MODIFYING THE COMPRESSIVE STRENGTH OF CONCRETE BY USING LOCAL AVAILABLE CACTUS GUM AS ADDITIVE

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY SCHOOL OF CIVIL ENGINEERING AND ARCHITECTURE

A PROJECT IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE IN CONSTRUCTION MANAGEMENT TECHNOLOGY TEACHERS EDUCATION

Advisor: Lemma Beressa (Eng)

Jun, 2015

Adama, Ethiopia

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CANDIDATE DECLARATION

We here by declare that this project entitled “**Modifying the Compressive Strength of Concrete by Using Local Available CACTUS GUM As Additive”** is our original work. This project has not been presented for any other universities and is not concurrently submitted in candidature of any other degree and that all sources of material used for the project have been duly acknowledged.

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Abstract

In modern construction, to modify the properties of Portland cement based mortars and concretes, commercial additives were used. Besides the cost of those materials, what is especially important for the case of massive buildings, the environmental issues are generally of little concern in this area. In fact, a numberof organic materials are reported as additivesto improve properties such as plasticity, durability andstrength in adobe, mortars and concrete However,the available literature is very scarce on the scientific detailsof ancient technologies or the consequences of theirmodern application.

Less than 100 years ago Ethiopia, had a tradition of constructing seven story loam buildings and it was almost forgotten [1]. Accordingly, the aim of this study is to connect new construction methods with the use of the gum extracted from the prickly pearcactus in concrete usedin modern buildings and civil engineering, as a greenalternative for some of the additives used in a construction technology.

Studying the effect of this material is done by checking the laboratory test results of concrete mixes for the 7, 14 and 28 days age of compressive strengths with andwithout the addition of the cactus gum on their constituent materials .The procedure for concrete preparation will be carried out according to EBCS by using OPC cement. In order to address the objective of this study, analysis of test results will be carried out on the laboratory experiments. The results obtained will be summarized in table form and the decisions for the optimal results will be madeby observing the best results.

Keywords: Portland cement, commercial additives,prickly pear cactus, cactus gum, green alternative, compressive strengths,

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List of abbreviations

CG	Cactus gum
WSC	Water submerging curing
PC	Portland cement
EBCS	Ethiopia building codes standard
FA	fine aggregate
CA	course aggregate
ASTU	Adama science and technology universty
SOCEA	school of civil endineering and architecture

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, the construction industry is really interested in finding research about new materials that help maximizing the quality of construction processes. Portland cement, sand and aggregates are the materials of great importance for the construction processes. They are the basis for the production of concrete. For such reasons, we were studied to improve one ofthe properties (compressive strength) of concrete.Other than the basic materials, locally available natural products called cactus gum extracted from abundant plant cactus (local name of the plant is “beles” or “kulkual”) is used as an additive.Which could be easily and rapidly produced at low cost and in such a way could improve some properties of construction materials,

The Cement Concrete Terminology, ACI SP-19, defines an additive as a material other than water, aggregates, and cement that is used as a mortar or concrete compound and is added to the mixture immediately before or during mixing.

Document No.162 of Agricultural Services of the Food and Agriculture Organization (FAO) refers to the “Agro-industrial use of the nopal” (“beles”. Saenz (2006) declares that many industrial sectors can benefit from the use of nopal. Among these sectors are the nourishing and their associated industries, the construction industry, pharmaceutics, and cosmetics industries [2].

As we are from the construction industry, the availability of prickly pear cactus (nopal) in most of our country especiallyin Northern Ethiopia, it is believed to cover more than 300,000 hectares of land (SAERT, 1994) [5]. And being a renewable product and being easy to harvest in barren places, we initiated to study on this.

1.1. Statement of the problem

In Ethiopia there are several construction projects which use Portland cement for the production of concrete and mortars. These projects use commercial admixtures to modify the property of those construction materials. Most of the commercial admixtures (additives) are imported from abroad.

As a developing country, not using the on-hand available resource efficiently and effectively affects its development directly or it retards its development. Importing commercial additives from abroad will bring problem of hard currency and has a negative impact on the development of the country. In addition the environmental issues are generally of little concern in this area. This is due to scarce application of new methods, technologies and studies on using our available resources. By applying deep studies and checking the importance of these locally available natural resources not only satisfying the local market but also can produce for the global market. And as a result can increase the amount of our foreign currency.

Therefore, this study tries to solve the problem by checking the use of locally available cactus gum for modifying the property of concrete which possibly increases the compressive strength.

1.2. Objective of the Study

This study has the following general and specific objectives

1.2.1. General Objective

The objective of this study is to know the effect of the local available material called cactus gum on the property of concrete (compressive strength).

1.2.2. Specific Objectives

The specific objectives of this study are:

- To improve the quality of construction materials by modifying the property of ingredients
- To increase the use of on-hand available resources
- To show the opportunity of using this abundant material for other researchers on this area
- To create job opportunity for those who have the capacity to process this in the industry and produce import substituted materials

1.3. Research Methodology

The study will be carried out with a standard procedure of sampling the ingredients of concrete, mixing & casting test cubes, curing & testing the cubes and comparing & contrasting of the test results obtained from nominal cubes and cubes with cactus gum additives.

1.3.1. Procedures of detail activities:

A. The procedures of concrete with cactus gum prepared by soaking method

1. Sampling of concrete ingredients will be sampled and collected including cactus cladode (leaves) from their sources
2. After collecting the cactus cladode will be cleaned, cut in to small pieces and left soak with water for five days in a plastic barrel
3. Twelve test specimens (cubes) of C-25 concrete will be produce. Three cubes as a control with the usual ingredients &mix ratio of C-25, and nine cubes with mix ratio of C-25 but by adding varying proportions of cactus gum.
4. The gum will be Separated and filtered after five days with a set of sieves
5. The test cubes will be cured for 7, 14 and 28 days compressive strength test. Compressive strength test will be conducted for both age with the standard procedure and equipment.

6. The test results of both ages, for all types of samples will be summarized for further observation, analyses and synthesis.
7. Studying the effect of cactus gum on concrete properties based on the test results will be done.
8. Studying the effect of different proportion of the cactus gum added on in the mix based on the test results.
9. Discussion, finding, recommendation and conclusion and future works will be given based on the data analyzed.

B. The procedures of concrete with cactus gum prepared by boiling method

1. Sampling the ingridents the same as A.
2. Clean and cut in to small pieces of cladode, add water and boil with the appropriate container
3. Let to cool and filter &separate the gum with narrow cloths. The gum will be put in a refrigerator till used.
4. Four cubes,one for the control and the other three with different amount of gum will be produced fo the age of 7,14 and 28 days
5. Studying the effect of the gum on the concrete properties will be done
6. Studing the effect of different proportion of the gum based on the results
7. Discussion, finding, recommendation and conclusion and future works will be given based on the data analyzed.

1.4. Scope of the study

As stated above in the literature review, the plant cactus is used for different applications in different fields, but our scope of the study is limited on the uses of this cactus gum to modify the property of concrete, i.e. the compressive strength.

1.5. Significance of the study

This study is helpful in solving the problem of importing additives from outside of the country and announces the use of this on –hand resource to those of local industries and small scale enterprises. Can Push those to think more and more and produce in a modern technological way .As a result creates job opportunities and can produce import substituted product

In addition, this study paper can be used as a reference for other researchers who want to work on the area of cactus related products to be used in the construction industry.

1.6. Organization of the study

This study contains four chapters. Chapter one covers the introduction of the study, statement of the problem, objective, methodology and scope of the study. Chapter two contains literature review, chapter three covers the data collection, data analysis and presentation, and chapter four covers the conclusion and recommendation part of the study.

CHAPTER TWO

RELATED LITERATURE REVIEW

2.1. Introduction

Mortars for use in historical buildings or monuments are usually derived from slaked lime putty, alkalis, copper salt, and sand, and incorporate pozzolanic and particulate materials. These mortars have a high mechanical resistance, increased water proof protection, and antifungal properties (Gomez del Campillo and Dorrego, 1995).

