International Research Journal of Engineering Science, Technology and Innovation (IRJESTI)
(ISSN2315-5663) Vol. 4(1) pp. 19-24, January 2015
DOI: http:/dx.doi.org/10.14303/irjesti.2014.083
Available online http://www.interesjournals.org/IRJESTI

Full Length Research Paper

Relevance of high performance concrete applications in modern civil engineering construction

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Abstract

Advances and new discoveries are on daily increase in the field of Engineering and Technology. These new discoveries are usually as a result of challenges facing the profession of Engineering and technology. The discoveries in the area of research, design and construction are the outcome of the complex and sophisticated erection of civil Engineering structural facilities we see in many parts of the world today. Among the latest art of Engineering and Technological advancement and discoveries is this "high performance concrete" this paper examines that a new term as high performance is used for concrete mixtures which possesses high workability, high strength, high modulus of elasticity, high density, high dimensional stability, low permeability, resistance to chemical attacks, and high degree of applications in modern Civil Engineering construction.

Key words: High performance concrete, production, admixtures, applications

INTRODUCTION

Modern Civil Engineering construction tends to progress towards more economic, design and construction of structures though, gradually improved methods of design and the use of higher strength materials. This has resulted in a reduction of cross sectional dimensions and consequent weight savings. Such developments are particularly important in the field of reinforced concrete, where the dead load represents a substantial part of the total design load. The application of high performance concrete has overcome the limiting features of ordinary reinforced concrete for the design and construction of civil Engineering structures. High performance concrete (H P C) is the latest catch phrase in concrete technology. It has replaced the high strength concrete of the past. It is defined as concrete that meets the requirements or goes beyond the normal performance range. High strength concrete having more than 60 M P A comprehensive strength with improved properties is generally known as high performance concrete.

High performance concrete means concrete with a high strength with a low permeability. The two properties are not necessarily linked to one another because high strength requires a low volume of pores. The only way to have a low volume of pores is for the mix to contain particles graded down to the finest size; this is usually achieved by the use of silica fume which fills the space between the cement particles and between the aggregates and the

cement particles. The mix must be sufficiently workable for the solids to be dispersed in such a manner that dense packing is achieved, which also requires deflocculation of cement particles. The defloccution of cement particles is also achieved by the use of super plasticizer at a large dosage .The super plasticer must be effective with given Portland cement, which means that the two materials must be compatible when these two conditions are satisfied, high performance concrete is achieved.

An overview on high performance concrete

A high performance concrete is a performance enhanced concrete, which is a specialized sense of concrete that is designed to provide several benefits in the construction of concrete structures, that cannot always to be achieved usually by using conventional ingredients, normal mixing and curing practices. A high performance is a concrete in which certain characteristic is developed for a particular application and environment, so that it will 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 will be subjected during its design life.

A high performance concrete substantially improved resistance to environmental influences (durability in service) or substantially increased structural capacity while maintaining adequate durability, it also include concrete which significantly reduces construction time without compromising long-term Serviceability. In the recent past, interest in the development and production of high performance concrete has increased due to the enhanced properties viz, higher compressive strength, improved modulus of elasticity, increased bond and fatigue strengths, lower permeability and better durability. These qualities make it a very competitive material. Higher compressive strength and increased value of modulus of elasticity of high performance concrete makes it very suitable material for use in the high compression element of a structure, such as lower level column and core walls of high rise buildings, which has certain advantages like the reduction in dead weight, and reduced size of the columns, which gives more usable space.

METHODOLOGY

The adopted methodology for this paper was a visit and critical analysis of most concrete structures that were built in major cities (e.g Abuja, Lagos, Ibadan, Port-Harcourt of Nigeria) A visit to these cities in Nigeria proved that structures like high rise buildings (commercial, Industrial, Residential, Institutions etc) and Bridges which would have been built with High performance concrete were simply built with ordinary Reinforced concrete. This is one indication why most of these structures failed to reach their designed and service life time. In addition, the modern Technology knowledge that is available every where now was a figure, not a reality when those structures were equally built with ordinary concrete. The availability of materials for High performance concrete then was equally not widely spread and known as it is today with advanced Technology in place.

