



Addis Ababa University  
Addis Ababa Institute of Technology  
School of Civil and Environmental Engineering

Study on the production process of the precast reinforced concrete ribbed beam through the micro and small enterprises in Addis Ababa: *“A case study on Bole, Yeka and Akaki kality Subcity”*

A thesis submitted to Addis Ababa University School of graduate studies, as a partial fulfilment of the requirements for the degree of Master of Science in Civil Engineering (Construction Technology and Management).

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Advisor: Dr. Abraham Assefa (Assistant Professor)

July, 2020

Addis Ababa, Ethiopia



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## Declaration

I, the undersigned, declare that this research is my own original work performed under the supervision of Dr. Abraham Assefa (Assistant Professor) and has not been presented as a thesis for a degree in any other university.

Abebaw Abebe Yirga

Name

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## **Abstract**

Concrete prefabrication is an essential and cost effective concepts of today’s fast track construction in the world. Because it is manufactured in the factory within a standard manner and transport the customized components in to the project site where the structure is to be located for assemblage. But it requires standard input resources, manufacturing process, and outputs to attain the desired function. Therefore, with this respect a research was carried out to assess the existing situations of the precast ribbed beam manufacturing process by the micro and small enterprise associations in Addis Ababa at Bole, Yeka, and Akaki Kality sub-city in general and to give recommendation inline with the outcome of the results of the research. Therefore, in the research non-destructive rebound hammer test results of precast ribbed beam samples were collected and analyzed. According to the result, 100% of precast ribbed beam samples couldn’t satisfy the requirement set by the standard known as C-25Mpa. It has been found out that 85.2% of precast ribbed beam samples had average compressive strength of  $15.9 \leq \bar{X} \leq 20.9$ Mpa and the remaining 14.8% of precast ribbed beam samples had average compressive strength of  $35.9 \leq \bar{X} \leq 45$ Mpa. Further, from the observations made in the manufacturing shades in addition to the interviews made with relevant personnel’s, it was conclude in the research that the production process of the precast ribbed beam is not near the standard beside extensive production problems had been seen in the production process due to the manufacturers lack of knowledge, the consultants regular supervision and quality controlling role is very poor, the absence of well-prepared precast ribbed beam production documents available to the manufacturers, and all most all manufacturers outsourced the key activities of them into the un-trained person illegally to accomplish the task. Another conclusion drawn from the research was that any kind of concerned bodies such as micro and small enterprises, regulatory bodies, respected organizations, professionals, researchers, consultants, etc. should be committed and quite responsive.

## **Keywords**

Competency, Compressive strength, Customization, Micro and Small Enterprises, Precast ribbed beam, Prefabrication, Production process, Rebound hammer test, and Standardization.

## **1. INTRODUCTION**

### **1.1. Background of the study**

Housing is one of the necessities of all human beings next to food and clothes. But the housing demand of the population primarily affected by the growth of populations. As a developing country, Ethiopia is faced with several intimidating problems such as high unemployment, a labor force with low levels of skill, and resultant poverty. To alleviate such problems the government of the federal democratic republic of Ethiopia launched the Integrated Housing Development Program (IHDP) since in 2004 E.C to promote urban development, create jobs, revitalize the urban economy through the establishment of micro and small enterprises (MSEs), encourage saving and empowerment of urban residents through property ownership and to develop the capacity of the construction sector (Asnake, M 2019).

In construction sector on the Integrated Housing Development Program (IHDP) such as 10/90, 20/80 and 40/60 housing project programs, micro and small enterprises (MSEs) are organized to produce precast ribbed beams, hollow concrete blocks, and engage in plumbing and laying electric power supply line works (Wubshet et al 2015). The precast ribbed beam is one of the reinforced concrete segments used for a ribbed slab construction with a hollow concrete filler/ribbed block together. It is very important to support rebated filler blocks, concrete, and other construction loads with assistance from temporary props before developing the full composite action. The manufacturing process must be done in the factory by using serial batch to achieve the accuracy of the production process, transportability, and assemblage unless the provided components may not achieve the anticipated desired value (Hong et al 2018 & Okugić 2013).