Interest in the development of different such formulations of lime mortars are growing, especially in Europe. Lime mortars in Mexican historical buildings commonly incorporate cactus juice extracted directly from the cooked pads of Opuntia spp., a centuries old practice. The nopal juice is added as an organic adhesive that prevents the mortar from drying too quickly and helps retain the necessary moisture that the mixture needs to set correctly, transporting CO_2 from the atmosphere that combines with the slaked lime to form an artificial limestone.

Cactus mucilage polysaccharide in the presence of $Ca(OH)_2$ could suffer structural modification, resulting in the ability of the polymer to form a gel network, hence promoting a better binding of stucco solid microstructure. The mechanical properties (strength and toughness) of dried mixtures of lime mortar with cactus mucilage should reflect these phenomena.[3]

Apart from traditional uses for cactus cladodes (e.g. foods or food additives), there is potential for a number of other novel uses. For example, in the construction industry they can be used as adhesives, for corrosion prevention and as an additive for paints and adobe. In agriculture, they can be used for soil improvement.

In a study by Hernández and Serrano (2003) on the addition of lyophilized cladode juice to mortars traditionally used in local construction, adding 0.5 g of lyophilized mucilage was found to improve the mixture’s characteristics, with better compression resistance than the control mixtures to which no mucilage had been added. The mixture of plaster, silicate sand and lyophilized cladode mucilage showed compression strength of 151.8 kg cm^{-2} in 28 days, compared with 125.6 kg cm^{-2} for the control.

Vigueras (personal communication) 6 confirmed that there was no industrial production and/or processing of cactus pear in Ethiopia. [4]

2.2. Concrete

Concrete is a versatile material with many uses. Good concrete, which achieves its specified properties, depends first of all on the careful selection and proportioning of its constituent materials, and on effective methods for handling, placing,compacting, finishing and curing.The properties of concrete, in its plastic and hardened states, are affected by the physical characteristics, the chemical composition, and the proportions of the ingredients in the mixture.In its basic form, it is a mixture of cement, water, fine andcoarse aggregates, which is plastic (can be worked andmolded) when first mixed, and hardens to a solid mass.

In its hardened state concrete must be strong enough tocarry the loads imposed on it, and durable enough to resistwear, weather and chemical attack. In its plastic state it mustsuit the methods of handling, placing, compacting and finishing.

The cement paste (cement and water) in the mixture lubricatesthe aggregates and allow them to move freely while theconcrete is placed and compacted. Generally, the morecement paste in the mixture, the more workable the concrete.It is important that concrete delivered to site is sufficientlyworkable for it to be placed and compacted by the meansavailable. If it is not properly placed and compacted, concretewill not achieve its potential strength and durability.

Addition of water increases the workability, but dilutes andweakens the cement paste. In this respect, cement paste islike any other glue: dilution will weaken it. It is the aim of concretemix design, or proportioning, to strike a balancebetween the need for workability, so that concrete can beplaced and finished, and the need for it to be strong anddurable. Workability can also be improved by the use of chemicaladmixtures such as plasticizers.

Many of the characteristics of concrete, particularly its strengthand durability, depend on the development of chemical andphysical bonds: of the cement paste itself as it hydrates and between the cement paste and the aggregateparticles as the concrete hardens. The chemical reactionbetween cement and water (hydration) takes time. Concretemust therefore be kept moist (cured) for a time to ensure thathydration continues and that the concrete achieves its potentialstrength and durability.

Technologists use a range of materials other than cement,water and aggregates to modify the properties of concrete.These include pozzolanic and other cementitious materials,chemical admixtures, and special aggregates.[20]

The word “concrete” comes from the Latin “concretus” means “hard” or hardened”. It is a non-elastic structural material, which became a well-known construction material in the 19th century. Its main components are cement (90% of used cement is Portland cement), other cementitious materials such as such as cement, aggregate, (a coarse aggregate such as gravel, limestone, or granite plus a fine aggregate such as sand), chemical admixtures and water. (Creep of concrete p2-p7)

2.2.1. Concrete materials

Cements

The term ‘cement’ covers a wide variety of organic and inorganic binding agents. By far the most widely used are those known as portland cements–finely ground inorganic materials that have a strong hydraulic binding action. These binders, when mixed with water, will harden in the absence of air to produce a stable, durable product.

Cement is produced by firing and subsequently grinding natural mineral raw. Materials obtained from quarries, earth and rocks which, owing to their geological composition, are suitable for producing cement and are found in almost all parts of the world in different national and regional concentrations. Firing at approx. 1400ºc in a kiln produces so-called Portland cement clinker. This after grinding and adding calcium sulphate (gypsum) to control the hardening process becomes Portland cement. Cement itself cannot be considered as glue or binder, by the reason of it is not behaving on this way. The bending property is a result of chemical reactions between cement minerals and water, namely hydration. Cement is called hydraulic when the hydration products are stable in an aqueous environment. The most often used cement type is the Portland cement (90% of used cement is Portland cement), which consists of hydraulic calcium silicate. (Portland cement p1-2)[6]

Cement types

- Ordinary Portland cement

Ordinary Portland cement is commonly used in general constructions. It has medium rate of heat generation and strength development and adequate resistance to draying shrinkage and cracking, but less resistance to chemical attack. Therefore, its usage is not recommended in special situations where cements have special properties such as quick setting, slow setting, or sulphate resistance is required.

- Rapid hardening Portland cement
- Extra rapid hardening Portland cement
- Low heat Portland cement
- Sulphate resisting Portland cement.
- Super sulphated cement
- High alumina cement
- Pozzolanic cement
- Portland blast furnace cement
- Air-entraining cement
- Hydrophobic cement

Aggregates

Aggregate is one of the three main ingredients of concrete and presents between 60-80% in its structure. It is a granular material, such as gravel, sand, iron blast-furnace slag, or crushed stone. Recent laboratory test shows that different aggregates can lead to different residual expansion in a long term therefore their pretest is more than necessary. Expansion can be affected by gypsum or other sulfate containing materials and high chloride containing aggregates, as well. (Standard practice, p223-5)

Aggregates can be divided into two main parts; coarse aggregate and fine aggregate. The only difference between these two groups is the size of the aggregate practices. Course aggregate practices are larger than 4,75mm, while fine aggregate practices are smaller than 4,75mm. Another way to form groups between aggregate types is based on the aggregates density.

Water

The water used in mixed concrete should be as clean as possible and free from all substances which can affect its quality and cause long term problems. These matters can be acids, oil, alkalis, sugar, salts and other organic materials. Sea water containing different chlorides and other salts can be prohibited to be used with concrete containing any reinforcement, for the reason that it can lead to the corrosion of reinforcement and efflorescence production.

The combination of clear water with some cementitious material generates a cement paste with the process of hydration. This cement paste is the one, which glues the aggregate together, allows it to form more easily and fills voids within. The mentioned hydration process can consist of many sub processes, which can happen at the same time. By the end of the reaction, all the individual gravel, sand practices and other concrete components will be gradually bounded together and form a solid mass.

The reactions of hydrations

Cement chemist notation: C3S + H2O ¡÷ CSH(gel) + CaOH

Standard notation: Ca3SiO5 + H2O ¡÷ (CaO)¡E(SiO2)¡E(H2O)(gel) + Ca(OH)2

Balanced: 2Ca3SiO5 + 7H2O ¡÷ 3(CaO)¡E2(SiO2)¡E4(H2O)(gel) + 3Ca(OH)2

While the mixing of concrete components, special attention is needed to make sure, that the amount of cement is in balance with the amount of water. If the amount of water is less than it needed, the hydration can cease. This situation arises at a water-cement ratio of 0.44 or less .Too much water can easily dilute the cement paste and lead to many other problems. There are some advantages of balanced water content listed below: (Creep of concrete)

- Reduced shrinkage and cracking
- Better bound between concrete and reinforcement
- Less volume change from drying and wetting
- Increased resistance to weathering
- Better flexural and compressive strength
- Increased water tightness and lower absorption result lower permeability

Admixtures

Admixtures are chemicals, added to concrete, mortar or grout at the time of mixing, to modify the properties, either in the wet state immediately after mixing or after the mix have hardened. They can be a single chemical or a blend of several chemicals and may be supplied as powders but most are aqueous solutions because in this form they are easier to accurately dispense into, and then disperse through the concrete.