DISCUSSION

A performance enhanced concrete or also known as High Performance Concrete (H P C) is a specialized series of concrete usually designed to provide several benefits in the construction of many concrete structures that cannot be achieved normally by using conventional ingredients, normal mixing and caring practices M. L Gambler (2005) defined high performance concrete in which certain characteristics are developed for a particular applications and environment, so that it will 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. It includes concrete that provides either substantially increased structural capacity while maintaining adequate durability.

The characteristics that may be considered in critical sense with the application requiring performance enhancement of high performance Concrete is as follows;-

(i) Ease of placement and compaction without segregation
(ii) Early age strength
(iii) Long-term mechanical properties
(iv) Permeability
(v) Density
(vi) Heat of hydration
(vii) Toughness
(viii) Volume
(ix) Long life in severe environment (i.e durability

The concrete possessing many of the characteristics above usually achieved higher strength High performance concrete is therefore of High strength concrete may not necessarily be of high performance. With the practical application of this type of concrete, the emphasis is usually shifted from the comprehensive strength to other properties, such as high modulus of elasticity, high density, low

permeability, and high resistance to some forms of attacks.

Attributes of high performance concrete over high strength concrete

A controversy between the terms high strength and high performance concrete was given consideration based on research carried out by professionals in concrete technology, High performance concrete is also a high strength concrete, but it has a few more attributes specifically designed with, it is logical to describe by the more widely embracing term as “high performance concrete”. The ingredient as contained in both types of concrete are the same, namely Portland cement, aggregates, water and admixture. High performance concrete contains a high range water reducer (super-plasticizer) and mineral admixture while high strength concrete does so only sometimes; the known how necessary to produce high performance concrete consists of specific knowledge of the properties of the ingredients and of their interaction.

Classification of high performance concrete

A suitable classification of high performance concrete according to different levels of performance requirements would usually enable design engineers to select appropriate performance criteria of high performance concrete for different application in different Environmental condition.
Valid classifications are stated below
High performance concrete is further divided in to two sub-classes according to whether or not they contain ultra fine minerals additives. They need high strength or high grade Portland cement with its content in the range of 400 to 450kg/m3
(i) Very high performance concrete: - this is obtained by providing a further reduced water cementitious radio between 0.20 and 0.35 with high dosages of Admixtures. The uses of aggregates with a maximum nominal size of 10 to 12mm are usually used.
(ii) Exceptional concrete :- this is laboratory concrete with characteristics strength as high as 250 mpa, and with water binder ratio of the order of 0.16

Production of high performance concrete

The production of high performance concrete usually calls for some changes in the conventional processing technology. The selection of the materials is a problem because cements and aggregates are suitable with widely varying composition and properties, without no clear cut guidelines as to the cement and aggregates types most suitable for high performance concrete .A number of chemicals and minerals admixtures must be used simultaneously, and there are no simple rules by which a judicious choice can be made.
(i) **Cement**: the first choice to be made when making high performance concrete is definitely that of cement, even when one or two supplementary cementitious materials will be used, because the performance of the cement in terms of Rheology and strength becomes a crucial issue as the targeted comprehensive strength increases. The standard strength performance of a given Portland cement measured using the mortar cubes does not always correlate well with the actual strength that can be reached when the cement is used at a very low water cement ratio.