In this research, the micro and small enterprises' precast ribbed beam production practices will be assessed on the manufacturing shade. The roles and responsibilities of the consultant will be discussed, the effects of a manufacturer's production capability and regulatory bodies' professional duty will be indicated based on product standard.

### **1.2. Statement of the Problem**

Addis Ababa is the capital city of Ethiopia located in the center of the country, since most industries located in the city, migration of people is rising rapidly. Besides that, now a time urban

unemployment and housing problem prevailed. To come up with such problems the government of the federal democratic republic of Ethiopia commenced two programs known as a micro and small enterprise (MSEs) and the Integrated Housing Development Program (IHDP) (Asnake, M 2019).

Micro and small enterprise office coordinates local economic development actors and organizes peoples seeking employment and support them to start a business. In the construction sector on the Integrated Housing Development Program (10/90, 20/80, and 40/60 housing program) micro and small enterprises are organized to produce a pre-cast beam, hollow concrete block, engage in plumbing, laying electric power supply line. But they should have professional certification to provide the services they are engaged in. The system of competency certification should be strengthened and no trade should operate without such a competency certificate. But the existing system shows the competent person (person with the certificate of competency and trade license) outsourced the key activities of the MSEs into a non-trained person assigned to accomplish the tasks. Such arrangements defeat the aim of specialization lying to rent-seeking behavior and compromise on quality (Wubshet et al 2015).

In this regard, this research intended to investigate the pre-cast ribbed beam production process through the micro and small enterprises and the supervision and quality control roles of consultants on the production process, indicate the effects of the consultant's professional duty and the manufacturer's production capability in the product standard.

### **1.3. Research questions**

2. What are the current precast ribbed beam production practices in Addis Ababa selected sub-cities through the micro and small enterprise associations?
3. What are the roles of consultants on the manufacturing shade during ribbed beam production?
4. To what extent do they affect the micro and small enterprises' production capability and the consultant's professional duty on the compressive strength test result?

## **1.4. Objectives**

The main objective of this study is to investigate the production process of the precast reinforced concrete ribbed beams through the micro and small enterprise associations at Bole, Yeka, and Akaki Kality Subcity in Addis Ababa.

### **1.4.1. Specific objective**

The specific objectives of this research are:

- To assess the current production practices of the precast ribbed beam through the micro and small enterprise associations to the standard manufacturing process.
- To investigate the role of consultant on the manufacturing shades during the precast ribbed beam production process.
- To show the production capabilities of the precast ribbed beam manufacturers and the professional duties of consultant in product standard through a non-distractive rebound hammer compressive strength test.

Furthermore, as part of the research objectives, this study will draw conclusions and forward recommendations based on the research finding and indicate areas for further study.

## **1.5. Scope of the research**

Based on the objectives of the study, the scope of the research is grouped into three major tasks:

- Evaluate the precast ribbed beam manufacturers (micro and small enterprise associations) production practice on the manufacturing shade only at Bole, Yeka, and Akaki Kality Subcity in Addis Ababa.
- Identify the roles of consultants based on the contractual arrangement on the ribbed beam production process.
- Evaluate the manufacturer's production capability and the consultant's professional duty to the product quality compliance criteria based on a non-distractive rebound hammer compressive strength test result.

## **1.6. Significance of the research**

In the study area, the precast ribbed beam is produced by the group of micro and small enterprise associations on the manufacturing shade provided by the shade agencies on each Subcity of Addis

Ababa as the government aims in creating job opportunities to reduce poverty and urban unemployment. This research can help the precast concrete manufacturers by adding a scientific concept that aims at the standard manufacturing process starting from the raw material selection until the final product before delivery. Besides, this research is significant for ribbed beam manufacturers and private manufacturing sectors required to measure its production capability and make challenges on the concerned regulatory bodies tend to provide some frameworks to develop and enhance the prefabrication technology in Ethiopia.

Generally, this study will have a great significance for the manufacturers and regulatory bodies including consultants to fabricate precast ribbed beams efficiently without any defect and it can be used as a reference for future material related studies.

