S0_4, SiO_2, Al_20_3, Fe_2O_3, CaO, TiO_2, K_2O, SO_3, organic matter (loss on ignition LOI=27%), moisture and available alkali, all with significant variations. The specific gravity is often between 1.6 and 2.8 and bulk density between 365 and 980 kgm^{-3}[6]. Because of its being usually rich in calcium carbonate, which are a good binding agent and its other chemical components, sawdust ash acts as a pozzolana with good stabilizing properties to improve the properties of cement composites.

In developing countries like Nigeria, proper utilization of agricultural waste has not been given due attention. The sawdust still constitutes an environmental nuisance as it forms refuse heaps in the areas where they are disposed. The present study is an effort in the direction of providing a cheaper alternative to conventional sulphate-resisting cement using local material hitherto wrongly seen as a waste.

Materials

Sharp sand, washed granite, saw dust and ordinary Portland cement were the major materials that were used in this research work. All the materials were sourced from within Ile-Ife in Ife Central Local Government Area of Osun State, Nigeria. The cement was manufactured by West Africa Portland Cement at Sagamu and conformed to the requirements of [1]. The granite used as coarse aggregate had a uniform size not exceeding 19mm while the sharp fine aggregate was of maximum size of 5mm. The saw dust was burnt in open air and sieved with a 212µm in order to have a fine uniform grain distribution. Preliminary tests were done to ensure compliance with the established standards.

Specimens

The test specimen was 100mm cube meeting the requirements of [12]-1, [12]-3 and [13]-2. The wooden modes were fabricated in compliance with [13]-1 specifications.

Exposure and testing

The control specimens were cured in accordance with [13]-2. The curing method that was adopted in this research was wholly water-submerged as it has been adjudged to be the best method for concrete [14]. The main specimens were in a similar manner exposed to 3% and 5% solutions of magnesium sulphate up to a period of 56days. The compressive strength test was carried out by using ELE 2000kN compression testing machine conforming to [13]-4&6 in accordance with [13]-3.

Results

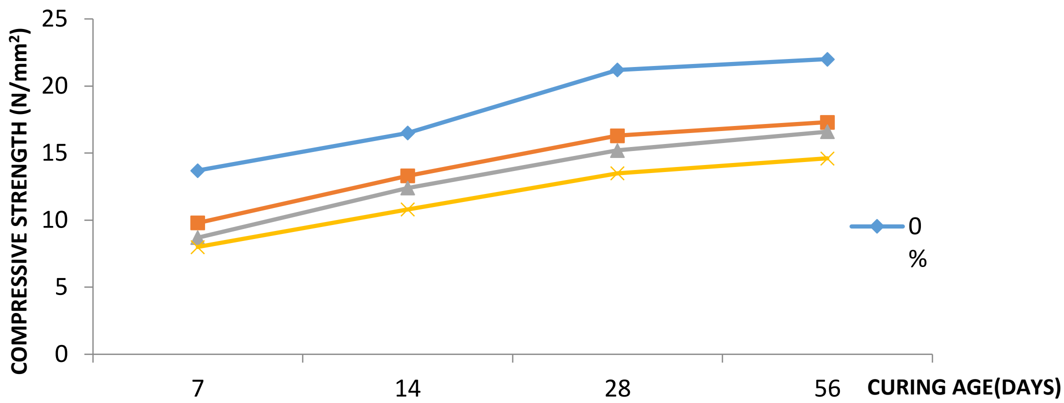

Figure 1: Variation of compressive strength of normal concrete with curing ages in water at various percentage replacement of SDA

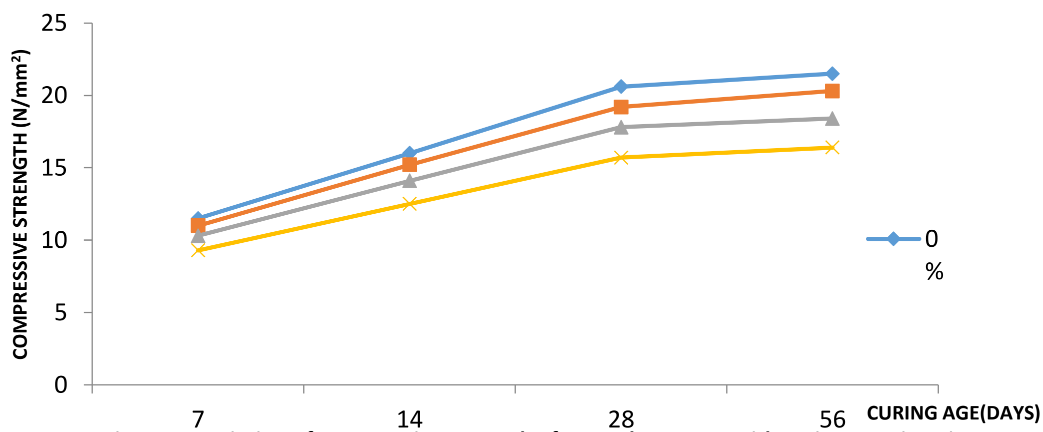

Figure 2: Variation of compressive strength of normal concrete with curing ages in 3% $MgSO_4$ at various percentage replacement of SDA

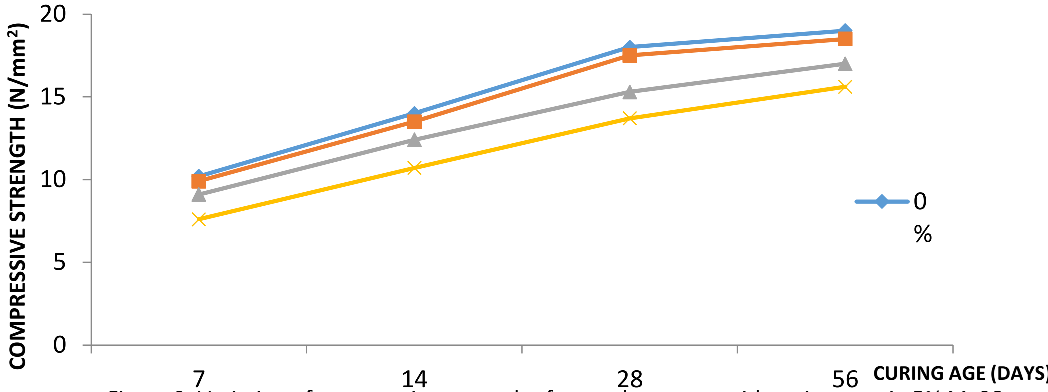

Figure 3: Variation of compressive strength of normal concrete with curing ages in 5% $MgSO_4$ at various percentage replacement of SDA

Conclusions

- SDA decreased the early strength of concrete
- Compressive strength decreased as the percentage replacement of cement with SDA increased.
- Compressive strength of SDA concrete increased as its curing age increased.
- The use of SDA improved the resistance of concrete to sulphate attack

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