Admixtures are usually defined as being added at less than 5% on the cement in the mix but the majority of admixtures are used at less than 2% and the typical range is 0.3–1.5%. This means the active chemicals are usually present at less than 0.5% on cement or 0.02% on concrete weight.
The dosage may be expressed as liters or kg per bag of cement,

Admixtures are important ingredients in concrete besides aggregates, water, fibers and hydraulic cement and they are added before or during mixing. If admixtures are used in the right way, many beneficial effects to concrete can occur, such as better quality, acceleration or retardation of setting time, control of strength development, better workability, enhanced sulfate and frost resistance and better finish ability.
Data obtained from laboratory testing and field experience show that the performance of admixtures is greatly influenced by the mixing time, ambient temperature and composition of cement. *(Standard Practice p223-4-5)*
Various types of admixtures are playing a key role in the quality of concrete. Most of them are laboratory made chemicals which affects are tested and documented.

Fig. 2.1. Liquid admixtures,(69795)

Making durable concrete and concrete products can be achieved by the use of inexpensive chemical admixtures. Utilizing the admixtures can result in using less cement, which is the most expensive constituent, per cubic meter of concrete. By lowering the cost of concrete the producer can increase profits while supplying a better product. Introducing the concrete industry to newer technology will benefit the industry by lowering the material costs per cubic meter and increasing the durability of the concrete. Initially the introduction of air entraining and water reducing admixtures will greatly increase the consistency and durability of concrete and concrete related products. In addition to materials, increasing the understanding of proportioning concrete mixes and how to adjust concrete mix proportions will benefit the individual producer by increasing the efficiency of each concrete mix. [10]

History of admixture use

Historically, admixtures are almost as old as concrete. It is known that the Romans used animal fat, milk, and blood to improve their concrete properties. Although these were added to improve workability, blood is a very effective air-entraining agent and might well have improved the durability of Roman concrete. In more recent times, calcium chloride was often used to accelerate hydration of cement. The systematic study of admixtures began with the introduction of air-entraining agents in the 1930s when people accidentally found that cement ground with beef tallow (grinding aid) had more resistance to freezing and thawing than a cement ground without it. Nowadays, as we mentioned earlier, admixtures are important and necessary components for modern concrete technology. The concrete properties, both in fresh and hardened states, can be modified or improved by admixtures.

Table 2.1.shows history of using admixtures

Romans	Retarders	Urine
	Air entrainment	Blood
	Fibres	Straw
Plasticizers	1932	Patent for sulphonated naphthalene formaldehyde plasticizers (but not available in commercial quantities)
	193?	Lignosulphonates used as plasticizers
	193?	Hydroxycarboxcilic acid salts used as plasticizers and retarders
Waterproofers	193?	Fatty acids, stearates and oleates
Air entrainers	1941	Tallow and fatty acid soaps for frost resistance
Superplasticizers	1963	Sulphonated naphthalene formaldehyde commercially available
	1963	Sulphonated melamine formaldehyde patent and available
	1990–1999	Polycarboxylate ether development and introduction

Admixture mechanism of action

Admixtures work by one or more of the following actions:

- Chemical interaction with the cement hydration process, typically causing an acceleration or retardation of the rate of reaction of one or more of the cement phases.
- Adsorption onto cement surfaces, typically causing better particle dispersion (plasticizing or super plasticizing action).
- Affecting the surface tension of the water, typically resulting in increased air entrainment.
- Affecting the rheology of the water, usually resulting in an increased plastic viscosity or mix cohesion.
- Introducing special chemicals into the body of the hardened concrete that can affect specific properties such as corrosion susceptibility of embedded steel or water repellence.

The benefits obtained from using the admixture are often in the hardened properties. However, with the possible exception of the last bullet point, these actions all affect the properties of the wet concrete between the time of mixing and hardening in one or more of the following ways:

One of these effects will usually be the primary property, the property for which the admixture is being used. However, the admixture can also affect one or more of the other wet properties. These are called secondary effects and it is often these which are key to admixture selection within an admixture type.

For example, a water-reducing admixture may be required to give low water: cement ratio for durability but if the concrete mix lacks cohesion and is prone to bleed, a water reducing admixture which also increases cohesion would be appropriate to prevent the bleed. The primary function is as a water reducer; the secondary function is to improve cohesion. Incorrect admixture selection could make the bleed worse.[9]

Effect of Admixtures on the Properties of Fresh Concrete.

- To increase workability without increasing the water cement ratio.
- To retard or accelerate time of initial or final setting.
- To modify the rate of bleeding.
- To retard segregation or increase cohesion.

- To improve pumpability
- To reduce the rate of loss of workability

Effect of Admixtures on the Properties of Hardened Concrete

- To accelerate the rate of strength development especially at early stage.
- To increase the strength
- To increase the durability
- To decrease the permeability
- To control expansion by alkali – aggregate reaction.
- To improve bond with reinforcement.
- To improve bond with old /new concrete.
- To improve impact or abrasion resistance
- To inhibit corrosion of embedded reinforcement.[11]

Corrosion-inhibiting admixtures

Corrosion-inhibiting admixtures are effective after the concrete has hardened and give a long-term increase in the passivation state of steel reinforcement and other embedded steel in concrete structures.

The most common cause of reinforcement corrosion is pitting corrosion due to the ingress of chloride ions through the covering concrete and subsequent diffusion down to the embedded steel. When the amount of chloride at the steel surface reaches a critical level, the passivation of the steel breaks down and corrosion starts. Carbonation of the concrete leads to a lowering of the alkalinity around the steel and when the pH drops below a critical level this causes a loss of passivation that results in general reinforcement corrosion. Corrosion inhibitors increase the 'passivation state' or 'corrosion threshold' of the steel so that more chloride must be present at the steel surface before corrosion can start. Although corrosion inhibitors can raise the corrosion threshold, they are not an alternative to using impermeable, durable concrete and are not cost-effective unless used in a high-quality mix.

The mechanism by which corrosion inhibitors operate is dependent on their chemical nature. Calcium nitrite-based corrosion inhibitors convert the passive layer on the steel surface into a more stable and less reactive state. When the chloride ions reach the layer, no reaction occurs – the steel is in a passive state. It is the anodic corrosion sites on the steel that are protected against the chloride attack and for these reason nitrites are called anodic inhibitors. It is important that sufficient nitrite is present to counter the chloride ions. The dosage of the admixture is therefore based on the predicted level of chloride at the steel over the design life of the structure.

Amino alcohol-based corrosion inhibitors coat the metal surface with a monomolecular layer that keeps the chloride ions away from the embedded steel. They also inhibit the reaction of oxygen and water at the cathodic sites on the steel, which is an essential part of the corrosion process. As a result amino alcohols can be regarded as both anodic and cathodic inhibitors.[9]

2.2.2. Strength of Concrete

Strength is defined as the ability of a material to resist stress without failure. The failure of concrete is due to cracking. Under direct tension, concrete failure is due to the propagation of a single major crack. In compression, failure involves the propagation of a large number of cracks, leading to a mode of disintegration commonly referred to as ‘crushing’. The strength is the property generally specified in construction design and quality control, for the following reasons: (1) it is relatively easy to measure, and (2) other properties are related to the strength and can be deduced from strength data.

The strength of concrete is commonly considered to be its most valuable property. It usually gives an overall picture of the quality of a concrete because strength is directly related to the structure of the hydrated cement paste. Moreover, the strength of concrete is almost invariably a vital element in structural design and is specified for compliance purposes (Neville 1996).

The strength of concrete originates from the strength of the hardened cement paste,which, in turn, originates from the hydration products. The major portion of thesehydration products is in the form of a rigid gel, called cement gel., it isreasonable to assume that the bonds of the gel particles to each other, to the aggregateparticles, and to other bodies in the concrete are responsible for the strength (Popovics1998).

There are several significant different ways to measure the strength of concrete,such as compressive strength, tensile strength, shear strength, tensional strength, impactstrength, etc.