The physical and chemical characteristics of cement play a vital role in developing strength and controlling Rheology of fresh concrete. The cement for high performance concrete should contain a little Tricalcium Aluminate [C_3A] as possible, because the lower the amount of (C_3A) the easier the control of Rheology and lesser the problems of cement super plasticizer compatibility. The cement should contain the right amount of sulphur Trioxide $[SO]_3$ in order to control rapidly an efficiently the formation of eccentricity. Finally, from strength point of view, the cement should be finely grounded and contain a fair amount of Tricalcium Silicate [C_3S], but not too much from the logical point of view.
(ii) **Coarse Aggregates:** The strength of normal concrete is dependent almost on the strength of the binder and the interfacial bond between the binder and the aggregate. Therefore the use of stronger aggregate does not improve the strength of the normal concrete. For the use of coarse aggregates, particles obtained by crushing a dense limestone rock or a plutonic type igneous rock (such as granite, synite, diorite and diabase) are usually satisfactory. Available data shows that larger than 25mm maximum size of the aggregates generally impairs the strength and impermeability of concrete. Therefore, 10-20mm Maximum size aggregate is usually considered optimum for high performance concrete.
(iii) Fine aggregate (sand) :- River sand and crushed stone can be used for the production of high performance concrete. Coarser finer sand increases the water demand of concrete and very fine may not be essential. The sand particles should also be pack to give minimum void ration, as the result show that higher void content leads to requirement of more mixing water.

The properties such as void ratio, gradation, specific surface and bulk density should be assessed

Table 1: Valid classifications of High Performance Concrete

Classifications	28-day comprehensive strength
i) ordinary hormal concrete(H C)	10 to 20 mpa
ii) standard honmal concrete (H C)	25 to 55 mpa
iii) high performance concrete(H P C	60 to 100 mpa
iv) very high performance concrete (VHPC)	100 to 150 mpa
v) Exceptional concrete (E C)	EC>150 mpa

in order to design dense high performance concrete mix with optimum cement content and reduced mixing water

Admixtures for high performance concrete

An admixture is a material other than cement, water and aggregates that is used as an ingredient of concrete and is added to the bath immediately before or during mixing. Admixture are also used to modify the properties of concrete so as to make it more suitable for any situation. It is difficult to predict the effect and the result of using admixtures because many a time the change in the brand of cement, aggregate grading, mix proportions and richness of mix sometimes usually alter the properties of concrete. Sometime many admixtures. Affect more, and the effect of more than one admixture is difficult to predict. Carefulness is the watch word in the selection of admixture, and in also predicting the concrete. The commonly used admixture for most Engineering construction are as follow:-

(1) **Plasticizer**: - these are also known as " water reducers". The action of plasticizers is mainly to fluidity the mix and improves the workability of concrete mortar grout. The basic products constituting plasticizers are:-

(a) Anionic surfactants; such as lignosulphonates and their modifications and derivatives salt of sulphonates hydrocarbons

(b) Nonionic surfactant; such as polyglycol esters acid of hydroxyl lated carboxylic acid and their modifications and derivatives

(2) **Super plasticixers**:- these are known as "high range water reducers" high range of super plasticizers in concrete is an important milestone in the advancement of concrete technology since their introduction in the early 1960. the use of super plasticizers permit the reduction of water to the extent up to 30 percent without reducing workability in contrast to the possible reduction up to 15 percent in the case of plasticizers

(3) **Retarders**: these are admixtures that usually slow down the chemical process of hydration of concrete, so that the concrete can remain plastic and workable for a longer time. Retarders are used to overcome the accelerating effect of high temperature on setting properties of concrete in hot weather concreting. Retarders are also used in casting and consolidating large number of pours without the formation of cold joint. The most commonly known retarders are calcium sulphates, lingo sulphonic acids and their salts, hydroxyl lated carboxylic acids and their salts. These can reduce the quantity of water requirement for a given workability. Sugar is one of the most effective world wide retarding agent used as an admixture for delaying the setting time of concrete without detrimental effect on the ultimate strength of concrete.

(4) **Accelerators**:- accelerating admixtures are usually added to concrete in order to increase the rate of early strength development in concrete and also for the following:-

(a) Permit earlier removal of form work.

(b) Reduce the required period of curing

(c) Advance the time that a structure can be placed in service

(d) Partially compensate for the retarding effect of low temperature during cold weather concrete in the emergency repair of work.

The commonly used material as an accelerator is calcium chloride. Other accelerators are mc- schnell oc, and mc- toricrecthife.