### **1.7. Organization of the study**

This research contains five chapters as described below:

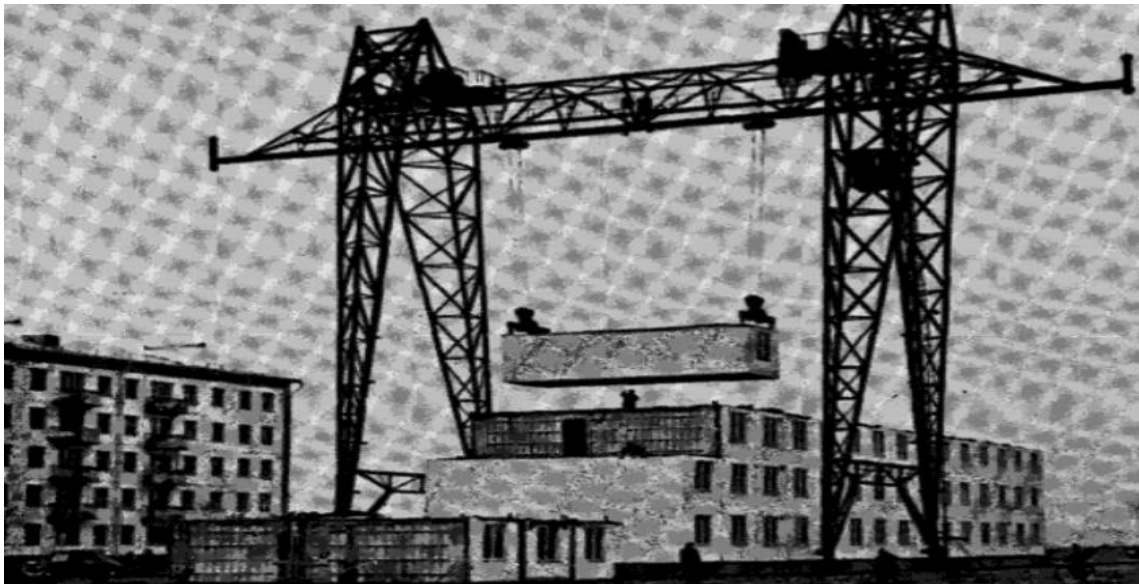
- Chapter one is an introductory part containing the background of the study, research statement and questions, objective of the study – general and specific objective, the scope of the research, importance of the study, and the organization or layout of the study.
- Chapter two presents a literature review with general descriptions by different researchers on the production process of precast concrete components and the roles and contributions of micro and small enterprises on it and related studies.
- Chapter three describes the methodology employed to achieve the objectives stated above.
- Chapter four gives the results and discussions on the production practices of precast ribbed beams through the micro and small enterprise associations on the selected Subcity manufacturing shades in Addis Ababa, the occurrence of production defects and its root causes, and discussed the effects of manufacturers production capability and regulatory bodies professional duty in product standard with respect to the rebound hammer compressive strength test results.
- Chapter five gives the conclusion and recommendations in accordance with the results obtained in chapter four.

## 2. LITERATURE REVIEW

### 2.1. Origins of prefabrication

Ancient Romans used to pour concrete into molds to build pipes, culverts, and tunnels beginning around 100 B.C. In modern times, it was first utilized in Liverpool, England by city engineer John Alexander Brodie in 1905. Later, the method was widely adopted in Eastern Europe and Scandinavia. In the US, the precast concrete product industry was established mostly encompasses non-prestressed precast concrete products for utility construction represented by the national precast concrete association (NPCA). In the meantime, the precast concrete "structure" industry which includes prestressed precast concrete and other precast elements used in buildings, bridges, and parking structures represented by the pre-stressed concrete institute (PCI) ([wikipedia.org/wiki/](http://wikipedia.org/wiki/)).