Compressive Strength

Compressive strength is typically considered to be the most important mechanicalproperty of concrete. In most structural applications, concrete is employed primarily toresist compressive stresses. In those rare cases where other stresses (flexural, etc.) are ofprimary importance, the compressive strength is still frequently used as the measure ofresistance because it is the most convenient to measure. For the same reason,compressive strength is generally used as a measure of the overall quality of a concrete,even when strength itself may be relatively unimportant.

Testing of compressive strength

The 28-day compressive strength of concrete determined by a standard uniaxial compression test is accepted universally as a general index of concrete strength.[22] (Anonymous,)

To ascertain that concrete has developed the desired properties, it is tested under specified or known conditions. There are many methods to test the properties of hardened concrete, but the most common of all tests on hardened concrete is the compressive strength test.

Tests are made mainly for two objectives as for quality control and for compliance to specifications. Compression test can be performed commonly on two types of test specimens, namely Cubes (150mm standard), Cylinder (150 x 300mm standard). The moulds are preferably metal moulds of cast iron or steel[7]

The compressive strength test of concrete or mortar is usually determined by submittinga specimen of constant cross section to a uniformly applied axial compression load,which is increased until failure occurs. The resulting strength is expressed as the ultimatecompression load per cross-sectional area, usually in newton per millimeter square(N/mm2) or Pascal's (Pa).

$$Stress = force/area$$

Testing of the compressive strength of concrete started about 100 years ago. Cubes are used inGreat Britain, Germany, and may other countries in Europe. Cylinders are the standardspecimens in the United States, France, Canada, Australia, and New Zealand. [8]

2.3. Prickly pear cactus

Opuntia (also known as cactus pear) Scientific Name **Opuntia**spp. (Cactaceae: Cactus Family)*Opuntia* spp. originated in the tropical and subtropicalAmericas and, wild or cultivated, theycan be found in a wide variety of agroclimaticconditions across the entire American continent.

The plant has spread further – carried by people asthey traded and settled – to Africa, Asia, Europe and Australia, where the cultivated and wild plantscontinue to provide food and materials.The cactus pear belongs to the *Cactaceae* family.

Its taxonomy is highly complex for a numberof reasons. For example, its phenotypes showhigh variability according to the prevailing environmentalconditions, polyploidy is common, itreproduces either sexually or asexually and thereare several interspecific hybrids.

According to the GermplasmResources Information Network (GRIN)of the United States Department of Agriculture'sAgricultural Research Service, the cactus pear belongs to the genus *Opuntia*.The scientific name Opuntia was coined byTournefort in 1700, in view of their resemblance to spiny plants that grew in the town of Opus inGreece (Scheinvar, 1999; Velásquez, 1998). Onceintroduced into Spain from Mexico, the speciesquickly spread throughout the Mediterraneanbasin.

The Opuntia species is known by differentnames in the various countries where it is found.The original name, in the Náhuatl language, isnochtli. Notwithstanding, the Spanish renamedthe plant chumbera and the fruit higo de las Indias(Indian fig), which today is known as higo chumbo(chumbo fig). In Italy it is known as fico d'India,in France as figue de Barbarie and in Australia,South Africa and the United States, as prickly pear.This is slowly evolving into the name cactus pear,to reduce the negative connotation of the word'prickly' (meaning 'with spines'). In Israel it isknown as sabras, meaning 'spiny outside but sweetinside'.

In Eritrea and Ethiopia it is called **beles**. InIndia it is called in a local dialect nagphani or andatorra or chapathi balli depending on the region. InBrazil it is known as Palma forrageira because it iscultivated mainly as forage for livestock.

Fig.2.2. prickly pear cactus (Opuntia ficus-indica)

Opuntia plants are native to many environments,ranging from desert areas below sea level to high altitudeareas such as the Peruvian Andes and fromthe tropical regions of Mexico, where temperaturesare always above 5 ºC, to areas in Canadathat can fall to -40 ºC in winter (Nobel, 1999). Itsadaptability is ample reason for considering thisspecies as a highly valuable resource for a widevariety of ecological zones.

One of the most striking characteristics of *Opuntia*is its anatomy and morphology, which haveenabled it to adapt to many highly stressful growingconditions, meaning that the plant can be a viableoption in regions where other plants will not survive.The characteristics that make the plant adaptableto arid conditions are related to the shape ofseveral of its organs. Nobel (1998) suggested thatthe shallow and extensive root system enabled theplant to exploit scarce rainfall in such environments.On the other hand, isolated rainfall inducesthe formation of secondary roots, which increasesthe contact surface with the soil and this facilitatesuptake of water and nutrients. At the beginningof a period of drought, the roots contract radiallyand this helps to reduce water loss.

Scientifically the stems are known as cladodesand commonly referred to as 'paddles', 'fleshyleaves' or 'racquets'. They are succulent and articulated.[12]

The tourist industry offers opportunities forexploiting Opuntia products, including the artisanalmanufacture of a number of traditionalproducts. For example, the lignified cladodes areused for making baskets and similar items.Another quite different but no less potentiallyimportant sector is construction. Recent interesthas been shown in the anti-corrosive propertiesof mucilage. Studies are under way on the useof cladode extracts as adhesives in paints and forwater clarification.[4]

2.3.1. Usesof cactus gum

Plant gums have been used in a variety of applicationssuch as in food emulsifiers, stabilisers, and thickeners,pharmaceuticals, cosmetics, textiles, and in art. Plantgums have been used for centuries as binding media, topaint, write and illuminate manuscripts and to apply metallic leaf decorations Gums and other kind ofsaccharide materials, such as honey, fig milk or starch,are known to have been used as binding media, sizingagents or mummification materials since antiquity. Actually,carbohydrates are contained in a variety of materialsused as support, binders and varnishes in painted objects.[13]

The OFI mucilage (i.e., prickly pear or Nopal) is a thicksubstance, comprised of proteins, monosaccharides andpolysaccharides, grows abundantly and is inexpensive andedible. Nopal pads are formed of complex carbohydratesthat have the ability to store and retain water, allowingthese plants to survive in extremely arid environments. Nopal mucilage is a neutral mixture of approximately high-molecular weight sugar residues composed basicallyof arabinose (67.3%), galactose (6.3%), rhamnose (5.4%)and xylose (20.4%) (Techtenberc & Mayer 1981; Radiaet al. 1988; Cardenas et al. 2008). Our chemical analysis isconsistent with the aforementioned references. It also containsseveral ionic species (Radia et al. 1988). In fact, itscomposition gives the OFI the capacity to interact withmetals, cations and biological substances (Benson 1982).

Cactus mucilage swells but does not dissolve in water(McGarvie & Parolis 1979). Natural gums have unique surfaceactivity characteristics which make them idealcandidates for enhancing dispersion properties, creatingemulsifications and for reducing the surface tension ofhigh polarity liquids.[14]

No sound scientific explanation for the use of cactus juice in lime mortar is available. Nevertheless, Cactus juice is known to be rich in insoluble fibers as well as water-soluble mucilage (Granados and Castaneda, 1991). This polysaccharide mucilage has a chemical composition similar to that ofpectin, and it generally contains varying proportions of L-arabinose, D-galactose, L-rhamnose, and D-xylose as the major neutral sugar units as well as D-galacturonic acid. Different species of nopal contain different percentages of mucilage, for instance in *Opuntia ficus-indica* the total pectincontent is 1.9% and for *Opuntia Robusta*is 3.3% (wet-weight basis). This mucilage displays a greattendency to aggregate in salt solutions, as we have previously demonstrated (Cárdenas *et al*.1997). Cactus mucilage can be dispersed in a salt solution at concentrations of up to 5% and itdoes not form a gel system but a high-viscosity solution. Even at this concentration level, themucilage has a mechanical spectra characteristic of an entangled network of disordered polymercoils (Cárdenas, 1997). Claims of the advantages of admixing cactus juice in lime mortar includeincreased impermeability and prolonged duration of the wall coating, thus effectively preserving theoriginal stones and bricks of ancient monuments.[3]

At the beginning of July, theAuroville Earth Institute initiateda series of experiments onthe waterproofing propertiesof cactus juice, an additive longused in the adobe techniques inSouth America. The Institute tookthe basis of their recipe fromMeskerem Assegued, a renownedEthiopian anthropologist andcurator, who had developed arecipe that did not include preciseproportions. By measuring carefullythe ingredients and preparationprocedures, the Instituteis researching to standardize thisrecipe for the cactus juice.

