ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Replacement of River Sand by Idaga Hamus Crushed Sandstone Sand in Reinforced Concrete and Hollow Concrete Block Production

A Thesis in Structural Engineering

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A Thesis

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science

The undersigned have examined the thesis entitled '**Replacement of River Sand by Idaga Hamus Crushed Sandstone Sand in Reinforced Concrete and Hollow Concrete Block Production**' presented by **Fitsum Reda**, a candidate for the degree of **Master of Science** and hereby certify that it is worthy of acceptance.

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I certify that research work titled "**Replacement of River Sand by Idaga Hamus Crushed Sandstone Sand in Reinforced Concrete and Hollow Concrete Block Production**" is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged / referred.

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ABSTRACT

This study aims to investigate crushed sandstone sand (CSS) in Concrete and hollow concrete block (HCB) properties as replacement of RS material. It was conducted by taking samples of CSS from Idaga Hamus, and RS from Gereb Giba quarry sites. The significance of blending CSS with RS materials using several laboratory tests were investigated. Total 36 samples of 15cmx15cmx15cm cubic concrete at 7^{th}, 14^{th}, and 28^{th} days of curing period for compressive strength of concrete, 9 samples 50cmx15cmx15cm beams for flexural strength of concrete with mix ratio of 1:2:3, and water to cement ratio 0.50 for 0% and 50% replacement of CSS and 0.55 for 75% and 100% replacement of CSS, and 24 samples of HCB at 7^{th} day curing period were prepared and tested. The test results on the specimens showed that the concrete and HCB manufactured using CSS as a partial and full replacement of RS have all strength, and density requirements specified in Ethiopian Standard ES 596:2001.

It can be concluded from the study that CSS can readily to be used as a replacement for RS, in Concrete and HCB as far as the quantity and procedures in this study are followed. Commercial sand production from the sandstone could also be taken as a potential solution for RS shortage.

The RS replaced by 100% of CSS greatly improves the physical and mechanical behaviors of concrete and HCB. The amount in percentage of silt content, and clay content in CSS and RS has been widely investigated.

The significance of the replacement of CSS to RS concrete with the characteristic strength of concrete C-25 and HCB were studied in mixtures prepared with constant workability. Compared to RS, CSS has better quality consistency and higher Strength in concrete. The manufactured CSS that is available in Idaga Hamus is well-graded. The strength properties of concrete were investigated with 0%, 50%, 75%, and 100% replacement of RS by CSS for C-25 mix proportion of concrete and 40cmx20cmx20cm, dimension of HCB.

There is a 15.4927% increment in the relative compressive strength of concrete, and a 13.226% increase the relative flexural strength of concrete with 100% replaced of CSS at the 28^{th} day of curing period compared with conventional concrete.

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Abbreviations

RS	River Sand
CSS	Crushed Sandstone Sand
RC	Reinforced Concrete
HCB	Hollow Concrete Blocks
ASTM	American society for testing materials
W/C	Water to Cement Ratio
EiTM	Ethiopian Institute of Technology Mekelle
MoE	Ministry Of Education
AAiT	Addis Ababa Institute of Technology
CSSC	Crushed Sandstone Sand Concrete
RSC	RS Concrete
ES	Ethiopian Standard
ASTM	American Society for Testing Materials
BS	British Standard
ACI	American Concrete Institute
CTM	Compressive Strength Testing Machine
IS	Indian Standard

CHAPTER 1

1.0. INTRODUCTION

1.1. BACK GROUND

In Ethiopia's Tigray region, CSS has been used extensively as a partial and full replacement of RS material in many structural and nonstructural elements of construction, without any experimental investigation. Several problems are associated with strength depending on the quality of RS. The most common problem is, it contains high impurity, silt, and clay content.

At this time, the RS is expensive with its poor quality. Silt, clay & impurities present in RS can reduce concrete strength. A few alternatives had come up for construction industry to solve this problem. The most suitable one is to replace RS by CSS. Usage of CSS can reduce the cost of RS. If the alternative CSS is made with modern technology machines, it does not contain impurities and wastages such as clay, wood, gravel coarse aggregate, etc. The use of CSS materials results for conservation of naturally resources, and helps to resolve the deficiency of RS.

In the Tigray region, there is a shortage of RS extracted from the river bed. Quality of sand has important role in strength control, & stability of structural and nonstructural elements of buildings. Despite, different types of materials such as sand, aggregate, water, and cement are used as main components, but sands are widely used because they are very important in bonding strength of concrete.

The difference between RS and CSS was investigated by different experimental equipment. In general, the experimental results show CSS materials usually had good quality, in contrast with compressive strength, and flexural strength on concrete and HCB production leading to collapse. Nowadays, there is an increasing interest in using CSS from quarries for any concrete works, and HCB production to overcome inherent deficiencies of RS.

In Tigray region, CSS is more abundant in the areas of Idaga Hamus, Adigrat, Hawzen, Frawn (Sinkata), Koraro, Hiwane and some parts of Mekelle city. However, its use is merely limited to plastering, cement screed, road basements, or landfill applications.

In Ethiopia, the production and utilization of concrete and fabrication of precast hollow concrete blocks (HCB) are increasing rapidly, which is resulting in increasing consumption of RS as component.

The price of RS is much greater than the price of CSS. RS is expected to increase during the rainy season from mid-June up to mid-September and decreases from mid-September – mid-June. The situation lead to question about shortage of RS. A possible solution to these problems is to produce alternative sand and use CSS mainly for reinforced concrete and nonstructural components. Finding enough amount of RS with rational cost is one of the challenge in construction especially in rainy season.

Price of RS is expensive, whereas CSS is cheap. Experimental Investigation of alternative options for the source of CSS would have a great important role in the safety of construction activities. The physical properties of CSS were investigated concerning the required quality.

The 100% replaced RS by CSS gave impressive results in compressive strength, flexural strength in concrete and compressive strength in hollow concrete block HCB. Currently, construction in Ethiopia is under huge shortage of good quality RS. Providing efficient and cost-effective alternative materials for the construction industry will have great importance. Studied the physical properties of CSS, which is abundantly and easily assessed in different parts of the region as option to RS providing potential for supply.

1.2. STATEMENT OF THE PROBLEM.

Increment construction cost in the country is basically depend on cost increment of construction materials like sand, aggregate, and cement. For instance, the price of RS increases annually by 77.8% in average. In 2019/2020 the price was 900 birr/m^3, however in 2022/2023 it becomes 1600 birr/m^3. So, using CSS which can be produced from the readily available sandstone rock mountain resource can play a great role in the reduction of construction costs.

CSS can easily produce and transported with minimum cost. The price of CSS had small increment contrast to RS, it increases annually by 53.84% in average. In 2019/2020 the price was 650 birr/m^3, however in 2022/2023 it becomes 1000 birr/m^3. Many specimens were utilized in this study to evaluate CSS effect, strength, and durability on concrete and HCB production in the construction field.

1.3. OBJECTIVE OF THE STUDY

In Ethiopia, The One and most basic difficulty facing the construction industry is the price escalation of RS and shortage of supplies. Insufficient quality of RS based on the reduction of resource has made contractors to look suitable alternatives fine aggregate. The One and good alternative is CSS. As RS is excavated from stream bed, it contained high percentage of inorganic materials, Silt, and Clay that mainly affect the strength and durability of concrete.

The Idaga Hamus, Hiwane, Koraro, Adigrat, Hawzen, Frawn (Sinkata), and Mekelle city sandstone have different types of colors that are white, yellow, and red. The white color has higher strength than the others. (Ayenew. Y, Teklay. A. & Saravanakumar Jagannathan, November 2017).

1.3.1. General objective

The main objective of this research is to evaluate and check the suitability of Idaga Hamus CSS as a replacement alternative for RS in concrete strength and HCB. It includes

- ✓ To examine desirable properties for CSS characteristics.
- ✓ To give remedial measurement.
- ✓ To make it usable as construction material of best quality.

This experimental investigation compares the characteristics property of concrete made with RS, and properties of concrete made with 0%, 50%, 75% and 100% replaced CSS.

1.3.2. Specific objectives

1) To determine the Physical Properties of raw material.
2) To determine the property of fresh concrete.
3) To determine mechanical property of concrete at different replacement level of CSS as RS.
4) To determine strength of HCB at different level of replacement.
5) To interpret the advantage of CSS from environmental erosion point of view.

Mixture proportions of the experimental investigation of concrete and HCB production will be determined depending on the following conditions:

- Equal cement type and content,
- workability after 30 minutes,
- The quantity, and well-distributed materials
- Same grain size distribution of RS and CSS mixture,
- same type and quantity of sand,

All unspecified variables like temperature and humidity were kept constant.

1.4. SCOPE OF THE STUDY

This research targeted to evaluate possibility and advantage of Idaga hamus CSS in concrete and HCB as replacement for RS in Tigray region and it can be applied in different areas of the country if the raw material is available. Besides, it determine the basic properties of CSSC depending on CSS content, and to compare them to the properties of concrete made with RS. The white sandstone sand has good density and compressive strength and it can produce higher strength than RS.

N.B

Concrete made with such CSS is called crushed sandstone sand concrete (CSSC) and concrete made with RS is called natural sand concrete (NSC).

1.5. SIGNIFICANCE OF THE STUDY

It can be concluded from this research that the CSS in Tigray can readily use as replacement for RS in reinforced concrete and HCB, as far as the production procedures in this study are followed. The CSS also serves as a RS replacement for nonstructural concrete production such as cement screed, plastering, mortar terrazzo, etc.

This distribution is significant for the client, contractor, and stakeholders by contributing knowledge on the experimental investigation of CSS in Concrete & HCB of the structural element. Conclusion and recommendation will state points to minimize the effects of RS and to spread the advantage of CSS in the country.

1.6. THESIS ORGANIZATION

The first part of this chapter is background, objective, scope, and significance of CSS are outlined in order to better define specific aspects in this thesis. The second chapter of this provides an overview of available literature. Chapters 3 - 4 explain the various experimental steps and a long-term performance of raw materials. Chapter 5 conclusion of the results of the simulations, and offers recommendations for improvements to this additional work. Program tables, and auxiliary calculations are contained within the Appendices.

CHAPTER 2

2.0. LITERATURE REVIEW

This present research is to systematically study the effect and significance of CSS on the properties of the most widely-used C-25 concrete and HCB. The aim of the CSS study is to apply the material into practice for concrete & HCB production and test the end products in the laboratory to give remedial and recommendation to the concerned parties accordingly.

There are not enough written documents about the history and invention of full and partial replacement of CSS as RS in concrete and HCB production, but its development is limited due to different reasons such as experimental investigation.

The shape and texture of CSS particles could lead to improvements in the strength of concrete due to better interlocking between particles. However, angular sand produces lower workability of mortar than spherical sand for the same water content and the same volume of cement paste. Additional water is incorporated into cement mixtures to improve workability, higher water content decreases mortar strength.

Other requirements for CSS include,

- Checking organic impurities, and
- Checking fineness modulus.

2.1. OCCURRENCE, FORMATION AND DISTRIBUTION OF SANDSTONE

2.1.1. Sandstone

Sandstone is a classic sedimentary rock comprising an aggregate of fragments of minerals, rocks, or fossils held together by mineral cement. Sandstone forms when sand is buried under successive layers of sediment. During burial, the sand is compacted and a binding agent such as quartz, calcite, or iron oxide is precipitated from ground water which moves through passageways between grains to create Sandstone (Ayenew. Y, Teklay. A & Saravanakumar Jagannathan, November 2017).