Precast construction started to be widely in the Union of Soviet Socialist Republic (U.S.S.R) in 1954. The products mainly consist of separate precast elements that would all be assembled on site. Since 1958, the precast cell system started to be produced. Through this new concept, individual large sections of buildings are manufactured instead of separate precast concrete elements. Parts of apartment buildings, as big as a once complete living unit at once, started to be precast and assembled as shown in figure 2.1 (Kibirt, B 2017).



*Figure 2.1 Apartment construction in the U.S.S.R. using prefabricated cells (Kibirt, B 2017).*

## 2.2. Importance of prefabrication

Currently, environmental pollution is a critical issue all over the world through the emission of dust from different industries. The construction industry is one of the causes of environmental pollution through the emission of dust into the atmosphere from different materials by people's actions during construction. Besides, prefabrication technology is more popular and preferable to environmental sustainability as compared to conventional construction. Because it is the acts of fabricating precast segments on the factory before transporting and assembling on the building to be constructed (Hong et al 2018). Reduction of waste, time, and life-cycle cost, risk, and pollutions are some importance of prefabrication technology. But the applications of prefabrication technology hindered by some factors like a technical risk but it is gradually resolved due to technological innovation and improvement (Hong et al 2018 and Alireza 2015). It is very effective and efficient as compared to conventional constructions of large construction projects. Figure 2.2 shows, importance and effectiveness of prefabrication through the standard resource, process, and product application and aware customization on the productions of precast segments (Shreyanka and Ashwin 2018).

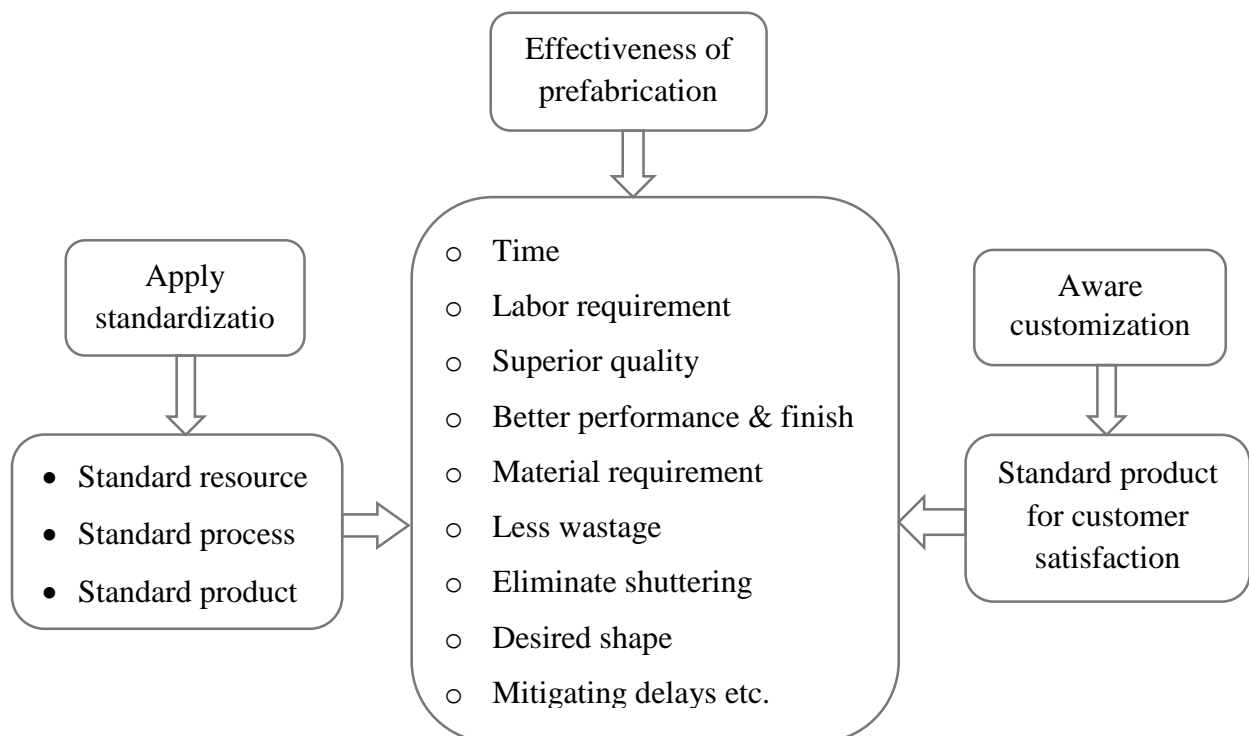


Figure 2.2 Importance and effectiveness of prefabrication (Shreyanka and Ashwin 2018).