The viscous liquid additive isderived by slicing up and soakingprickly pear cactus pads in waterfor 3 days. This liquid can thenbe added directly to the adobemixture, used as a coating on thebricks, or mixed with lime for aplaster coating.Under the guidance of T.Ayyappan and Satprem Maïni,the Auroville Earth Institutecreated eleven samples of limeplasters and paints, ranging from

a control sample with no coatingof any sort, a sample with thelime plaster typically used by theInstitute, a paint from lime andcactus juice, solely cactus juice,and lime-stabilized earth plasterwith varying levels of cactus juiceand soil. Two samples additionallyincluded marble powder.Two types of adobe bricks weremade: one composed with waterand the other with cactus juice.

To test these samples, a literof water was poured on eachsample and a pane of glass wassealed over the top to minimizethe evaporation of the water. Theaim was to test the absorptionand percolation of water in thecontext of the varying samples.Another test was performedupon a cup made of clay mixedwith cactus juice, which wasfilled with water and analyzed forits ability to hold form and resistleaking. A third test studied the waterabsorption in the frog of a brick,and the indentation was filledwith water and observed.

Fig.2.3. Frog with cactus gum

Fig. 2.4.Frog without cactus gum [15]

Mexican natives used nopal mucilage to bind adobes in ancient times (Granados, 1997). They also used lime and mucilage mixtures as walls stucco. Recent investigations demonstrated the benefits of adding nopal to products such as lime, plaster, and Portland cement (Hernandez-Zaragoza, 2007). Noriega (2005) demonstrated that nopal works as an additive for construction materials when used whole, that is, mucílage and rind of nopal dried at high temperatures.

According to (J. PACD – 2008), the compressive strength of both mixtures M1 and M2 was evaluated at early ages: three, seven, and fourteen days. The compressive strengths show an increase at all ages in mortars having additive of nopal (M2), when compared with regular mix mortars (M1)

According to the results obtained, as far as the normal consistency of the pastes is concerned, mixture M2 had a more fluid consistency than mixture M1. This shows that the nopal additive improved the workability of the mixture.

The initial setting time (fi) for mixture M1 occurred at 330 minutes after placing the sample in the Vicat apparatus and the final setting time (ff) occurred at 390 minutes. For mixture M2, fi occurred at 435 minutes and ff at 495 minutes. Therefore, the additive of nopal slowed down the setting time

[18]

Portland cement-based mortars of the standardtype used for modern constructions, were modified byadding liophilized cactus gum, extracted froman indigenousMexican cactus. The results show an increase incompressive strength as high as 65 % with respect tostandard mortars.In this regard, the vast family of cactus representsa potential source of low-cost materials for the civilengineer. However, almost all the basic chemical researchon cactus has been concerned with the extraction andidentification of their alkaloids and other chemicals. Fromthe green-technology standpoint, cactus pulp is used [16]

Another extra bonus for the use of cactus gum forthe modifying mortars and other construction materials is illustrated in Table Indeed, one of themain parametersleading to the failure of actual buildings is the corrosionof their reinforcing steel structures, embedded in themortar or concrete. The fundamental problem behind isthe mixture pH. In the case of gypsum, a widely usedconstruction material, either by itself or as an additive tomortars and concretes, the low pH (of around 9, typically),leads easily to corrosion. The use of cactus gum,especially, the lyophilized one, as shown in Table, leadsto the pH control of the resulting composite, thus helpingto reduce corrosion susceptibility.

Table 2.2.Results of PH measurements

Material	Test temperature, K	pH
Liophilized cactus gum	299.1	4.64
Cactus gum as extracted	299.3	4.94
Gypsum + silica sand	299.7	9.67
Gypsum + silica sand + liophilized cactus gum	299.6	11.38

The results are not simply due to a rheologicalrole of the cactus gum, as the first thought could be, butthey involve a complex chemistry of the polyelectrolytescontained in the lyophilized gum, which not only reactwith the Portland cement constituents, but also catalyzethe standard reactions.

Nopal has been used in many applications of building construction in Mexico, since remote times. Now, previous knowledge is being used to find new applications in hydraulic cementitious materials, such as Portland cement used in mortar fabrication. Results of the investigation demonstrate that mortar made with nopal as an additive had a greater compressive strength than mortars made without the additive. The time of setting was improved enormously, that means that the nopal acts as a retardant in mortar manufacture.

2.4. Advantage of usinglocally available material

The use of local materials and techniques is one of the main features from vernacular architecture. When compared with industrially-produced materials, vernacular materials have low environmental impacts, being an alternative for sustainable building. However, industrialization have brought new standardized materials that led to the homogenization of the different building approaches and spawned a universal architecture often with no context concerns and with significant environmental impacts.

As for sustainability, vernacular materials have potential to evolve and to be adapted to contemporary needs, helping to reduce the embodied energy and environmental impacts. Therefore, this paper adresses potential advantages of using local materials and techniques in the Portuguese context. Moreover, this paper establishes a comparison between vernacular and industrially-produced at level of environmental indicators (embodied energy and global warming potencial).

Vernacular materials should be perceived as those that are locally sourced and used and closely related to specific local conditions (lithology, climate, agricultural crops, etc.), being an identitary factor of architectural differentiation.

Sustainable Building Basics applies to any engineering level, from the very simple, which can be found in theurban areas of less developed countries, to the very sophisticated urban planning projects of the western world.Buildings account for one-sixth of the world’s fresh water withdrawals, one-quarter of its wood harvest, and twofifthsof its material and energy flows. Building in a ‘sustainable’ way is an opportunity to use our resourcesefficiently while creating buildings that improve human health and well-being and preserving a better environment,keeping economic costs affordable.

A sustainable building is a structure that is designed, built, renovated, operated or reused in a resource-efficientmanner. Sustainable buildings are designed to meet certain objectives such as protecting occupants’ health andwell-being; improving employee productivity; using energy, water, and other resources more efficiently; reducingimpacts on the environment.

With the Industrial Revolution, and later with the Modern Movement, the increasing use of newindustrially-produced and standardized materials led to the homogenization of the different usedconstruction approaches, until then dependent on available local materials. Their wide dissemination

meant that the use of these materials became predominant and traditional techniques and materials

fell into disuse. Modern architecture, based on the use of industrially-produced materials,spawned a universal architecture often with no context concerns and very dependent on energyconsumption (Montaner 2001; Graça 2000). Beyond this, industrially-produced materials requirea high energy-intensity and have considerable environmental impacts (Mota et al. 2012). On theother hand, using alternative materials and techniques, like the vernacular ones (lime, adobe, timber,vaulted ceilings, etc.), the total embodied energy of a building can be significantly reduced,as well as environmental impacts (Venkatarama Reddy & Jagadish 2003; Shukla et al. 2009;Sanz-Calcedo et al. 2012). For example, natural materials such as timber have positive impactsin the overall life-cycle assessment (Mota et al. 2012).

These issues are particularly relevant for the building sector as it has significant environmentalimpacts, being responsible for almost a third of all carbon emissions (Ürge-Vorsatz et al. 2007)and for consuming more energy and raw materials than any other economic sector (Pacheco-Torgal &Jalali 2012) — with some existing reserves forecasted to last only a few dozen yearsmore (Berge 2009).

Nowadays, energy efficiency and sustainability of buildings are important research issues. Asthe buildings become more energy efficient during the operation phase, the concern with the embodiedenergy in building materials is emphasized, thus demonstrating the need to also look at theenergy used to produce components (Ramesh 2012). In life-cycle assessment of buildings, environmentalimpacts associated with all life stages of products are estimated (Bragança & Mateus2011). One of the components of major relevance in this evaluation is the global warming potential,related to the emission of greenhouse gases (GHG) (Bragança & Mateus 2011), in particular[17]

In Ethiopia as a developing country, in addition to the aforementioned problems , not using the localy available resource efficiently and effectively affects its development directly or it retards its development. This means most of the industrially-produced materials importing from abroad will bring problem of hard currency and has a negative impact on the development

The material we examine is categorised as *green material* based on the contribution it makes toenvironmental protection. This is based on renewable natural resources and recovery of materials.