Occurrence and Formation of Sandstone

Rocks are considered to be a natural aggregate of mineral grains connected by strong and permanent cohesive forces. Geologically Rocks are classified into three major divisions according to their mode of formation as follows:

i) **Igneous Rocks**: - are formed by the cooling and solidification of magma within or on the surface of the Earth's crust e.g. granite, basalt, dolerite, gabbro, andesite, rhyolite, pegmatite, peridotite, syenite.
ii) **Sedimentary Rocks**: - are formed by consolidation and cementation of sediments deposited usually laid down under water e.g. **limestone**, **sandstone**, shale, dolomite, mudstone, and conglomerate.
iii) **Metamorphic Rocks**: - are formed from older rocks when they are subjected to increased temperature, pressure, and shearing stresses at considerable depth in the earth's crust e.g. slate, schist, marble, quartzite, gneiss.

All sands originate, directly or indirectly, from solid rocks by the process of weathering. The process of weathering of the rock decreases the cohesive forces binding the mineral grains and leads to the disintegration of bigger masses into smaller and finer particles. The weathering of the rocks might be mechanical (disintegration) and chemical (decomposition).

2.1.2. Geological Background Of Sandstone Rock

The bedrock geology of Ethiopia embraces a great variety of rock types within a wide age range (Mohr 1971, Kazmin 1972, Mengesh et al. 1996 ;). Precambrian metamorphic and igneous rocks cover 23% of the country and include some of the most interesting building stone sources, such as marble, granitoids, and soapstone. Thick successions of Paleozoic and Mesozoic sediments (25%) overlie the Precambrian. These include building stone-quality limestone and sandstones.

A large part of the country is covered by Tertiary and Quaternary volcanic rocks (44%), and in these areas, basalts, however, the Proterozoic rocks of northern Ethiopia, though strongly deformed, are only weakly metamorphosed. A variety of igneous rocks, predominantly granitoids of Proterozoic to Early Paleozoic age, occur as intrusive bodies within the Precambrian metamorphic units. Some of these have been emplaced before, or contemporaneous with, tectonic metamorphic events; others postdate these events. The Late Paleozoic to Mesozoic sedimentary rocks of Ethiopia were deposited during a regional transgression of the Indian Ocean, followed by Late Mesozoic uplift and erosion (Kazmin 1972).

In the eastern-central part of the region, the lower portion of the Mesozoic succession is represented by the **Adigrat Sandstone** of the Triassic to Jurassic age. This rests uncomfortably on the Precambrian basement, or slightly uncomfortably on locally developed Paleozoic sedimentary rocks.

In Tigray, sandstone and limestone are widely used in the domestic market. Within both the Adigrat sandstone and the Antalo limestone there are still possibilities for exploration of new resources, though these will be limited to the relatively small areas where these units are exposed. Regarding building sandstone, the best potential of sandstone lies within the thick, red bed series of the Adigrat Sandstone along an axis from Ambo in the south, through the Abay area Figure 2.3 geological map of Ethiopia. (Woyesa Ararsa, Emer Tucay Quezon, Abraham Aboneh, 2018).

Figure 2.1 Idaga Hamus sandstone mountain

Figure 2.2 Adigrat sandstone mountain

2.1.3. Process of Sandstone Formation

Sandstone is an abundant material in and around Idaga Hamus, Adigrat, some parts of Mekelle city, and its surrounding areas accessed at a very shallow depth and in some parts found as a mountain. It is made up of mainly sand particles with fewer amounts of fine cementing particles. Besides, it is a rock that can be easily crushed by machinery using an excavator or manually by using a hammer constituting smaller particle sizes.

It is common to see, when construction work is done for different projects in Idaga Hamus, Adigrat, and Mekelle city around the diaspora, Most of the ground material is sandstone and mostly it was carted away as a waste material. Nowadays, some people are using it in a place of RS mainly in HCB production, cement screed, plastering, and terrazzo production without any experimental investigation.

2.1.4. Study Area Of Research

Idaga Hamus town is located around 1019 km north of Addis Ababa, in the Tigray region. In Idaga Hamus and Adigrat, the Sandstone is quarried by machinery and manually from sandstone rock.

In Ethiopia, the thickest developments of red bed sandstones are within the Triassic successions; it is called the Adigrat sandstone. These are found predominantly in the northern part of the country in the Tigray region but also found in central parts of the country, such as the Ambo (Oromia), Bure (Gojam), and Abay area. (Biazen 1962, Heldal et al. 1997). The abundance of sandstone in Ethiopia is presented in Figure 1 below of the geological map of Ethiopia.

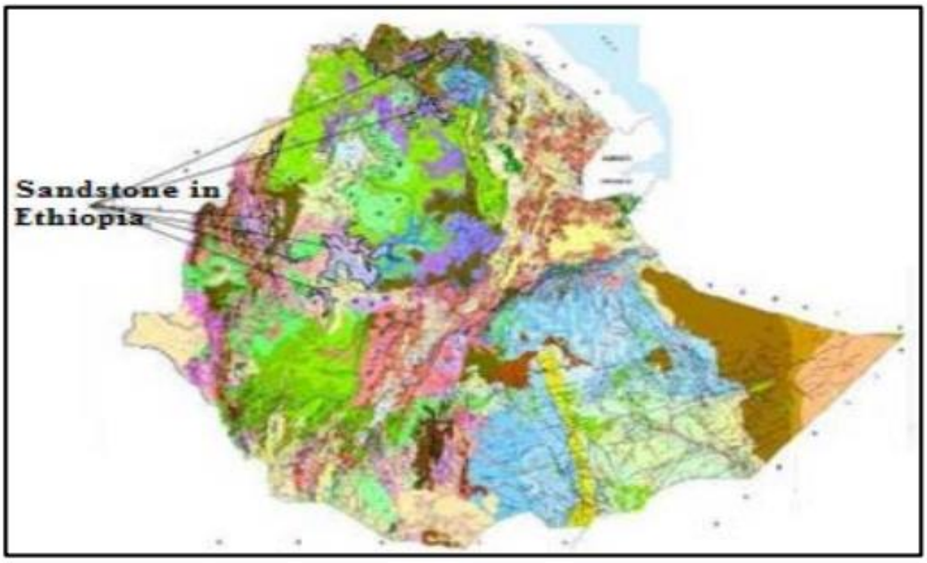

Figure 2.3 geological map of Ethiopia

The geological map of Ethiopia shows the occurrence of sandstone and limestone-developed bodies in Ethiopia. Exploitation mainly occurs in the deposits near the town of Idaga Hamus. Here, the cross-bedded, white and red sandstone is worked to ashlars, split bricks, and slabs mainly with the help of simple tools such as sled hammers, wedges, and crowbars (Biazen 1962, Heldal et al. 1997).

The Adigrat sandstone varies in thickness from a few to 800 m and consists essentially of white, red, and yellow well-sorted quartz sandstone. The upper part, however, is in places calcareous, particularly close to the transition to the overlying limestone of the Antalo Group. Thick limestone is developed in the middle part of this group (Woyesa Ararsa, Emer Tucay Quezon, Abraham Aboneh, 2018).

2.2. <u>PRODUCTION PROCESS OF CSS</u>

Considering the vast importance of RS as raw material for the utilization of structural, nonstructural concrete, and HCB production in the construction industry, I had chances to visit RS quarries & CSS plant about its production process where they found in Gereb Giba & Idaga Hamus Tigray region respectively. During my visit to the quarries and plant, I saw that the production process for crushing sandstone requires sophisticated electrical machinery and extracted by an excavator.

Since, the increment of RS cost in Ethiopia, the readily available sandstone raw materials, and the availability of sufficient machinery and human labor with optimum cost; it requires to assess an experimental investigation on the replacement of CSS as RS in concrete and HCB production.

To address this research, I focused on the concrete property and HCB production using experimental equipment and a HCB production machine.

2.3. COST ANALYSIS

Usage of sands in Ethiopia has been and will continue to be a local business based on readily accessible deposits. Most of the quarry sites are owned by the local farmers on their private land. They sell their sand products or lease the quarry sites to contractors for extracting the sand. In Tigray, there are several quarry sites found. One of which is the Idaga Hamus, Hiwane CSS Quarry site, Gereb Giba, and Samre RS Quarry sites. However, the process of manufacturing fine aggregates from Idaga Hamus sites provides the cheapest cost of materials as compared with the manufactured CSS from Hiwane, and RS extracted from Gereb Giba and Samre. In other words, the cost of sand is influenced by various factors such as production and transportation costs play a major role.

2.3.1. Material Costs

From the raw material source of 2022/2023 year, the average production cost of RS at the Gereb Giba quarry site is 1600 ETB/m^3 including VAT, while CSS at the Idaga Hamus Quarry Site is 1000 ETB/m^3 including VAT.

2.3.2. Transportation Costs

Based on the Contractor's recorded data for 2022/2023 year, they were construct building projects in Mekelle city at the 70 Karie site, the transportation cost to brought material from Idaga Hamus CSS Quarry Site to 70 Karie site was 6000 ETB per Sino truck (16.0 m^3 Capacity). The construction site is around 101 km distance from the quarry site. On the other hand, considering the 70 Karie site, around 35 km away from the Gereb Giba RS quarry site, the transportation cost per Sino truck (16.0 m^3 Capacity) was 4000 ETB.

Production and transportation costs of CSS and RS

Table 2.1 Production and transportation costs of CSS and RS.

Sand type	Cost of fine aggregate material per m^3	Transportation cost per Sino truck (16.0m^3) Pick-up Price	Average total cost per Sino truck	Location (quarry site)
Idaga Hamus CSS	1000 ETB	6000 ETB	22000	Idaga Hamus
Gereb Giba NS	1600 ETB	4000 ETB	29600	Gereb Giba

As it is observed from the above table 2.1, Idaga Hamus CSS has a relative economical and quality advantage over RS. For construction projects around Mekelle, Idaga Hamus, and the Adigrat area. Idaga Hamus CSS cost is fair.

CSS is an alternative resource of RS for concrete construction and HCB production. CSS is produced by crushing hard sandstone rock. The crushed sandstone sand is spherical with grounded edges, and graded to as a construction material. According to ES the size of CSS is 150µm - 4.75mm.

2.4. ECONOMICAL ADVANTAGE OF CSS

Since the usage of CSS has increased durability, strength, and reduction in segregation, low permeability, increased workability, and decreased post-concrete defects such as cracks; it proves to be economical as a construction material replacing RS.

Due to the fast-growing construction industry, the demand for RS has increased extremely, causing a deficiency of suitable RS in most of the country. The reduction of good quality RS for the use of construction and the usage of CSS has been increased.

Another reason for the use of CSS is its high availability, quality production, and fair transportation cost for most of the Tigray region.

Since CSS is manufactured from sandstone rocks, it can be readily available for construction projects, reducing the cost of production. Thus, the cost of construction can be controlled by the use of CSS as an alternative material for construction. The other advantage of using CSS is, that it can be dust-free, and CSS can be controlled easily so that it meets the required grading for the given construction.

Figure 2.4 Idaga Hamus CSS

2.5. PROPERTIES OF CSS FOR CONCRETE AND HCB PRODUCTION

2.5.1. Higher Strength of Concrete

The Idaga Hamus CSS had required gradation of fines, and physical properties such as shape, surface textures and consistency which make it the best sand suitable for construction. These physical properties of sand provide greater strength to the concrete by reducing segregation, bleeding, voids, and capillary. Thus required grade of sand for the given purpose helps the concrete fill voids between coarse aggregates and makes concrete more compact and dense, thus increasing the strength of concrete.