(5**) Air- Entraining Admixture:-** An entrained concrete is made by mixing a small quantity of air entraining agent or by using air entraining cement. The following types of air entraining agents are used for making air entrained concrete:-

(a) Natural wood resins

(b) animal and vegetable fats oil such as follow olive oils and their fatty acid, astearic and oleic acid.

(c) various wetting agents such as alkali salts or such alkali salts or sulphated and sulphonated organic compounds

(d) water soluble soaps of resin acids

(e) miscellaneous materials such as the sodium salts of petroleum Sulphonic acids, hydrogen peroxide and aluminmium power

The factors affecting the amount of air-entrainment in a mix is affected by many factors. The important ones are:

(a) The type and quantity of air entraining agent used.
(b) Water cement ratio of the mix
(c) Type and grading of aggregates
(d) Mixing time
(e) The temperature
(f) Type of cement
(g) Influence of compaction
(h) Admixture other than air-entraining agent used.
(6) Pozzolanic admixtures: Pozzolanic mineral are siliceous or aluminous materials which in themselves possesses little or no cementitious value, but will finally divide. Form, and in the presence of moisture chemically react with calcium hydroxide liberated on hydration at ordinary temperature to form compounds possessing cementitious properties. Examples of pozzolanic materials are:-
(a) Natural pozzolans:-
(i) clay and shales
(ii) opalinc cherts
(iii) diatomaceous earth
(iv) volcanic tuffs
(v) pumicites
(b) artificial pozzolans:
(i) fly ashes
(ii) silica fume
(iii) rise husic ash
(v) micro silica
(7) Gas forming agents:- Gas forming agents are chemical admixtures such as aluminum powder. They usually reacts with the hydroxide of produced in the hydration of cement to produce minute bobbies of hydrogen gas
(8) Bonding Admixtures:- bonding admixture are water emulsion of several organic materials that are mixed with cement or mortar grout for application to an old concrete surface just to the prior of patching with mortar or concrete.
The function of the bonding admixtures is to increase the bond strensth between the old and new concrete. The commonly used bonding admixtures are made from natural rubbers, synthetic rubber or from any organic polymers.

Construction practices of High performance concrete

The first and the foremost use of high performance concrete is in high rise buildings, where advantages like reduction in dead loads and reduced sizes of the columns which gives more rentable space can be employed. In the construction of high rise buildings, high performance concrete can be used to increase the usable area and to avoid segregation. The major reason for using the high strength concrete for high rise buildings are to reduce the dead loads, the vibration, the noise, and also the maintenance cost.

High performance concrete is being increasingly used for highway pavements due to the potential economic benefit that can be derived from the early strength gain of high performance concrete, its reduced permeability; increased wear of abrasion resistance to steel studded fires and improved freeze-thaw durability. While the conventional normal strength concrete continue to be used in most cases of pavement construction, different types of high performance concretes are being considered for pavement repairs for early opening to traffic; bridge deck overlays, and special application of rehabilitation of structures and other developments.

In many other applications, high performance concrete is required to meet certain specific performance requirements besides high strength. In prestressed concrete bridges, concrete should have not only high strength, but reduced shrinkage and creep. For bridges, off shore structures, high ways and airport pavement and machine foundations, concrete should posses high fatigue strength. For nuclear containers exposed to very high temperatures, concrete should have high resistance to thermal cracking.

CONCLUSION

The applications of high performance concrete is very relevant and timely for many African countries like Nigeria. At present, Nigeria is facing a lot of challenges in the areas of infrastructural development, self- sufficiency in food grain, health, education, industrial development, poverty alleviation, etc completion of infrastructural facilities is of utmost importance in order to meet other challenges facing the country. The country should continue to train and produced sound professionals for civil Engineering construction projects in order to enjoy the services provided in high performance concrete.
There is little doubt that the use of high performance concrete will continue to grow. No technical difficulties exist. However, such growth necessitates a provision for ready mixed concrete producers of concrete made under a very high control of quality of ingredients and of processing. At the same time, such Provision is conditional upon demand from the Engineers and other professionals. The value for money should also be assessed, not in terms of initiation cost alone, but also of enhanced durability of high performance concrete.

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