Therefore, this study tries to solve the problem by checking the use of locally available cactus gum for modifying the property of concrete which increases the compressive strength.

CHAPTER THREE
EXPERMENTAL RESULTS, DISSCUSSION AND IFNDINGS

3.1. Presentations

This chapter will present the details of laboratory tests and will include test design and apparatuses, specimen preparation, experimental procedures and findings

3.1.1 Test design and specimen preparation

Based on the primary objective of this research, the laboratory tests were designed to evaluat the compressive strength of concrete specimen resultsprepared with different amount of cactus gum (as an admixture). Two types of mix design composition with different method of gum extraction were prepared.

The compositions of materials for the usual concrete ingredients were made from the standard mix design of EBCS. We have taken the mix ratio of concrete 1:2:3,the concretewas prepared by hand mixing.For the first mixing batch ,water was added by trial until the desired consistency was obtained. This trial water was measured and used as a reference for the next mixing batches The amount of an admixture in our case the amount of the cactus gum (mucilage) was conducted by trial and error method to gain the appropriate dosage.The apparatus which were available in our campus laboratoryand appropriate for our analysis were used. But because of the deficiency of calibration and the shortage of some instruments there were problems.

1. **Composition of materials with cactus gum extracted by the soaking method**

As stated in the methodology part of chapter one,20 pcs of cactus cladode(leaves) were brought to the laboratory,

- the external parts of the cladode or leaves were cleaned from any dirty martials
- cut and chopped into small pieces at approximately 2cm wide by using a traditional knife
- put it on the container and weighted

  Total weight=12.130kg

  Weight of the container =1.685kg

  Then net weight of the chopped cladode was=10.450kg
- we were added 4.5 litre measured amount of pure water and soaked and stayed for about 5 days

- on the beginning of the 6th day we started to separate the gum by using set of sieves and the obtained amount of gum was 5.5litres
- the gum obtained by soaking mechanism has been used for different proportions (compositions) as an admixture and stated on the table bellow

Fig.3.1. cactus cladode ready for cutting

Fig.3.2. cutting and chopping of cactus cladode

Fig.3.3. weighting of the chopped cladode

Fig. 3.4.Add measured amount of water for soaking

Fig.3.5. prepared cactus ready for soaking

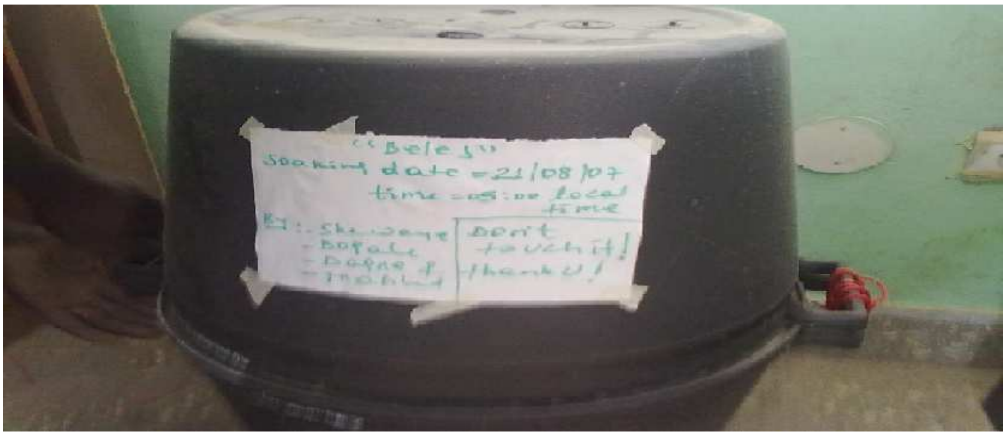

Fig.3.6. Cactus (locally beles) during soaking

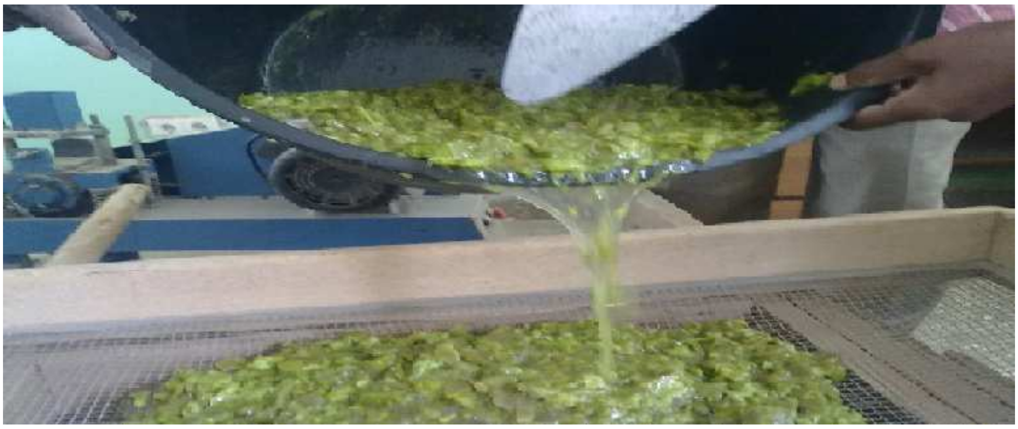

Fig.3.7.Separation of the gum by using sieves

Table 3.1.Shows the composition of materials for the control sample with soaked cactus

No	Materials	Amount	Unit	Remark
1	Sand	8.25	Kg	
2	Course aggregate	15.5	Kg	
3	Cement	4	Kg	
4	Cactus gum(mucilage)	0	Liter	For the control sample

Table 3.2. Shows the composition of materials for sample one with soaked cactus

No	Materials	Amount	Unit	Remark
1	Sand	8.25	Kg	
2	Course aggregate	15.5	Kg	
3	Cement	4	Kg	
4	Cactus gum(mucilage)	1	Liter	For sample one

Table 3.3.Shows the composition of materials for sample two with soaked cactus

No	Materials	Amount	Unit	Remark
1	Sand	8.25	Kg	
2	Course aggregate	15.5	Kg	
3	Cement	4	Kg	
4	Cactus gum(mucilage)	1.5	Liter	For sample two

Table 3. 4. Shows the composition of materials for sample three with soaked cactus

No	Materials	Amount	Unit	Remark
1	Sand	8.25	Kg	
2	Course aggregate	15.5	Kg	
3	Cement	4	Kg	
4	Cactus gum(mucilage)	2	Liter	For sample three

2. Composition of materials with cactus gum extracted by boiling method

10 pcs of cactus cladode(leaves) were brought to the laboratory,

- Cleaned from debris and remove the spines of the cladode
- Cut and chopped in to small pieces as in the case no- 1
- Add 1 litre of water then boiled for about 30 minutes at approximately 60^{0}c until the bubbles are removed in the traditional boiling method(photo shows the details of the procedures)
- Stay cool and then squeezed by using narrower clothes, let in the refrigerator for one day till we used for the next samples
- We got 1.2 litre of net gum after squeezing. The gum obtained by boiling mechanism has been used for different proportions (compositions) as an admixture and stated on the table bellow

Fig.3.8.Shows how to boil the cladode

Fig.3.9. Shows how to squeeze the gum by narrow cloth

Table 3.5.Shows the composition of materials for the control sample with boiled cactus

No	Materials	Amount	Unit	Remark
1	Sand	2.75	Kg	
2	Course aggregate	5	Kg	
3	Cement	1.33	Kg	
4	Cactus gum(mucilage)	0	Ml	For the control sample

Table 3. 6. Shows composition of materials for sample one with boiled cactus gum

No	Materials	Amount	Unit	Remark
1	Sand	2.75	Kg	
2	Course aggregate	5	Kg	
3	Cement	1.33	Kg	
4	Cactus gum(mucilage)	5	Ml	For sample one

Table 3.7. Shows composition of materials for sample two with boiled cactus gum

No	Materials	Amount	Unit	Remark
1	Sand	2.75	Kg	
2	Course aggregate	5	Kg	
3	Cement	1.33	Kg	

4	Cactus gum(mucilage)	7	Ml	For sample two

Table 3. 8. Shows composition of materials for sample three with boiled cactus gum

No	Materials	Amount	Unit	Remark
1	Sand	2.75	Kg	
2	Course aggregate	5	Kg	
3	Cement	1.33	Kg	
4	Cactus gum(mucilage)	9	Ml	For sample three

3.2. Experimental procedures

At different stages, tests and investigations can be carried out to ensure that materials and their production process are efficient and conform to desired standard practice. Some of the known quality tests that can be carried out to satisfy our study were slump test, water/cement ratio, setting time and compressive strength testes.