2.5.2. Durability of concrete

Since CSS is processed from selected good quality sandstone rock, it has balanced physical and chemical properties for the construction of concrete structures. This property of CSS helps the concrete structures withstand extreme environmental conditions and prevents the corrosion of reinforcement steel by reducing permeability, and moisture ingress effect increasing the durability of concrete structures.

2.5.3. Workability Of Concrete

Size, shape, texture, and water-cement ratio play an important role in the workability of concrete. With more surface area of sand, the demand for cement, and water increases to bond the sand with coarse aggregates. The control over these physical properties, of CSS makes the concrete require less amount of water and provides higher workable concrete. The less use of water also helps in increasing the strength of concrete less effort for mixing and placement of concrete and thus increases the productivity of construction activities at the site.

2.6. ADVANTAGE OF CSS FROM ENVIRONMENTAL EROSION POINT OF VIEW

The usage of CSS prevents the scouring of river beds to get RS which leads to environmental disasters like groundwater depletion, water scarcity, and risk to the safety of bridges, dams, etc. The quality of sand is as much of important as other materials for concrete. The sum of the percentages of all harmful material shall not exceed 6% for RS and 7% for CSS according to ES specifications. Materials must be checked for organic impurities such as decayed vegetation humps, coal dust, etc. Mostly common used sand in construction is RS. Thus, crucial to find the best type and good quality fine and coarse aggregates at site, because those material forms main components for the concrete mixture.

Due to growing construction activities in the country RS resources are increasingly minimized and at mean time its cost is very high. Depending to this, finding for a new source substitute of sand for reinforced concrete and HCB for the replacement of RS is significant.

A very well manufactured CSS as a partially and fully replacement to RS is the urgent necessity of the time. With the decline in the availability of RS alongside with the geological condition to minimize the mining of fine aggregate from rivers, the alternative to use CSS as replacement will increase.

2.7. SAND QUALITY TESTING AT CONSTRUCTION SITE

Different types of testing method for sand quality at quarry sites were executed. The Following illustrated tests are for sand quality in construction site:

1) Organic impurities.-test conducted at quarry site for every $20m^3$
2) Silt content:-test conducted for every $20m^3$
3) Particle size distribution test:-test conducted in laboratory or in quarry site for every 40m3.

The definition for the size of fine aggregate particles varies between about 150 µm - 4.75mm in diameter, however particles finer than this size are classified as silt and clay. Aggregates with particle size from 4.75mm-37.5mm are classified as coarse aggregate.

2.8. MANUFACTURING PROCESS OF CSS

CSS prepared by the following processes.

i) Decomposition of materials
ii) Mining
iii) Crushing
iv) Organizing by their grain size distribution

2.8.1. Decomposition of materials

The decomposition of materials takes many years. The mining and crushing take considerably small years relative to natural decomposition. The Idaga Hamus plant is stationary and has operated in the same location for years. Another type of sandstone crusher is movable (mobile) machine which are used for inaccessible construction sites. This type of machinery are not available in Tigray. Fixed machines can fabricate several amount of meter cube per day, whereas mobile machine are lesser and their result is always less than stationary machine.

2.8.2. Mining

Mining of sandstone is processed by scooping it up from the sandstone mountain with a manpower excavator to the crushing machine. After the sandstone is extracted with an excavator machine, it is then put onto conveyor belt for the crushing process.

2.8.3. Crushing

Sandstone rock are crushed to make a particular grain or texture that seems naturally accessible material.

- The crusher rotating cone in which the sandstone rock falls between an upper rotating cone and lower fixed cone that are separated by a very small distance. Any particles larger than this separation distance are crushed between the heavy metal cones, and the resulting particle fall out the bottom.

2.8.4. Organizing by their grain size distribution

In the processing plant, the incoming material is first crushed by machine. If the material is heavily bound together with clay, it passes through a blade mill which breaks it up into smaller gravel sizes.

The material then pass through several perforated screens or plates with different diameter hole to separate the particles according to their size. They are vibrated to allow the trapped material on each level to work its way off the end of the screen and onto separate conveyor belts. The coarsest screen, with the largest holes, is on top, and the screens underneath have progressively smaller holes.

2.9. QUALITY CONTROL

Larger crushing sandstone rock machines are computerized, and used to control the process. Such as

- Rate of feeding for entering material, and
- Vibrational rate of the mesh (screens)

All determined proportions of the finished products were controlled and examined. ES requirement for concrete & HCB mix require certain distribution size and shape of sand,

and sand manufacturer ensured the crushed sandstone satisfies that specification. Smaller particles silt & clay were isolated and sent to the sand classifying tank.

CHAPTER 3

3.0. MATERIALS, METHODOLOGY AND INVESTIGATION

3.1. MATERIALS

In production of concrete materials like cement, fine aggregate, coarse aggregate, and tap water are used.

The research was conducted with four basic steps.

1) Physical properties of the CSS & RS were studied. Then HCB and concrete samples were produced using different percentages of CSS and RS, then tested.
2) Laboratory test of fresh concrete and workability were conducted.
3) Bulk density of hardened concrete, Compressive strength and Flexural strength tests on casted concrete samples using CSS collected from Idaga Hamus and RS collected from the Gereb Giba quarry site were examined.
4) The compressive strength, of HCB with 0%, 50%, 75%, & 100% replacement of CSS as RS after 7th days of curing period were examined. A total of 24 hollow concrete blocks were manufactured using CSS, by varying proportion ratios of 0%, 50%, 75%, and 100%.

Physical laboratory tests, such as silt content and grain size distribution analysis conducted in the geotechnical laboratory of Mekelle University on samples to determine the fineness modulus of the material.

3.2. MATERIAL QUALITY ASSURANCE

All material collectors and workers were trained, sufficient information was given to the daily labor and professionals during every survey, and the collected raw material was stored, encoded, transported, and processed with care in the laboratory.

3.3. CRUSHED SANDSTONE SAND VS. RIVER SAND

3.3.1. Crushed sandstone sand

For CSS manufacturers, sands are final fine aggregate materials, but for concrete producers, sands are one of concrete constituents to be used for concrete production. Quality of sand depends by raw materials of sandstone rock chemical and physical composition. Besides, a fine aggregate extracted from RS and manufactured by crushed sandstone sands are the major resources of fine aggregate in Tigray region. So, searching for another alternative of RS is a necessary. One option used as option is CSS. Because of limitation in supply of RS and rising of construction activities, CSS plays an important role as one of main ingredient in concrete and HCB production.

Characteristics of Crushed Sandstone Sand

CSS is produced by crushing sandstone rock depositions into appropriate sizes. Sandstone rock is a sedimentary rock produced under high stress, and contains sand particles confined together by cementing materials composed of quartz, $CaCo_3$ (calcium carbonate), and Fe_2O_3 (iron oxide). (Ayenew. Y, Teklay. A & Saravanakumar Jagannathan, November 2017).

It is also noted that properly processed CSS will improve concrete strength properties such as compressive strength of concrete, and flexural strength due to better bond relatively to RS. Physical properties of sandstone particle size, color, and surface texture of materials depend on the quality of sandstone. Crushed sandstone produced using machines had great substitute for RS. The use of Sands and its important role is in adjusting the characteristics of fresh and hardened concrete and hollow concrete block.

3.3.2. Properties Of Sandstone Rock

General properties:

- Variable colors and types are found in sandstone. For example, most of them are white color. Darker type of sandstone indicates the presence of organic content like clay in the composition.
- Red, brown, yellow, and green colors are shows the presence of iron oxide in the cement, and matrix of sandstone.

Crushed sandstone sand has also been used extensively as material for main parts of structural element. However, the following problems assessed when CSS use as a replacement of NS.

- ✓ Strength and durability
- ✓ Economic benefit
- ✓ Accessibility of material

Therefore it is appropriate to consider some remedial measures or construction techniques to avoid any failure from such properties of the CSS. In order to solve the above problems, the use of CSS mixed with NS can be one of the appropriate techniques.

The type and size of the CSS materials were identified, the percentage of the mixture, and the practical and theoretical considerations for these mixed materials are the main issues that discussed and clarified. In this thesis, a study had been conducted on the effects of blending CSS with naturally available sand materials using several laboratory tests. The concrete materials produced by mixing CSS with RS materials are referred to as “mixed sand”.

Chemical properties of sandstone

Sandstone has various mineral, content such as calcite, clay, feldspar, micas, quartz, and so on. The chemical compound content of sandstone rock is aluminum oxide, CaO, iron (III) oxide, potassium oxide, MgO, Sodium oxide, silicon dioxide, and so on. Biological, chemical, and mechanical weathering are common in sandstone.

Table 3.1 chemical properties of sandstone rock

Chemical property	Percentage (%)
CaO	4.6
SiO2	78
Al2O3	8.7
Fe2O3	4.1
MgO	1.4
K2O	1.8
Na2O	1.4
total	100

3.3.3. River Sand

Fine aggregate from the river by the naturally case of erosion, the shape and texture of the material becomes smoother and round shape. It carries high moisture between particles. This characteristics made better workable. The Other issue related with this type of sand is obtaining sufficient grading of fineness modulus of 2.3 - 3.1 according to ASTM C 33, and 2 - 3.5 ES.CD 3.201 recommendation. Nowadays it has increasingly hard to find good consistent quality of grading requirements and small amount of silt and clay.

The RS particles are rounded texture and are usually almost spherical. Well-shaped material is an ideal for the workable of mixture. Overall, spherical shape of RS is ideal in a concrete mixture to provide the best material to handle the job and finish the surface.

3.4. MATERIALS AND DATA COLLECTION

Every required data for this study was collected from inquiries of the crushed sandstone material professionals and by continuous follow-up of the concrete & HCB production and experimental investigation of the material. The CSS is purchased from Idaga Hamus, and RS is extracted from Gereb Giba.

The CSS was prepared according to the Ethiopian building code standard minimum requirements of RS for concrete and HCB production applications in Ethiopia. Silt and clay content of the CSS in laboratory was investigated.

Type of cement that meets the ES, and the maximum size of 9.5mm-25mm crushed coarse aggregate with a minimum specific gravity of 2.64 were used for concrete, and maximum size of 9.5mm crushed coarse aggregate, 4.75mm-150µm manufactured stone fine aggregate with a minimum specific gravity 2.64 was used for HCB. The mix proportions are intended for concrete and HCB that has a normal unit weight & target mean compressive strength of concrete was C-25 and 4.2 MPa for HCB.

Materials used in this research for hollow concrete block production and concrete mix are illustrated below;

3.4.1. Source Of Materials

A. Ordinary Portland cement (OPC) - from the Messobo cement factory.

B. Coarse aggregate - from Debri, one village around Mekelle, Tigray

C. Fine Aggregate (FA) - CSS from Idaga Hamus and RS from Gereb Giba.

D. Water: - is supplied by mekelle city authority.

Fine aggregate

River Sand and Crushed Sandstone Sand

Fines available in two sources Idaga Hamus, and Gereb Giba were used. Physical tests were conducted on the RS and CSS.