### **2.3. Types of precast system**

Depending on the load-bearing structure, the precast system can be divided into large-panel systems, frame systems, slab-column systems with walls, and mixed systems (Kibirt, B 2017, and [www. Paradigm.in](http://www.Paradigm.in)).

#### **2.3.1. Large-Panel systems**

The designation "large-panel system" refers to a multistory structure composed of large wall and floor concrete panels connected in the vertical and horizontal directions so that the wall panels enclose appropriate spaces for the rooms within a building. The forms of such panels are a box-like structure. The functions of both vertical and horizontal panels are resisted gravity load. Wall panels are usually one-story height. Horizontal floor and roof panels span either as one way or two-way slabs. When properly joined together, horizontal elements act as diaphragms that transfer the lateral loads to the walls.

#### **2.3.2. Frame systems**

Precast frames can be constructed using either linear elements or spatial beam-column sub-assemblages. Precast beam-column slab-assemblages have the advantage that the connecting faces between the sub-assemblages can be placed away from the critical frame region. However, linear elements are generally preferred because of the difficulties associated with forming, handling, and erecting spatial elements. The use of linear elements generally means placing the connecting faces at the beam-column junction. The beam can be seated on corbels at the columns, for ease of construction and to aid the shear transfer from the beam to the column. The beam-column joints accomplished in this way are hinged. However, rigid beam-column connections are used in some cases, when the continuity of longitudinal reinforcement through the beam-column joints needs to be ensured.

#### **2.3.3. Slab-column systems with shear walls**

These systems rely on shear walls to sustain lateral load effects, whereas the slab-column structure resists mainly gravity load. There are two main systems in this category known as a lift-slab system with walls and a prestressed slab-column system. In the lift-slab system, the load-bearing structure consists of precast reinforced concrete columns and slabs. Precast columns usually two stories height. All precast structural elements are assembled using special points. Reinforced concrete

slabs are poured on the ground in forms, one on top of the other. Precast concrete floor slabs are lifted from the ground up to the final height through lifting cranes. The slab panels are lifted to the top of the column and then moved down into the final position. Temporary supports are used to keep the slabs in the position until the connection with the columns has been achieved.

The prestressed slab-column system uses horizontal prestressing in two orthogonal directions to achieve continuity. The precast concrete column elements are one to three stories high. The reinforced concrete floor slabs fit the clear span between columns. After erecting the slabs and columns of a story, the columns and floor slabs are prestressed using prestressing tendons that pass through ducts in the columns at the floor level and along the gaps left between adjacent slabs. After prestressing, the gaps between the slabs are filled with in situ concrete and the tendons then become bonded with the spans. Seismic loads are resisted mainly by the shear wall (precast or cast-in-place) positioned between the columns at the appropriate locations.

#### **2.3.4. Mixed systems**

A precast structure may include a combination of any of the above systems or even have some part of cast-in-place members. This would bring no structural incompatibility, but stability and robustness should be checked for.

### **2.4. Clarification of terms used to construct precast concrete elements**

Precast concrete elements are classified into precast pre-stressed concrete and precast reinforced concrete members based on the construction process (István 2015 and Okugić 2013).

#### **2.4.1. Precast prestressed concrete elements**

Precast prestressed concrete members are consist of pre-stressing tendons within the element to provide a predetermined force needed to resist external loading and crack. Prestressing tendons could be "individual hard-drawn wires, cables of hard-drawn wires, or bars of high strength alloy steel" used for pre-tensioning or post-tensioning the precast concrete members presented on Table [1].