After preparing specimen samples of materials of concrete on the laboratory, thereafter conducted the following laboratory tests concrete.

3.2.1. Fresh concrete test

- Slump test

Purpose of Test Procedure: Workability tests to show the effect of the gum on the workability of concrete;

This test is a measure of the consistency of the concrete. A change in the slump indicates that something in the manufacturing of the concrete has changed.

The slump test is performed by:

1. Dampening the slump cone and a nonabsorbent flat plate
2. Filling the slump cone with three equal volumes
3. Rodding each layer 25 times,
4. Raising the mold steadily without twisting; and
5. Measuring the slump to the displaced originalcenter of the top of the specimen.

The results were in the table below

Fig.3.10.Rodding the concrete in three layers

Fig.3.11. removing the slump cone without twisting

Fig.3.12. shape of the slump without gum

Fig.3.13. Shape of the slump with CG

Table 3. 9. Slump test results conducted with the gum extracted by soaking method

No	Sample name	Amount of water (in litre)	Amount of cactus gum(in litre)	Slump result (In mm)
1	Control sample	3.2	0	10
2	Sample one	2.2	1	15
3	Sample two	1.7	1.5	20
4	Sample three	1.2	2	22

Table 3.10. Slump test results conducted with the gum extracted by boiling method

No	Sample name	Amount of water (in ml)	Amount of cactus gum (in ml)	Slump result (In mm)
1	Control sample	900	0	8
2	Sample one	900	5	9
3	Sample two	900	7	10.5
4	Sample three	900	9	11

- Setting time test

Purpose of Test Procedure: to show the effect of the gum on the setting time of the Portland cement. But because of the absence of one part of the instrument (apparatus) in the laboratory, we were not conducted the test.

3.2.2. Hardened concrete tests

Of the hardened concrete tests our target was the compressive strength test conducted to evaluate the effect of the CG on the compressive strength of concrete.

The procedureswereas thefollowing;

1. The plastic cube moulds with a dimension of 150mm for the test specimens were cleaned thoroughly and the interior faces oiled.
2. The mixed concrete was placed into the mould in three layers.
3. Each layer of concrete was compacted by not fewer than 35 strokes of a 25mm diameter steel rod until full compaction without segregation was achieved.
4. After compaction of the final layer, the top surface was finished by means of a hand trowel.
5. The cubes were left undisturbed for about 24 hours in the laboratory to set and harden.

At the end of this period, the concrete cubes specimens were stripped of the moulds and placed in their respective curing environmentsuntil their compressive strengths were determined at ages 7, 14, and 28 days. The concrete specimens were cured using Water Submerged Curing (WSC): This technique involved the submersion of the concrete cube specimens in water.

Fig.3.14.Balancing the ingredients

Fig.3.15. Batching of the ingredients

Fig.3.16. Dry mixing of the ingredients

Fig.3.17.Measured amount of CG to the mix

Fig.3.18.Clean and oiled the moulds

Fig.3.19. The cubes compacted in a layer

Fig.3.20.Stripped of the moulds

Fig.3.21. leveling a code in to the sample

Fig.3.22. The cubes inter in to the curing tank

Fig.3.23Cubes ready for crushing

The cubes were removed from the curing tank, dried and grit removed. They were tested using a calibrated compression machine. The test was carried out by competent personnel at a certified Test House of Ethiopian Conformity Association Addis Ababa Branch. The cubes were tested on the face perpendicular to the casting face.

The compression machine exerts a constant progressing force on the cubes till they fail. The reading at failure is the maximum compressive strength of the concrete. The corresponding results arerecorded on the table below.

Table 3.11.Shows values of compressive strength for the CG extracted by soaking method

No	Sample name	Compressive strength in Mpa			Remark
		7days	14days	28days	
1	Control sample				
2	Sample one				
3	Sample two				
4	Sample three				

Table 3.12. Shows values of compressive strength for the CG extracted by boiling method

No	Sample name	Compressive strength in Mpa			Remark
		7days	14days	28days	
1	Control sample				
2	Sample one				
3	Sample two				
4	Sample three				

3.3. Findings;

Table 9 and11 summarizes the results ofthe slump tests and the compressive strengthtested after 7,14 and 28 days of aging of different samples prepared with different amount of cactus gum **extracted by the soaking method.**The results Showed that, as the amount of CG increased the workability of the mix also increased.But the strength of the concrete is gradually decreased.

Table 10 and 12 summarizes the result of the slump test and compressive strength tested after 14 days of aging of different samples prepared with different amount of cactus gum **extracted by the boiling method.** The results showed that as the amount of the CG increased also the workability of the concrete increased. But the strength is on progress…………………………………………………….

CHAPTER FOUR

CONCLUSSION, RECOMMENDATIOM AND FUTURE WORKS

4.1. Conclusion

From the literature review, different scholars give the definition, scope and the use of the cactus gum (mucilage) used as an additive for different construction purposes as water proofing, as increasing the durability and strength of mortars, for modifying the workability of mortars, as retardants by elongating the setting time of PC, and corrosion resistance for reinforced concrete by increasing the PH values of the ingredients on Portland cement. But there is no one which states clearly about the correct mechanisms of extracting the gum from the plant. Due to this it is difficult to know the exact method of extraction the gum and its dosage. For this reason we design our material composition and method of extraction by ourselves.

4.2. Recommendation

- International workshops were held on our country about the use of cactus for food, feed, soil and water Conservation and other products in Africa, and different sectors were participated. But no any discussion about the constructional use was discussed. So for the future the construction industry/ sectors must participate on these workshops.
- The experience and thevision of the local researchers will be able to launch the cactus pear as

one of the primary crops must be studied for its construction use in East Africa Countries, as the plant is abundant in these countries

- Work in close collaboration with countries with extensive experience in cactus development for different uses of cactus, especially for construction industry. Work collaboration with experienced countries may use to transform their skill and knowledge about how to apply the plant for the construction industry.
- As stated in the literature review, there is no any cactus processing industry in Ethiopia. Since the plant is available in all parts of the country and being a renewable product and being easy to harvest in barren places, will be great potential for the construction industries, not only the food and agriculture sectors but also different stakeholders must focus on this interesting issue
- The exact effects of cactus gum on concrete properties needs to be examined and the method of extracting the gum and exact amount /dosage must be quantified in future research.

4.3. Future works

Firstly, this study more emphasizes to evaluate the effect of the gum on the compressive strength of concrete by designing the trial and error method to find the exact method of extracting the gum and its dosage /amount per mix. The study is done by taking of the available species which is called prickly pear cactus or Opuntia ficus-indica. But as stated in the literature review the plant gum can beused for different construction purposes and there are varying amount of species of the Opuntia (cactus pear) in Ethiopia.

Secondly, in this study the chemical analysis of the gum would not studied.because it needs another effert,time,budget and chemical experts.

Therefore, one can extend this study by further studying the chemical constitutent of the gumand how can affect the other property of concrete and any construction materials. And can take the others species of this plant, as a result the final goal of the study may achieve.