Property tests and test methods

Table 3.4 Property tests and test methods

Property Tests	**Test Methods**
Sieve analysis (Idaga Hamus CSS, debri CA)	A.S.T.M C-136
Unit weight (Idaga Hamus CSS, NS Gereb Giba)	A.S.T.M C-29
Silt content (Idaga Hamus CSS and NS Gereb Giba)	A.S.T.M C117
Specific gravity and absorption (Idaga Hamus CSS, NS Gereb Giba)	A.S.T.M C-127

3.4.2. Sieve Analysis

Sieve analysis is a method to determine particle size distribution of all aggregates. And also applied to find modulus of fineness, an index to the fineness, coarseness, and uniformity of aggregates. This properties of the CSS materials significantly affect the characteristic properties of concrete and HCB (Priyanka A. Jadhav, Dilip K. Kulkarni, 2013).

3.4.3. Unit Weight

Unit weight is the weight of a given volume of well graded fine aggregate. And measurement of density also called bulk density. The merely process of unit weight measurements is by filling a known container volume and weighing it. Though, time of vibration will cause to vary the amount of void space.

3.4.4. Specific Gravity

Expression of sand density is called specific gravity. And it is relation between the ratio of the material and the same volume of water.

3.4.5. Silt Content

Fine material that is less than 150 microns are called silt content. And these substances are unstable in the presence of water. Material in CSS finer than 75μm considered as clay. The occurrence of silt and clay mainly affects the workability of concrete mix and its result has effect on the strength of concrete and hollow concrete block.

The bonding between cement and sand can reduce due to the excessive quantity of silt and clay, the characteristic strength and stability of concrete, low potential for high density, and sensitivity to cracking.

3.5. METHODOLOGY

3.5.1. Methods of Material Sampling & Blending

All the sampling and blending methods for the manufacturing of concrete and HCB followed all the practical recommendations of the ES and construction materials laboratory manual by Abebe dinku (June 2002). A sample of the raw materials was taken from quarry site of the selected place used for making concrete & HCB production.

3.5.2. Methods of Specimen Production

The methods for the production of the specimen are applied to all the methods of concrete & HCB manufacturing method. Moreover, the production steps followed the design procedures of the ASTM C31 code.

3.5.3. Test Specimen And Procedure

The specimens were made in a laboratory and DE molding approximately 24 hours after its casting then curing 7^{th} days, 14^{th} days, and $28t^{h}$ days for samples of concrete and 7^{th} days for HCB. Then each specimen will dry by exposing it to natural sun light.

The final product of this concrete & HCB was tested in Mekelle University Construction and Geotechnical Engineering Laboratory for different experimental investigations and a recommendation would be forwarded based on the test result. An experimental investigation was carried out by ES using a compressive strength testing machine.

3.5.4. Procedure Of Specimen Production

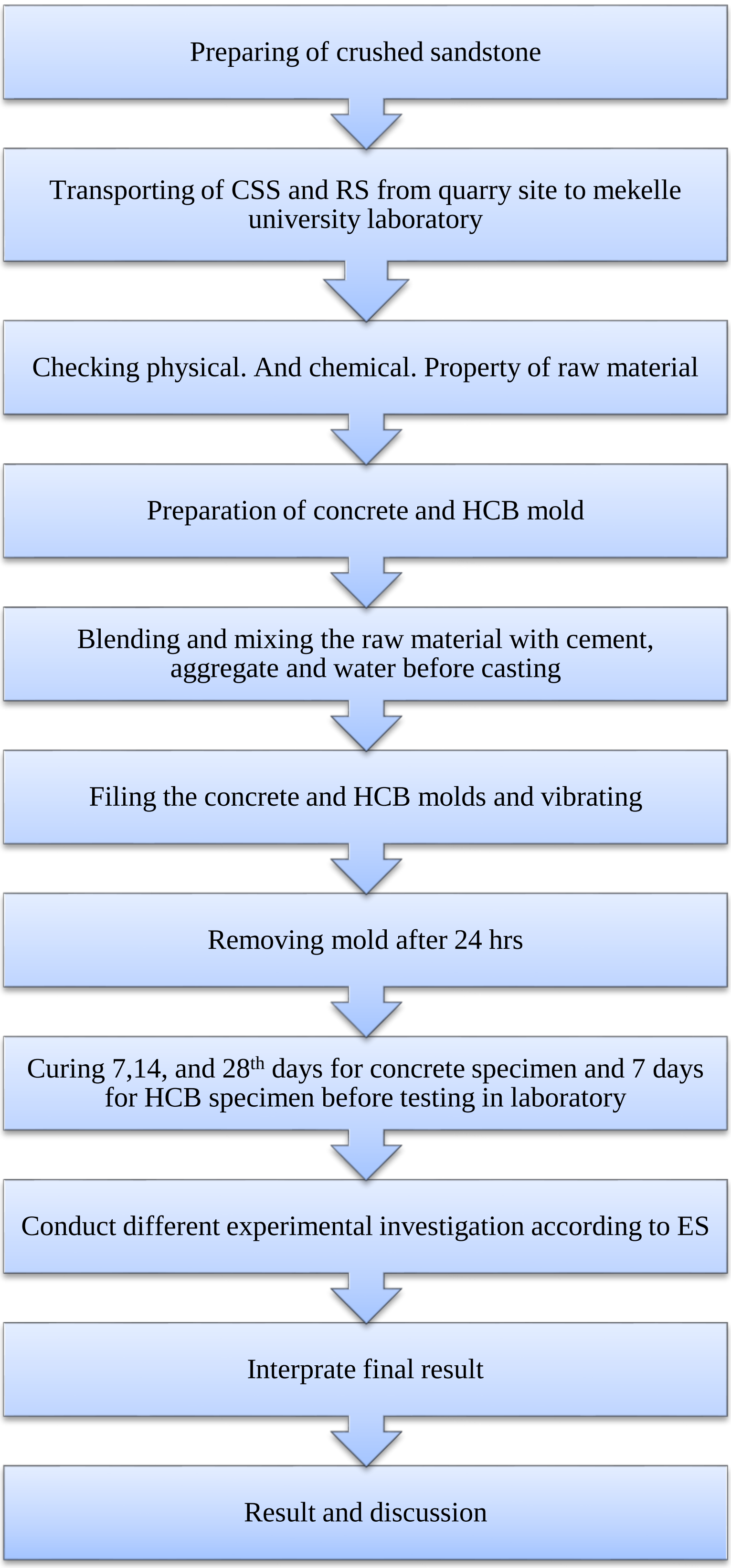

Figure 3.1 procedure of specimen production

CHAPTER 4

4.0 EXPERIMENTAL RESULT AND DISCUSSION

PRELIMINARY INVESTIGATIONS BEFORE RAW MATERIALS, CONCRETE AND HCB PROPERTY TEST

4.1. EXPERIMENTAL PROGRAM

The materials investigated in this work were the fine aggregate's physical property, and process to apply and adjust the required concrete and HCB property due to their presence. The effect of replacement CSS on fresh concrete mortar and hardened concrete strength was determined. For fresh concrete study workability of concrete also included, whereas the hardened concrete and HCB properties studied its strength.

Four types of percentage replacement (0%, 50%, 75%, and 100%) were evaluated with well-graded particle size distribution of fine aggregate. Concrete mixtures with a 1:2:3 ratio of approximately 215 kg fines per m^3 of concrete were tested. Also, HCB mixtures with 1:1:2:4 (50kg of cement, 1 construction cart of sand ($0.078125m^3$), 2 construction cart manufactured stone fine aggregate ($0.15625m^3$) and 4 construction carts coarse aggregate $0.3125m^3$ and water) ratio were studied. Water to cement ratio (w/c) in all concrete mixtures was constant at 0.5 for RS and 0.55 for CSS in concrete production.

The workability of fresh concrete mixtures for all tests was adjusted to the value of slump value 50mm-100mm.

4.2. EXPERIMENTAL LABORATORY INVESTIGATION

Initial and final results of laboratory tests for concrete and HCB were tabulated. Testing for fresh and hardened samples plays an important role in confirming the material quality ratio of concrete works.

Unfortunately, very little information is available on concrete and HCB properties manufactured using CSS, and this is mainly because many investigators have not concentrated most of their efforts on finding solutions to the strength behavior associated with these CSS.

Furthermore, a full knowledge of durability are essential to estimate bearing capacity of the foundation and also to evaluate the stability of the building, road sideway, and retaining wall built with these CSS concrete. This laboratory experimental investigation, the strength of concrete, and HCB are calculated using CSS for C-25 concrete mix ratio and HCB with none, partial and full replacement of CSS as RS.

For the present experimental investigation, 36 specimens of 150mmx150mmx150mm cubes of concrete mold for compressive strength and 9 specimens of 500mmx150mmx150mm beams for flexural strength are prepared. 24 sample specimens of 40cmx20cmx20cm HCB were cast. The mix design of concrete were 25 MPa and the optimum strength is 4.2 MPa for HCB. Concrete property at age of 7th, 14th, and 28th days of curing period for C-25, and 7 days of curing for HCB.

4.2.1. <u>Physical Properties of CSS and RS</u>

Physical property test was conducted in Mekelle University on samples taken from the Idaga Hamus, and Gereb Giba quarry site, to estimate silt, and clay content of the CSS and river (NS) sand.

Figure 4.1 CSS material

Figure 4.2 RS material

4.2.2. Test for Silt Content of RS and CSS

If sands contain more than allowable percentage of silt, and clay must be washed to bring with allowable limits. Depending to Ethiopian standard the materials shall be washed or rejected if it exceed the value of 6% for RS and 7%, for CSS.

Figure 4.3 CSS and natural (rive) sand washing

Results showed that CSS from the Idaga Hamus quarry site indicated 5.2% silt content which is smaller than the required Ethiopian standard of 7%, while from the Gereb Giba RS quarry site indicated 8.6% silt content. This physical property test result exceeded the 6% Ethiopian standard. This sample should be rejected or properly washed.

4.2.3. Results and Discussion of Silt Content

According to the Ethiopian Standard (ES), it is recommended to wash the sand or reject it if the silt content exceeds a value of 6% for RS and 7% for CSS. Depending on the results in the above Table 4.1. Silt content of Idaga Hamus crushed sand (CSS) satisfied the ES recommendation, and Gereb Giba RS exceeded the limit of Ethiopian standards. After execution the process, the Silt content of Idaga Hamus CSS and RS of Gereb Giba, fine aggregate (FA) average silt content showed 4.62% and 5.4% which was less than the allowable 7% and 6% respectively.

4.3. SIEVE ANALYSIS OF FINE AGGREGATE

The main objective of this test is to determine the particle size distribution of fine aggregate CSS and RS.

4.3.1. Test For Grading Of Sands

Based on particle size of fine aggregates the material graded into four zones i.e. graded, poorly graded, uniformly graded, and gap graded according to their uniformity coefficient. The above fine aggregate categories has directly association with a strength of concrete manufactured using the fine aggregate.

4.3.2. Sieve analysis comparison of CSS with RS after washing

Sieve analysis of Idaga hamus CSS

Fineness Modulus

Idaga Hamus CSS Fineness modulus

$\mathrm{FM} = 2.946$

Sand said to be well graded, if the uniformity coefficient (Cu) is greater than 6, and the coefficient of curvature (Cc) lies in b/n 1 to 3.

From the above gradation curve of Idaga Hamus we obtain

D_{10}=0.17, D_{30}=0.44, D_{60}=1.1

$\mathrm{Cu} = \frac{D60}{D10} = \frac{1.1}{0.17}$=6.47

$\mathrm{Cc} = \frac{(D30)^2}{D60*D10} = \frac{0.44^2}{1.1*0.17}$=1.0353

If Cu is greater than 4 the sand is categorized as well graded. However if Cu is less than 4, the sand is categorized as poorly graded, and/or uniformly graded. Therefore Idaga hamus CSS grain size distribution is well graded.