Table 1 Pre-tensioning vs Post-tensioning production phases (István 2015 and Okugić 2013)

Pre-tensioning	Post-tensioning
1. Preparing the mold	1. Preparing the mold
2. Placing of reinforcement	2. Placing of reinforcement and duct
3. Pre-stressing	3. Casting of concrete
4. Casting of concrete	4. Removing the mold
5. Removing the mold	5. Pre-stressing
6. Storage	6. Storage

Pre tensioning is the process that involves pulling prestressing tendons in a frame or between anchorages that would stay at the end surfaces of the member, and pouring fresh concrete around it. After the concrete has been set, the tensioned steel is released slowly to transfer stress to the concrete that it has already bonded with. It takes a certain distance from the end of the member for the force to transfer and this is called the transfer length. Post-tensioning is when the concrete is cast around ducts through which prestressing tendons would pass. After the concrete sets, the tendons are passed through the concrete member tensioned using portable jacks. Post-tensioning can be done on the job site without any need for heavy temporary anchorages (Kibirt, B 2017).

#### 2.4.2. Precast reinforced concrete elements

Precast reinforced concrete elements are consist of reinforcement bars and welded wire meshes within the elements to provide the tensile strength and resist against cracks. Such as façade walls, beams, columns, slabs, refuse chutes, staircases, and parapet walls are some examples of precast reinforced concrete structural elements. The construction process which includes the casting of reinforced concrete members on the ground level at a precast plant, or on a portion of the ongoing construction at the site. Briefly stated, the casting process first requires reinforcement bars to be placed in the mold. Next, fresh concrete is poured into the molds and vibrated for consolidation. Then, these cast reinforced concrete members are placed in a curing pond, or a curing chamber so that the concrete can completely undergo hardening reaction (Okugić 2013 and Kibirt 2017).

#### 2.4.3. Precast reinforced concrete ribbed beam

Precast reinforced concrete ribbed beam is one segment of precast reinforced concrete elements manufactured on the factory used to construct ribbed slab (precast beam-block floor stab system)

with rebated filler blocks together and it is aligned accordingly to the length of rebated filler blocks on ribbed slab construction. The precast reinforced concrete ribbed beam is produced through the properly designed concrete with the cast in reinforcing steel according to Engineer's design. Figure 2.3 shows a precast reinforced concrete ribbed beam and is an arrangement to construct a ribbed slab with a rebated filler block together (Elmi 2007 and Bonga 2015).



a) Precast ribbed beam handling



b) Ribbed beam installation with blocks

*Figure 2.3 Ribbed beam handling and its arrangement on slab (Elmi 2007 & Bonga 2015).*

#### **2.4.4. The production process of precast reinforced concrete ribbed beams**

The production of precast reinforced concrete elements has been done in the casting yard and the required equipment for production in the factories are; steel mold for wall/beam/slab panel/staircase, batching plant, transit mixers, vibrators and concrete buckets (Larsen and Toubro 2016). According to István (2015) and Okugić (2013) justification, precast reinforced concrete ribbed beam is one segment of precast reinforced concrete elements so the production process which includes;

- Step 1 - Procurement of raw materials
- Step 2 - Design concrete mix
- Step 3 - Assembling of the mold components
- Step 4 - Mold cleaning and preparation
- Step 5 - Fixing of re-bars and spacer fitting
- Step 6 - Concreting
- Step 7 - Demolding (dismantling of the mold components)

- Step 8 - Curing and,
- Step 9 - Final inspection/ transfer to storage

#### **2.4.4.1. Procurement of raw materials**

Procurement is the act of collecting/purchasing services and goods/raw materials from the appropriate source into the required location. Purchasing describes the process of buying and it covers the knowledge of the requirements, identifying and selecting a supplier, and negotiating price. But material quality inspection is very essential in procuring progress because the quality inspection is very much helpful in improving the quality, minimizing the manufacturing cost, and eliminating the scrap losses, and also it is the most common important method used to attain standard quality (Cheng 2004). Quality inspection for the procurements of raw materials has its broad objectives which include;

- Identification of the problem (identifying problems that can be related to the incoming raw materials and parts).
- Prevention of the problems (prevent the occurrence of problems in the area of incoming and reception of raw materials and parts, in the production process and the finished goods).
- Elimination of the problems (eliminate the problems of the procured raw materials for poor quality, pilferage, shortage, or damage of any kind).