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Appendixes

Appendix 1. List of test reports and Letters

የኢትዮጵያ የተስማሚነት ምዘና ድርጅት
Ethiopian Conformity Assessment Enterprise

ቁጥር (No.) 2/6/9/829/07
ቀን (Date) 24 ግንቦት 2007

ለአዳማ ሳይንስና ቴክኖሎጂ ዩኒቨርሲቲ
አዳማ

ሚያዝያ 29 ቀን 2007 ዓ.ም በቁጥር SoCEA/13/1549/07 በተጻፈ ደብዳቤ የConcrete cube ናሙናዎች እንዲፈተሽላችሁ መጠየቃችሁ ይታወሳል።

ስለሆነም በጥያቄው መሠረት ፍተሻው ተካሂዶ 4 ገጽ የፍተሻ ውጤት በዚህ ደብዳቤ ሸኝነት የላክን መሆኑን እንገልፃለን።

ከሠላምታ ጋር

አምሳሉ እንየው
የሜካኒካል ፍተሻ ላቦራቶር የቡድን መሪ

አባሪ፡ 4 ገጽ የፍተሻ ውጤት MTR/1135-38/15

ግልባጭ፣

በኢትዮጵያ የተስማሚነት ምዘና ድርጅት

- ለፍተሻ ላቦራቶሮች ዳይሬክትሬት /ያለአባሪ/
- ለቅርንጫፍ ማስተባበሪያና ደንበኞች አገልግሎት
  አዲስ አበባ

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Addis Ababa, Ethiopia
Tel: +251 (0)11 647 0193-Ex 140,122
Fax:+251 (0)11 645 9720
Fax:+251 (0)11 667 0245
Email: info-cp@eca-e..com
(Complain Handling)
Web site: www.eca-e.com
Bank Account
Commercial bank of Ethiopia (CBE)
megenagna branch
Account no 1000005054366
Tin no 0020245227

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Tel: +251 (0)11 896 0258
Email: info-cs@eca-e.com

Certification Services
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Email: info-cd@eca-e.com

Inspection Services
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Email: info-id@eca-e.com

Testing Laboratory Services
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Email: info-tld@eca-e.com

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Email: info-cc@eca-e.com

Finance and Supplies
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Admin. Human Res. Dev.
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Email: addisababa-br@eca-e.com

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North Western Branch (Bahir Dar)
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Fax: +251(0)58 220 0724
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Eastern Branch (Dira Dawa)
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Fax: +251 (0)25 112 1426
Email dredawa-br@eca-e.com

Northern Branch (Meksle)
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Fax: +251(0)34 440 6280
Email: mekele-br@eca-e.com

Western Branch (Jimma)
Tel: +251 (0)47 111 0432
Fax: +251 (0)47 111 7020
Email: jmma-br@eca-e.com

ወደ ላቀ ብቃት የሚያደርስ!
Moving you forward!

ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No. TLD/F5.10-1	
		Copy No: -	Rev No: 1
Title:	TEST REPORT ይህ የናሙና ፍተሻ ሪፖርት እንጂ ሰርተፍኬት አይደለም	Page No: 1 of 1	Effective Date: 1Jan 13

Report No MTR/1135/15
Test order No soCEN13/1549/07

1	Name and address of client	Adama Science & Technology University Tel. 0228118563, Adama
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	11/05/15
5	Client's sample code	1,2,3,4 Respectively
6	Laboratory designated sample No.	724309, 724310, 724311 & 724312
7	Type of sample	Concrete cube
8	Test method	ISO 4012:1978E
9	Test date(s)	11/05/15
10	Date of Submission of test report	01/06/15

Test result

Sample code & LDS No	Ser No.	Compressive strength (Mpa)	Curing Time
724309	1	9.12	7 days
724310	2	6.55	7 days
724311	3	8.03	7 days
724312	4	10.36	7 days

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory

Test report authorized by, Name Yohannes Kedir Position Analyst V. Sign.

✉ 11145 ☎ 011 6 46-05-69, Fax. 011 6 45-97-20, E-mail info-cs@eca-e.com Web site: www.eca-e.com
BOLE SUBCITY, WOREDA 6
ADDISABABA, ETHIOPIA

7 days of Test report shows the results of concrete cubes with addition of soaking CG

ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No. TLD/F5.10-1	
		Copy No: -	Rev No: 1
Title:	TEST REPORT ይህ የናሙና ፍተሻ ሪፖርት እንጂ ሰርተፍኬት አይደለም	Page No: 1 of 1	Effective Date: 1Jan 13

Report No MTR/1136/15
Test order No soCEN13/1549/07

1	Name and address of client	Adama Science & Technology University Tel. 0228118563, Adama
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	11/05/15
5	Client's sample code	1,2,3,4 Respectively
6	Laboratory designated sample No.	725010, 725011, 725012 & 725013
7	Type of sample	Concrete cube
8	Test method	ISO 4012:1978E
9	Test date(s)	18/05/15
10	Date of Submission of test report	01/06/15

Test result

Sample code & LDS No	Ser No.	Compressive strength (Mpa)	Curing Time
725010	1	7.67	14 days
725011	2	8.41	14 days
725012	3	10.32	14 days
725013	4	11.62	14 days

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory.
2. The Direction of the force applied on the sample with LDS No. 725010 was not according to the standard.

Test report authorized by, Name Yohannes Kedir Position Analyst V. Sign.

✉ 11145 ☎ 011 6 46-05-69, Fax. 011 6 45-97-20, E-mail info-cs@eca-e.com Web site: www.eca-e.com
BOLE SUBCITY, WOREDA 6
ADDISABABA, ETHIOPIA

14 days of Test report shows the results of concrete cubes with addition of soaking CG

ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No. TLD/F5.10-1	
		Copy No: -	Rev No: 1
Title:	TEST REPORT ይህ የናሙና ፍተሻ ሪፖርት እንጂ ሰርተፍኬት አይደለም	Page No: 1 of 1	Effective Date: 1Jan 13

Report No MTR/1138/15
Test order No soCEN13/1549/07

1	Name and address of client	Adama Science & Technology University Tel. 0228118563, Adama
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	11/05/15
5	Client's sample code	1,2,3,4 Respectively
6	Laboratory designated sample No.	726422, 726423, 726424 & 726425
7	Type of sample	Concrete cube
8	Test method	ISO 4012:1978E
9	Test date(s)	01/06/15
10	Date of Submission of test report	01/06/15

Test result

Sample code & LDS No	Ser No.	Compressive strength (Mpa)	Curing Time
726422	1	11.0	28 days
726423	2	11.9	28 days
726424	3	10.8	28 days
726425	4	11.2	28 days

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory.

Test report authorized by, Name Yohannes Kedir Position Analyst V. Sign.

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BOLE SUBCITY, WOREDA 6
ADDISABABA, ETHIOPIA

28 days of Test report shows the results of concrete cubes with addition of soaking CG

ECAE ኢትምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No. TLD/F5.10-1	
		Copy No: -	Rev No: 1
Title:	TEST REPORT ይህ የናሙና ፍተሻ ሪፖርት እንጂ ሰርተፍኬት አይደለም	Page No: 1 of 1	Effective Date: 1Jan 13

Report No MTR/1137/15
Test order No soCEN/13/1549/07

1	Name and address of client	Adama Science & Technology University Tel. 0228118563, Adama
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	11/05/15
5	Client's sample code	1,2,3,4 Respectively
6	Laboratory designated sample No.	726418, 726419, 726420 & 726421
7	Type of sample	Concrete cube
8	Test method	ISO 4012:1978E
9	Test date(s)	01/06/15
10	Date of Submission of test report	01/06/15

Test result

Sample code & LDS No	Ser No.	Compressive strength (Mpa)	Curing Time
726418	1	28.3	14 days
726419	2	29.6	14 days
726420	3	26.8	14 days
726421	4	28.8	14 days

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory.

Test report authorized by, Name Yohannes Kedir Position Analyst V. Sign.

✉ 11145 ☎ 011 6 46-05-69, Fax. 011 6 45-97-20, E-mail info-cs@eca-e.com Web site: www.eca-e.com
BOLE SUBCITY, WOREDA 6
ADDISABABA, ETHIOPIA

14 days of Test report shows the results of concrete cubes with addition of boiled CG

Appendix 2.List of project pictures