Sieve Analysis of Gereb Giba RS

Fineness Modulus

Gereb Giba RS Fineness modulus

$\mathrm{FM} = 2.7534$

Particle size distribution of Gereb Giba RS

From the above gradation curve of Idaga Hamus it was obtained

D_{10}=0.18, D30=0.5, D_{60}=1.15

$\mathrm{Cu} = \frac{D60}{D10} = \frac{1.15}{0.18} = 6.3889$

$\mathrm{Cc} = \frac{(D30)^2}{D60*D10} = \frac{0.5^2}{1.15*0.18} = 1.20773$

When Cu is greater than 4, the sand is classified as well graded, whereas when Cu is less than 4 the sand is classified as poorly graded or uniformly graded.

4.3.3. <u>Result and discussion Of Sieve Analysis</u>

The cumulative percentage passing of particles were compared to CSS with RS and presented in the above Table 4.3 and Table 4.4 as the sieve analysis result revealed that the CSS and RS fulfill ASTM C 33.

Also, the sieve analysis result indicated that 2.946 fineness modulus of the Idaga Hamus CSS were slightly greater than that of Gereb Giba RS 2.7534 fines modulus. This means the sands from the Idaga Hamus are coarser sizes than materials from the Gereb Giba RS quarry site.

The particle size distribution curve shown in the above figure 4.5 that the CSS possesses good grading but with large size particles falling on finer limit, and has 4% micro fines. And also Gereb Giba RS possesses better grading and meets ES requirement as it undergoes inherent sieving, filtering and washing process. Gereb Giba RS has 2.458% micro fines.

In Figure 4.5, it shows the particle size distribution curve, Idaga Hamus CSS possessed proper grading but with large size particles which were under the limit. According to ASTM C33-03, the sand should not be more than 45 % passing in any sieve and retained on the next consecutive sieves, while its fineness modulus should not be less than 2.4 and not be more than 3.1.

Based on the results, the fineness modulus of Idaga Hamus CSS quarry site indicated 2.946, while the Gereb Giba NS indicated 2.7534. It means both fine aggregates are well-graded representing workable concrete mixes.

4.4. LABORATORY TEST OF FRESH CONCRETE

4.4.1. Test For Workability Of Concrete

Mixing and Testing

Coarse aggregate and 2/3 of water was added to the mixer, and mixed together for 1 minute, Then All types of fine aggregate materials were added (CSS, and RS) and cement with proportion, then materials were mixed for 10 minutes.

Workability of fresh concrete was determined by the slump test. The first result wasn't adequate, then Workability adjusted to 50mm-100mm.

4.4.2. Slump test

Slump test was measured on the replaced of RS by CSS on mortar mixtures for different percentages, such as 0%, 50%, 75%, and 100%, and other concrete materials. After achieving the planned slump test and removing some concrete for the preparation of specimens for hardened concrete tests, mixing continued, and the slump was measured every 20 minutes until the slump was reduced approximately to zero. The workability test was determined and recorded only for the above Series replacement ratio.

The initial slump for each mixture was adjusted to 50mm-100mm, and the results presented are normalized to that initial slump. The slump was adjusted by adding a medium range of water. The slump test result adjusted more rapidly compared with mixtures in which workability was achieved by adding water.

Types of slump test

1) True slump
2) Shear slump
3) Collapse slump

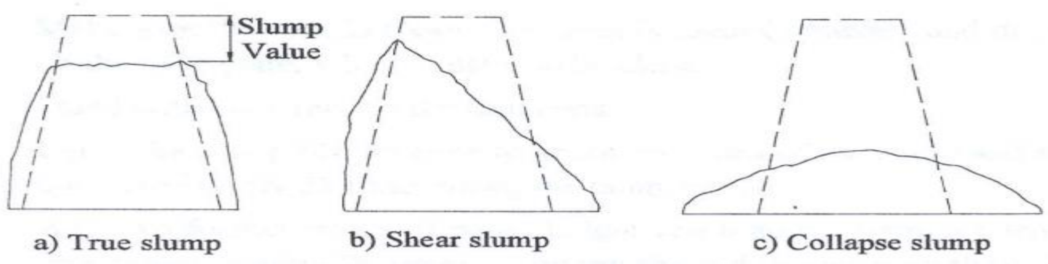

Figure 4.4 Types of slump test

Table 4.5 average workability of concrete on none, partial, & full replacement of RS by CSS

NO.	Percentage of RS	Percentage of CSS	Water Content	Average Result
1	100 %	0 %	0.5	93
2	75 %	25 %	0.5	80
3	50 %	50 %	0.5	76
4	25 %	75 %	0.55	63
5	0 %	100 %	0.57	57

4.5. TESTS PERFORMED ON HARDENED CONCRETE

4.5.1. Test for compressive strength, of concrete

A detailed study of compressive strength of concrete, and HCB is carried out in the laboratory using a compressive strength testing machine (CTM). For verification, 36 cubic samples of concrete were manufactured using CSS and RS, and their physical and mechanical properties were tested.

In the production process, both CSS and RS samples were taken, but to minimize uncertainties from protruded CSS, mostly selected raw material samples were tested, and standard sizes were used. For each test, the strength behavior including the influence of water absorption with the strength parameters are evaluated and discussed.

4.5.2. Specimen Preparation

The specimen were cast by standard molds of concrete. The specimen's 150mmx150mmx150mm dimension was equal to the ES specification. Extreme care was taken when casting. The material samples of CSS were manufactured using machinery and manpower. The lowest silt content of RS after washed was below 4.97%, but on average it was 5.4%. Below this silt content, the sands are extremely hard and have high enough strength for testing. For the preparation of samples, the Ethiopian standard mechanism was followed.

Figure 4.5 150mmx150mmx150mm cubic mold

4.5.3. Test Procedure

Machine equipment was used for testing the specimens in the Mekelle University construction and geotechnical engineering laboratory. For each specimen, a carefully cast was taken and attached paper on the side with a marker.

4.5.4. Calculation

Compressive strength test was carried out on the samples prepared to compare the strength of the concrete with none, partial and full replacement of RS by Idaga Hamus CSS. Tests at 7^{th}, 14^{th} and 28^{th} day was conducted according to (BS EN12390 part 3 2002).

4.5.5. Sample Size and Sampling Procedure

The result of tests was used to compare the strength of normal weight concrete with sandstone fine aggregate concrete. There were three samples of cube size of 150mmx150mmx150mm mold used for each test of the characteristic compressive strength of concrete based on (BS EN12390 part 3 2002).

Figure 4.6 compressive strength machine and tested cubic concrete

4.5.5. <u>Concrete Mix Design</u>

American concrete institute (ACI) method of concrete mix design is used to prepare the concrete mortar mixes particularly the mix was prepared for C-25 compressive strength. The water to cement ratio used was 0.50 for RS, & 0.55 for CSS, and cement content of 360kg/m^3, although the highest size of coarse aggregates for concrete is 25 mm and a minimum 4.75mm sieve size.

The mix design, proportion 0%, 50%, 75%, and 100% CSS from Idaga Hamus and RS from Gereb Giba Quarry Sites as none, partial and full replacement was prepared with a ratio of 1:2:3 concrete mix design.

Table Concrete mix design for 100% Idaga Hamus CSS

IDAGA HAMUS 100% CSS									
Design of Normal concrete mixes. C-25									
Concrete mix design for class AII (25 Mpa) Cube Strength.									
Stage	**Item**		**Reference or calculation**			**values**			
1	1.1	Characteristic strength	Specified	Compressive 25		N/mm^2 at		28	days
				Proportion defective				5	Percent
	1.2	Standard deviation		____4___		N/mm^2 or no data			N/mm^2
	1.3	Margin	C1	(k = 1.64) 1.64 X 4			=	6.56	N/mm^2
	1.4	Target mean strength	C2	25	+	6.56	=	31.56	N/mm^2
	1.5	Cement type	Specified	PPC					
	1.6	Aggregate type: Coarse		CRUSHED					
		Aggregate type: Fine		CRUSHED					
	1.7	Free water/Cement ratio		0.58		Use the lower value			
	1.8	Maximum free-water/cement ratio	Specified	0.45					
2	2.1	Slump or V-B	Specified	Slump 50 - 75 mm				-	S
	2.2	Maximum aggregate size	Specified					20	mm
	2.3	Free water content						190	kg/m^3
3	3.1	Cement content	C3	190	÷	0.45	=	422	kg/m^3
	3.2	Maximum cement content	Specified					-	kg/m^3
	3.3	Minimum cement content	Specified	360	kg/m3 ---Use if greater than Item 3.1				
					and calculate Item 3.4				
	3.4	Modified free-water/cement ratio				-			
4	4.1	Relative density of aggregate (SSD)		2.77					
	4.2	Concrete density						2477	kg/m^3
	4.3	Total aggregate	C4	2477 -	190 -	422	=	1865	kg/m^3
5	5.1	Grading of fine aggregate	BS 882	Zone	2				
	5.2	Proportion of fine aggregate						48	Percent
	5.3	Fine aggregate content		1865	X	0.48	=	895.2	kg/m^3
	5.4	Coarse aggregate content	C5	1866	-	895	=	971	kg/m^3
			Cement		**Water**	**Fine aggregate**		**Coarse aggregate**	
	Quantity		**(Kg)**		**(Kg or L)**	**(Kg)**		**(kg)**	
	- Per m3 (to nearest 5kg)		**422**		**190**	**895**		**971**	
	- Laboratory trial mix of 0.027 m^3		**11.4**		**5.13- 5**	**24.2**		**26.2**	
	- Admixture (Min 0.5 - 3%)								
	per the weight of cement								
By fitsum reda					Date 12/08/2024				

4.5.6. Experimental Tests And Average Results of Compressive Strength

In this laboratory investigation, the characteristics strength of concrete were obtained using Idaga Hamus and Gereb Giba for 25MPa. To determine compressive strength of concrete, a total of 36 samples of concrete cubes were casted and tested using ACI method and procedure. Three cubes were casted on each replacement of CSS as RS. The average results are given below in Table 4.6.

4.5.7. Average Compressive Strength of concrete specimens @ different days

Table 4.6 Average Compressive Strength of concrete cubic specimens @ different days

NO.	% of Gereb Giba RS Composition	% of Idaga Hamus CSS Composition	Average Compressive Strength @ 7th day	Average Compressive Strength @ 14th day	Average Compressive Strength @ 28th day
1	100%	0%	18.084 MPa	22.566 MPa	27.52 MPa
2	50%	50%	19.0474 MPa	24.74 MPa	30.286 MPa
3	25%	75%	20.231 MPa	26.43 MPa	34.281 MPa
4	0%	100%	22.563 MPa	29.4 MPa	39.593 MPa

Average % of relative compressive strength of concrete specimen

Table 4.7 Average % of relative compressive strength of concrete specimen

% of crushed sandstone sand	Relative compressive strength at 7th day		Relative compressive strength at 14th day		Relative compressive strength at 28th day	
	average	relative	average	relative	average	relative
0%	18.08		22.56		27.52	
50%	19.04	5.32	24.73	9.61	30.28	10.05

75%	20.23	6.21	26.43	6.85	34.28	13.19
100%	22.56	11.52	29.44	11.22	39.59	15.49

4.5.8. Compressive Strength Vs. Percentage Of Replaced Sand

Figure 4.10 shows that the increment in the percentage of CSS, result of the compressive strength of concrete increases up to 15.49274% for 100% of CSS, this slightly upward side graph implies there is an increase in compressive strength of concrete at 28th days curing period. This shows that 100% replacement of CSS will increase the strength, therefore it has good compressive strength compared to 100% of RS.

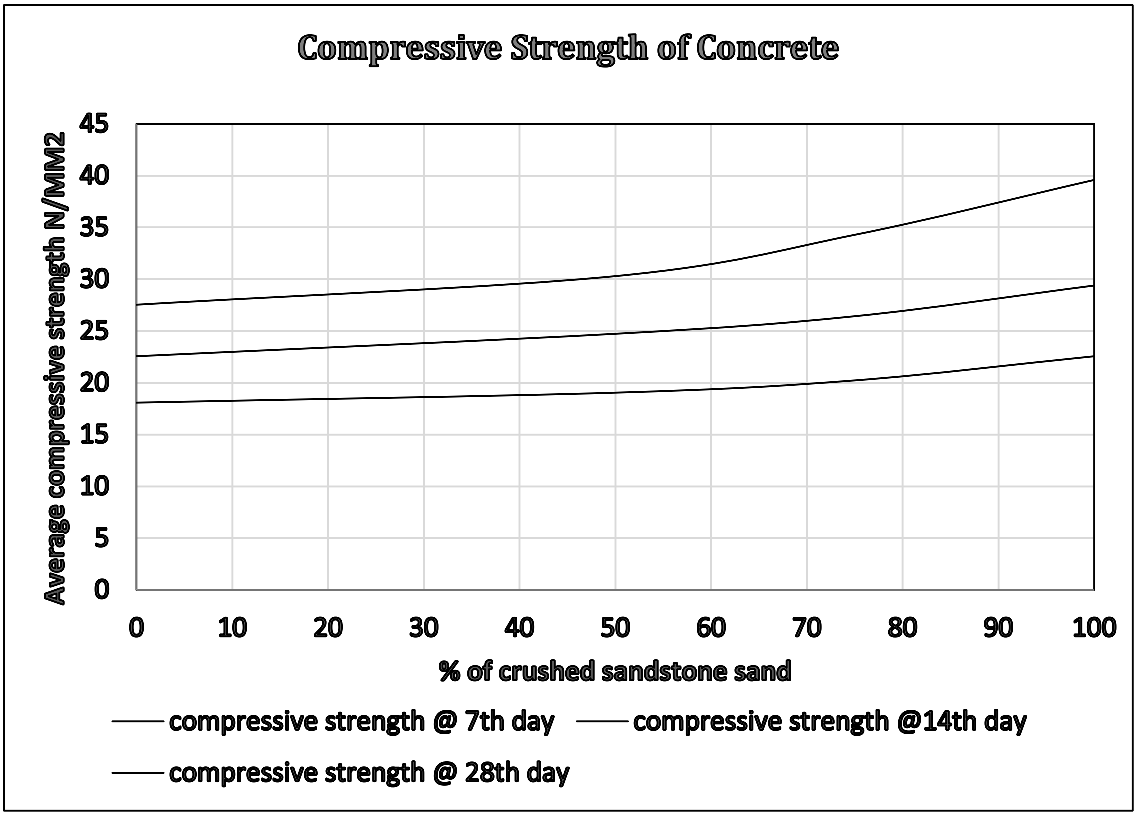

Figure 4.7 compressive strength of concrete curve on 0%, 50%. 75% and 100% replacement of RS by CSS

4.5.9. Average Unit Weight of concrete at different curing period and replaced RS by CSS

Three cube specimens for different percentages RS replacement by CSS were investigated to obtained the 7th day, 14th day, and 28th day compressive strength of concrete, using a 2000kN capacity compressive strength Testing Machine. It revealed that the 28th-day curing period specimen increases up to 15.4927% relative strength replaced by CSS.

Table 4.8 Average unit weight of concrete specimens @ 7th, 14th and 28th curing period

NO.	% of Gereb Giba RS Composition	% of Idaga Hamus CSS Composition	Average unit weight @ 7th day gm/cm^3	Average unit weight @ 14th day gm/cm^3	Average unit weight @ 28th day gm/cm^3
1	100%	0%	2.393	2.456	2.463
2	50%	50%	2.370	2.417	2.447
3	25%	75%	2.404	2.4098	2.371
4	0%	100%	2.4077	2.4338	2.4494

4.5.11. Result and Discussion

Maximum improvement was generally seen on the 28th day of the curing period. Appendix - A presents the compressive strength on the 7th, 14th, and 28th days relative to the control mixture NSC and CSSC at a different percentage of replacement. A development of greater than 5.3291% was perceived for 50% replaced of CSS in all samples.

At a CSS content of 100%, the improvement of concrete strength relative to the control mix was 11.526% for the average Sample 7th day curing period, 11.226% for the average sample 14-day curing period, and 15.4927% for the average Sample 28 day curing period. Mixtures exhibited that the strength increased as the CSS content increased. Generally at a CSS content of 0%, 50%, 75%, and 100%, and 28th days curing period of concrete the mean unit weight was 2.463 gm/cm^3, 2.447 gm/cm^3, 2.371 gm/cm^3 and 2.4494 gm/cm^3 respectively.

Based on the test outcomes, the average strength was described on the 7th day, 14th day, and 28th day curing period for 100% River Sand.

- The highest recorded compressive strength for RS (i.e. 0% of CSS) on the 7th day was 18.889MPa between the tested three specimens, within average compressive strength were 18.084MPa. This result indicates it fulfills the ES requirement i.e. 65% of compressive strength at 28 days.
- On the 14th day curing period 23.175 MPa maximum compressive strength were recorded, whereas the average compressive strength was 22.575 MPa. This result indicates it fulfills the ES requirement i.e. 90% of compressive strength at 28 days.
- On the 28th day curing period, the highest recorded was 28.75 MPa for sample 1, 27.5 MPa for sample 2, and 26.3 MPa for sample 3. The average compressive strength, obtained was 27.520 MPa. From the 7th day up to the 28th-day curing period. It fulfills the ES requirement i.e. 25 MPa of compressive strength at 28 days.

The average strength, was described on the 7th da, 14th day, and 28th day curing period for 100% CSS.

- The highest recorded compressive strength for CSS on the 7th day was 23.2 MPa among the three samples tested, with a mean compressive strength of 22.5667 MPa. It fulfills the ES requirement i.e. 65% of compressive strength at 28 days.
- On the 14th day curing period the highest recorded compressive strength, was 30.6 MPa, while the mean compressive strength; was 29.4 MPa. It fulfills the ES requirement i.e. 90% of compressive strength at 28 days.
- On the 28th day curing period, the highest recorded was 40.6 MPa for sample 1, 38.39 MPa for sample 2, and 38.787 MPa for sample 3. The average compressive strength, obtained was 39.59 MPa. From the 7th day up to the 28th-day curing period. It fulfills the ES requirement i.e. 25 MPa of compressive strength at 28 days.

4.6. TESTS FOR FLEXURAL STRENGTH OF CONCRETE

Flexural strength is the ability of a beam or slab to resist failure in bending. It is measured by loading unreinforced concrete beams with a span three times the depth as ES recommendation. The flexural strength is expressed as “Modulus of Rupture” (MR) in MPa.

Tests are carried out on beams conforming to IS 516: 1959 to obtain the flexural strength at the age of 28th day of curing period. In the flexural test a standard plain concrete beam of rectangular cross section is simply supported and subjected to central point loading test method until failure.

Three beam samples each, total 9 beams at 0%, 50% and 100% CSS of the mix were tested to determine the flexural strength using a 1000kN Universal compression Testing Machine (UTM). The result of average flexural strength of Concrete is given in Table 4.9. It is seen that the flexural strength increases up to 13.226% relative to control concrete mixture. The test was carried out using center point loading test method.

Figure 4.8 flexural strength testing machine

The following graph shows the flexural strength of concrete for the 0%, 50% and 100% mix proportion of crushed sandstone sand (CSS) at 28th day of curing.

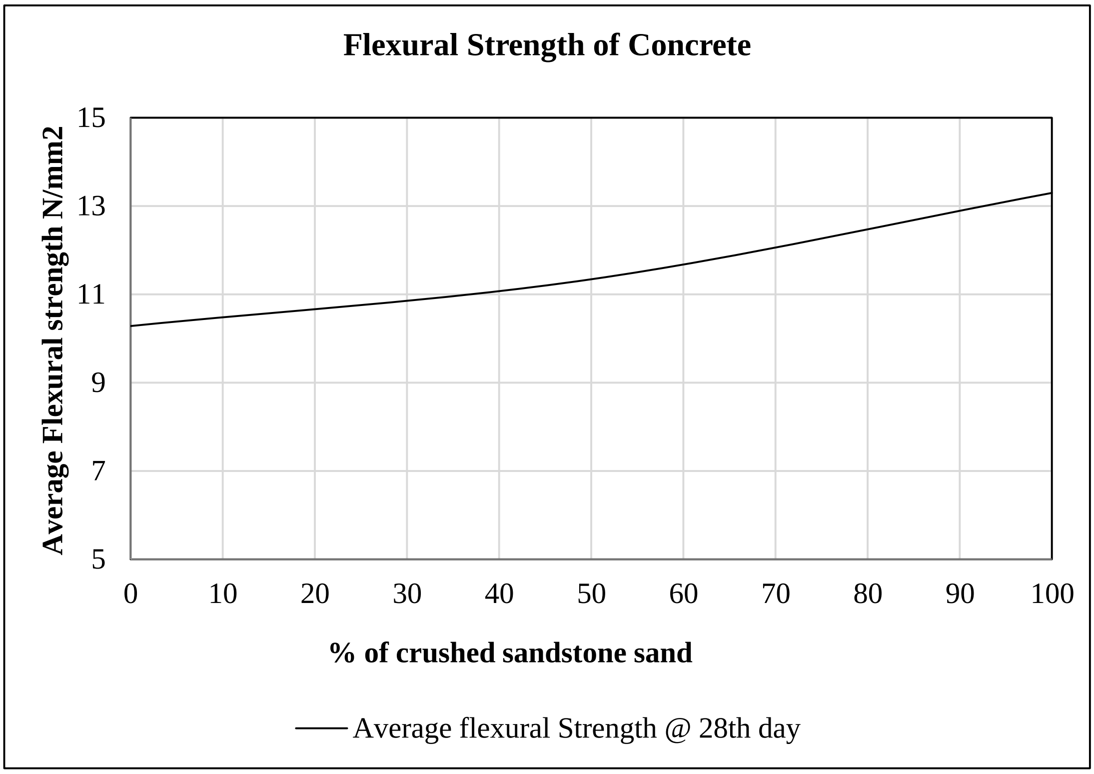

Figure 4.9 Average Flexural strength@ 28 day (N/mm^2)

4.5.10. Average Test Result On Flexural Strength

The test was carried out conforming to ES 516-1959 to obtain the 28th day of curing period of concrete flexural strength with none, partial, and full replacement of RS by CSS.

Table 4.9 the average relative Flexural Strength Values for Replacement of RS by CSS

Number of specimens	percentage of RS	Percentage of replaced CSS	Average of Flexural strength at 28th day (MPa)	Relative flexural strength (%)
S1	100%	0%	10.41	-
S2	50%	50%	11.745	12.8242
S3	0%	100%	13.298	13.2226

4.5.11. Conclusion

The table 4.9 and figure 4.12 showed the flexural strength values for the conventional and CSS replaced concrete. From the above table and graph, it was found that there was increasing in the concrete flexural strength values up to 100% replacement of RS by CSS. The relative Flexural strength value is increased by 13.226% more than conventional concrete for CSS sand replaced concrete, up to 100% replacement of CSS compared with conventional concrete.

The experimental results revealed that 100% replacement of CSS with RS is the best replacement for the grades of concrete C-25.

4.6. COMPRESSIVE STRENGTH TEST FOR HCB

Hallow concrete block are masonry units, usually solid or with single or multiple hollows, made of various ingredients: cement, fine aggregate, gravel, crushed stone and water. According to ES HCB are classified into three classes: Class A, B and C. (abebe dinku 2002)

Class A and class B, load-bearing units suitable for use as:

- External walls pointed, rendered and plastered.
- The inner leaf of cavity walls or as backing to brick or stone masonry.
- Internal wall or partitions.

Class C, non-load bearing units suitable for as:

- Non-load bearing walls and partitions, and
- Non-load bearing internal panels in steel framed and reinforced concrete framed buildings

4.5.12. Density Of HCB Blocks

The weight of hallow concrete block (HCB) should not be high; otherwise it will impose high dead load pressure on the structural members of the building or any other work. According to, IS 596:2001 class A, B and C blocks are recommended to have a density ranging from 900 kg/m^3 to 1500 kg/m^3. As can be seen from the result, the densities of all the blocks are up to the required range for class A, and B HCB.

According to the tested specimens IS: 2185 (Part I) – 1979, HCB made using RS & sandstone sand (CSS) are slightly below the other types of stones. In addition, lower weight will also have its advantage in reducing the total dead load the structural members of a building are expected to carry. Then these HCB were tested in the construction materials laboratory of Mekelle University. The compressive strength test was performed using a 1000kN Universal compression Testing Machine (UTM).

<u>Minimum compressive strength for the three classes of HCB [ES C.D3.301]</u>

Table 4.10 minimum compressive strength for the three classes of HCB [ES C.D3.301]

Class	Average of 6 units (N/mm^2)	Individual units (N/mm^2)
A	4.2	3.8
B	4.0	3.2
C	2.0	1.8

When used for the construction of structural walls stone, bricks and blocks should be strong enough to safely carry superimposed loads in addition to their own weight of overlying units. That is

Hollow concrete block production site

Figure 4.10 Hollow concrete block production site

Average Compressive Strengths at different percentage replacement of sands for 40*20*20 cm hallow concrete block (HCB)

Table 4.11 computation of average compressive strength for concrete block

NO.	Percentage of river sands Composition	Percentage of crushed sandstone sand Composition	Average HCB Compression Strength (7th Day), MPa
1	100%	0%	5.9
3	50%	50%	6.31
4	25%	75%	7.25
5	0%	100%	8.23

CHAPTER 5

5.0.CONCLUSION AND RECOMMENDATION

5.1.CONCLUSION

The experimental investigation works carried out in the laboratory were to evaluate the fresh, and hardened properties of concrete, and HCB production using none, partial, and full replacement of RS by Idaga Hamus CSS. As a result, the production cost of Idaga Hamus CSS at quarry sites is cheaper than the price per cubic meter of Gereb giba RS.

- It is observed that the compressive strength and flexure strength of concrete and compressive strength of HCB is improved by partial and full replacement of RS by CSS.
- The maximum mean compressive strengths on the 28th day curing period the Idaga Hamus CSS attained the minimum required strengths for C-25 grade concrete. When the percentage of replacement of CSS goes beyond or above 50%, the strength is considerably increased.
- To sum up, Idaga Hamus crushed sandstone sand fits the standard specifications with all laboratory test results. Therefore, before using it in a concrete mix and HCB, it must follow this thesis procedure thoroughly which can be served as a suitable replacement for RS.

5.2. RECOMMENDATION

From the above experimental results it is proved that CSS can be used as a partial and full replacement for RS. Given the results of this study, it seems that the current limitation on CSS content in concrete should be reevaluated.

The results proved that the replacement of 100% of RS by CSS induced higher compressive strength, and higher flexural strength both in concrete and HCB production. However, additional characteristics strength of concrete and chemical property of CSS are need further investigation to evaluate the raw material. Some of them are listed below:

1) The cementitious property of CSS.
2) The tensile strength of concrete & HCB with fully and partially replacement of CSS as RS.
3) Air content test.
4) Concrete permeability test.
5) Flow test.

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6) ASTM C-117 this test method covers the determination of the amount of material finer than a 75-µm (no. 200) sieve in aggregate by washing.
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APPENDIX

Appendix – A

Silt content Result of CSS and RS

Table 4.1 Silt content Result of CSS and RS

Source of CSS and river (NS) Fine Aggregate (FA)	Before washing		After washing		Silt content of FA (%) before washing	Average Silt content of FA (%) after washing
	A	B	A	B		
Idaga Hamus CSS	3.9mm	75 mm	3 mm	65 mm	5.2 %	4.62%
Gereb Giba river (NS)	7 mm	81 mm	4 mm	74 mm	8.6%	5.4%

Appendix - B

Grading requirement of fine aggregate (ES C) Abebe dinku

Table 4.2 grading requirement for fine aggregate (ES C.D3.201) abebe dinku

Sieve size	Percentage Passing
9.5mm	100
4.75mm	95-100
2.36mm	80-100
1.18mm	50-100
600µm	25-60
300µm	10-30
150µm	2-10

Appendix - C

Table 4.3 Sieve Analysis of Idaga Hamus CSS

Sieve no.	Sieve size	Weight of retained (gm)	CSS % retaining	CSS cumulative % passing	Cumulative retained (%)	Recommendation ES C.D3.201 % passing
	9.5 mm	0	0	100.00	0	100
No. 4	4.75 mm	19.5	3.898	96.1	3.898	95-100
No. 8	2.36 mm	65.8	13.15	82.95	17.05	80-100
No. 16	1.18 mm	103.4	20.67	62.28	37.72	50-85
No. 30	600 µm	112.23	22.43	39.85	60.15	25-60
No.50	300 µm	98.5	19.69	20.16	79.84	10-30
No.100	150 µm	80.645	16.12	4.04	95.96	2-10
No. 200	75 µm	20.01	4	0.0429	99.96	-
	total	500.085	99.96	100	294.6	-
	Fineness modulus				2.946	

Appendix - D

Particle size distribution of Idaga Hamus CSS

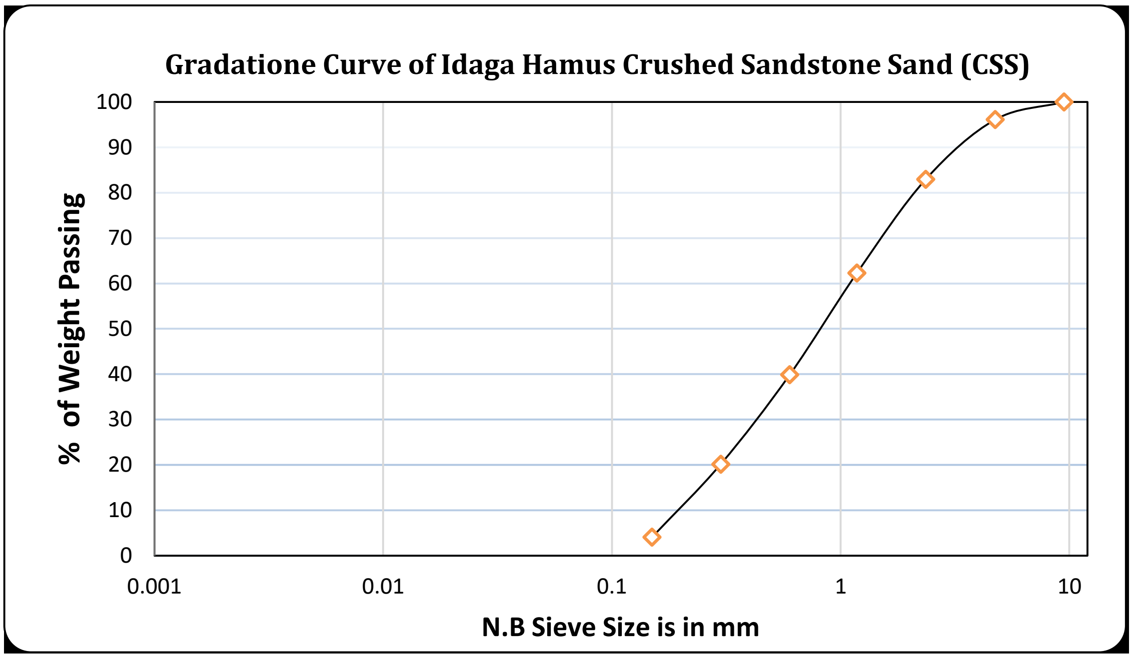

Fig. 4.5 Idaga Hamus CSS gradiation curve

Appendix - E

Table 4.4 Sieve Analysis of Gereb Giba CSS

Sieve no.	Sieve size	Weight retained (gm)	RS % retaining	RS cumulative % passing	Cumulative retained (%)	Recommended ES C.D3.201 % passing
	9.5 mm	0	0	100.00	0	100
No. 4	4.75 mm	15.6	3.12	96.88	3.12	95-100
No. 8	2.36 mm	46.5	9.29	87.59	12.41	80-100
No. 16	1.18 mm	123.33	24.65	62.94	37.06	50-85
No. 30	600 µm	58.6	11.71	51.223	48.78	25-60
No.50	300 µm	138.6	27.7	23.529	76.48	10-30
No.100	150 µm	105.09	21.0	2.514	97.49	2-10
No. 200	75 µm	12.3	2.458	0.0559	99.94	-
	total	500.02	99.944		275.34	-
	F.M				2.7534	

Appendix - F

Particle size distribution of Gereb Giba Natural (River) Sand

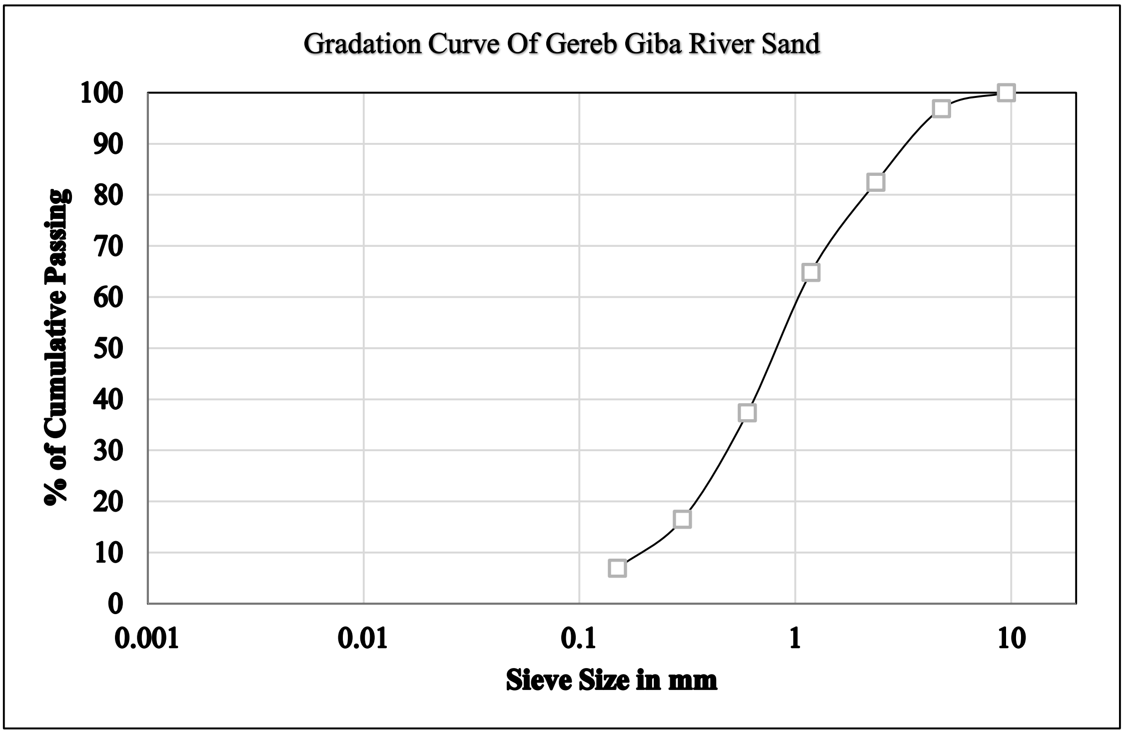

Figure 4.6 gradation curve of gereb giba natural (river) Sand (NS)

Appendix - G

Computation of compressive strength for concrete

To obtain the compressive strength, 36 cubes were casted and tested. Three cubes were casted on each replacement of CSS as NS. The results are given below in Table.

Table A-1 Computation of compressive strength for concrete prepared by 100% of RS and 0% of CSS.

No.	Test age (day)	% of RS	% of CSS	Weight (gm.)	volume (cm^3)	failure load (kN)	compressive strength (MPa)	unit weight (gm/cm^3)
1	7	100%	0 %	8100	3375	400.75	17.81	2.40
2				8200	3375	425.0	18.889	2.43
3				7950	3375	394.9	17.5511	2.35
						Average	18.0837	2.393
No.	Test age (day)	% of RS	% of CSS	Weight (gm.)	Volume (cm^3)	Failure load (kN)	Compressive strength (MPa)	Unit weight (gm/cm^3)
1	14	100%	0 %	8325	3375	490.5	21.825	2.47
2				8123	3375	521.4	23.175	2.41
3				8420	3375	511.3	22.725	2.50
						Average	22.575	2.4561
No.	Test age (day)	% of RS	% of CSS	Weight (gm.)	Volume (cm^3)	Failure load (kN)	Compressive strength (MPa)	Unit weight (gm/cm^3)
1	28	100%	0 %	8521	3375	646.9	28.75	2.52
2				8002	3375	618.8	27.5	2.37
3				8415	3375	591.9	26.3067	2.490
						Average	27.52	2.463

Table A-2 Computation of compressive strength for concrete prepared by 50% of RS and 50% of CSS

No.	Test age (day)	% of RS	% of CSS	Weight (gm.)	Volume (cm^3)	Failure load (kN)	Compressive strength (MPa)	Unit weight (gm/cm^3)
1	7	50%	50%	7968	3375	427.7	19.01	2.36
2				8122	3375	415.5	18.4667	2.40
3				7908	3375	442.5	19.6667	2.370
						Average	19.0474	2.3667
No.	Test age (day)	% of RS	% of CSS	Weight (gm.)	Volume (cm^3)	Failure load (kN)	Compressive strength (MPa)	Unit weight (gm/cm^3)
1	14	50%	50%	8345	3375	535.7	23.8089	2.4726
2				8000	3375	551.8	24.5244	2.37
3				8130	3375	582.2	25.875	2.409
						Average	24.736	2.417
No.	Test age (day)	% of RS	% of CSS	Weight (gm.)	Volume (cm^3)	Failure load (kN)	Compressive strength (MPa)	Unit weight (gm/cm^3)
1	28	50%	50%	7988	3375	666.6	29.627	2.367
2				8655	3375	680.2	30.231	2.564
3				8133	3375	697.5	31.0	2.41
						Average	30.286	2.447

Table A-3 Computation of compressive strength for concrete prepared by 25% of RS and 75% of CSS

No.	Test age (day)	% of RS	% of CSS	Weight (gm.)	Volume (cm^3)	Failure load (kN)	Compressive strength (MPa)	Unit weight (gm/ cm^3)
1	7	25%	75%	8006	3375	494.9	21.995	2.372
2				8225	3375	427.6	19.004	2.437
3				8111	3375	443.1	19.693	2.40
						Average	20.231	2.403
No.	Test age (day)	% of RS	% of CSS	Weight (gm.)	Volume (cm^3)	Failure load (kN)	Compressive strength (MPa)	Unit weight (gm/ cm^3)
1	14	25%	75 %	8300	3375	576.0	25.6	2.46
2				8100	3375	614.2	27.3	2.40
3				8000	3375	594	26.4	2.37
						Average	26.432	2.41
No.	Test age (day)	% of RS	% of CSS	Weight (gm.)	Volume (cm^3)	Failure load (kN)	Compressive strength (MPa)	Unit weight (gm/ cm^3)
1	28	25%	75%	7889	3375	827.0	36.756	2.337
2				7999	3375	756.0	33.6	2.37
3				8122	3375	731.0	32.489	2.41
						Average	34.281	2.37

Table A-4 Computation of compressive strength for concrete prepared by 0% of RS and 100% of CSS

No.	Test age (day)	% of RS	% of CSS	Weight (gm.)	Volume (cm^3)	Failure load (kN)	Compressive strength (MPa)	Unit weight (gm/ cm^3)
1	7	0%	100 %	8155	3375	522	23.2	2.416
2				8003	3375	508.5	22.6	2.371
3				8220	3375	492.5	21.889	2.44
						Average	22.5667	2.4067
No.	Test age (day)	% of RS	% of CSS	Weight (gm.)	Volume (cm^3)	Failure load (kN)	Compressive strength (MPa)	Unit weight (gm/ cm^3)
1	14	0%	100 %	8310	3375	643.5	28.6	2.46
2				8200	3375	688.5	30.6	2.43
3				8133	3375	652.5	29	2.41
						Average	29.4	2.433
No.	Test age (day)	% of RS	% of CSS	Weight (gm.)	Volume (cm^3)	Failure load (kN)	Compressive strength (MPa)	Unit weight (gm/ cm^3)
1	28	0%	100 %	8350	3375	913.5	40.6	2.47
2				8150	3375	863.8	38.39	2.41
3				8300	3375	895.2	38.787	2.46
						Average	39.59	2.449

Appendix - H

Computation of Flexural Strength of Concrete at 28th Day curing period

To obtain the flexural strength, 9 samples were casted and tested. Three plain concrete beam were casted on each replacement of CSS as NS. The results are given below in Table.

Table B-1 computation of flexural strength of concrete at 28th days of curing period.

No.	Test age (day)	% of RS	% of CSS	weight (gm)	Volume (cm^3)	Failure load (kN)	Modulus of rapture MPa	Unit weight (gm/cm^3)
1	28	100 %	0%	12800	11250cm^3	15.23	10.28	1.138
2				12900	11250cm^3	14.45	9.75	1.1467
3				12888	11250cm^3	16.5	11.198	1.1456
Average							10.41	1.143

Table B-2 computation of flexural strength of concrete at 28th days of curing period.

Sample No.	Test age (day)	% of RS	%of CSS	weight (gm)	Volume (cm^3)	Failure load (kN)	Modulus of rapture MPa	Unit weight (gm/cm^3)
1	28	50 %	50%	13009	11250cm^3	16.8	11.34	1.156
2				12960	11250cm^3	17.3	11.68	1.152
3				13200	11250cm^3	18.1	12.22	1.173
Average							11.745	1.160

Table B-3 computation of flexural strength of concrete at 28th days of curing period.

Sample No.	Test age (day)	% of RS	%of CSS	weight (gm)	Volume (cm^3)	Failure load (kN)	Modulus of rapture MPa	Unit weight (gm/cm^3)
1	28	0%	100 %	13100	11250cm^3	20.6	13.91	1.164
2				12948	11250cm^3	18.9	12.76	1.151
3				13100	11250cm^3	19.6	13.23	1.1644
Average							13.298	1.159

Appendix - I

Computation of Compressive Strength for Concrete Block

To obtain the compressive strength of hollow concrete block, 24 samples were casted and tested. 6 specimens were casted on each replacement of CSS as NS. The results are given below in Table.

Table C-1 Computation of compressive strength for HCB prepared by 100% RS (0% of CSS)

No.	Dimension (cm)			% of RS	% of CSS	Weight (kg)	Volume (m^3)	Density (kg/m^3)	Failure (kN)	Compressive strength (MPa)
	L	H	W							
1	40	20	20	100 %	0%	9.26	0.0073	1265	520	6.5
2	40	20	20	100 %	0%	9.99	0.0073	1365	600	7.5
3	40	20	20	100 %	0%	9.02	0.0073	1233	320	4.0
4	40	20	20	100 %	0%	10.63	0.0073	1453	560	7.0
5	40	20	20	100 %	0%	9.43	0.0073	1289	352	4.4
6	40	20	20	100 %	0%	9.99	0.0073	1365	480	6
									Average	5.9

Table C-2 Computation of compressive strength, for HCB prepared by 50% RS (50% of CSS)

No.	Dimension (cm)			% of RS	% of CSS	Weight (kg)	Volume (m^3)	Density (kg/m^3)	Failure (kN)	Compressive strength (MPa)
	L	H	W							
1	40	20	20	50%	50%	11.06	0.00732	1511	632	7.9
2	40	20	20	50%	50%	8.22	0.00732	1123	584	7.3
3	40	20	20	50%	50%	9.59	0.00732	1311	544	6.8
4	40	20	20	50%	50%	8.74	0.00732	1195	328	4.1
5	40	20	20	50%	50%	9.04	0.00732	1235	440	5.5
6	40	20	20	50%	50%	10.48	0.00732	1432	504	6.3
Average										6.3167

Table C-3 Computation of compressive strength for HCB prepared by 25% RS (75% of CSS)

No.	Dimension (cm)			% of RS	% of CSS	Weight (kg)	Volume (m^3)	Density (kg/m^3)	Failure (kN)	Compressive strength (MPa)
	L	H	W							
1	40	20	20	25%	75%	8.24	0.00732	1126	432	5.4
2	40	20	20	25%	75%	8.86	0.00732	1211	656	8.2
3	40	20	20	25%	75%	8.052	0.00732	1100	584	7.3
4	40	20	20	25%	75%	8.784	0.00732	1200	720	9.0
5	40	20	20	25%	75%	9.18	0.00732	1254	408	5.1
6	40	20	20	25%	75%	9.99	0.00732	1365	680	8.5
									Average	7.25

Table C-4 Computation of compressive strength for HCB prepared by 0% RS (100% of CSS)

No.	Dimension (cm)			% of RS	% of CSS	Weight (kg)	Volume (m^3)	Density (kg/m^3)	Failure (kN)	Compressive strength (MPa)
	L	H	W							
1	40	20	20	0%	100%	9.026	0.00732	1233	552	6.9
2	40	20	20	0%	100%	8.48	0.00732	1159	520	6.5
3	40	20	20	0%	100%	9.85	0.00732	1346	760	9.5
4	40	20	20	0%	100%	10.89	0.00732	1488	736	9.2
5	40	20	20	0%	100%	8.4	0.00732	1148	720	9
6	40	20	20	0%	100%	9.596	0.00732	1311	664	8.3
									Average	8.233