#### **A. Procuring process of raw materials**

Cement, aggregates, water, and rebars are the basic ingredients of the procured raw materials. Chemical admixtures are an optional used based on the conditions to enhance one or more properties of the concrete to improve the handling and placing characteristics. (CCAA, 2010 & NPCA, 2008). But the entire procuring process of raw material which includes: receiving, inspecting and accepting of the procured raw materials if it's satisfied the required international standard ([Http:// www. Ddegjust.ac.in](http://www.Ddegjust.ac.in)).

- Receiving means the act of taking possession of goods/raw materials to stage them for inspection or place them into inventory.
- Inspecting implies examining goods/raw materials that have been supplied by the supplier to check the quality of what was ordered via a purchase document. But It requires

specialized skill or expertise to examine (check, measure, and test) the goods/raw materials to ensure the required standard.

- Acceptance is the legal act of documenting that the goods or services conform to the requirements of the purchase document, terms, and conditions.

However, the accepted raw materials must satisfy their quality requirements, unless the target required outcome is not on behave of the recommended specification. In this stage, the constituent materials of precast reinforced concrete must fulfill the recommended standards. This means the properties of precast reinforced concrete making materials must be well defined and it should be compatible with the standard required documents (Kamran et al 2015). Table [2], represents the minimum recommended quality assurance tests of precast concrete making materials during the procuring progress.

Table 2 Recommended quality assurance tests (*Larsen and Toubro 2016*).

S.No	Description	Test required	Result required
<b>I. Cement</b>			
1.	Setting time i. Initial  ii. Final	50 --100 tone – 2 100-200 tone – 3 201-300 tone – 4 301-500 tone – 5 501-800 tone - 6 801-1300 tone -7	Not less than 30 minutes  Not greater than 600 minutes
2.	Fineness	1 test per 5 samples test	80% content should pass from a 0-micron sieve
3.	Consistency	As per requirement	
4.	Fineness test by specific surface	1 test per 5 samples	OPC=235cm/gm. PPC+300cm/gm.
5.	Chemical test	1 test per 5 samples	Magnesium Oxide < 6% Sulphur trioxide < 2.75%
<b>II. Aggregate: Coarse and Fine</b>			
<b>A. Fine Aggregate</b>			
1.	Silt content	1 test per 150 cum (10 kg sample)	Shall not be more than 3%
<b>B. Coarse Aggregate</b>			
1.	Gradation test	I test per 50 cum	As per IS 2386:1963
2.	Impact test	I test per 50 cum	As per IS 2386:1963

3.	Abrasion test	I test per 50 cum	As per IS 2386:1963
4.	Soundness test	I test per 50 cum	As per IS 2386:1963
<b>III. Concrete</b>			
1.	Concrete cube Strength	Up to 5 cum - 1 set 6-15 cum - 2 set 16-30 cum - 3 set 31-50 cum - 4 set 51 & above -5 set (for each 50cum or part thereof)	As per IS 456:2000
2.	Workability	Once per each shift	As per IS 456:2000
3.	Slump test	Once per each shift	As per IS 456:2000
4.	Hardened concrete	Cubes 7 & 28 days as directed	As per IS 456:2000

## **B. Procured raw materials usage and storage**

After receiving the procured raw materials through evaluation, the quality of the material is affected by the handling problems known as usage and storage/martial deterioration. But problems such as agglomeration of wet cement, corrosion of steel, and the mix of reinforcement with different diameters should be avoided by proper management of storage and usage. On the one hand, the contractor should make reasonable arrangements to avoid overstocking lots of materials on-site and materials should be stored with signs for the different categories with inspection and supervision on-site when being used (Cheng 2004).

### **2.4.4.2. Concrete mix design**

A concrete mix design is a process of specifying the mixture of ingredients required to meet the anticipated properties of fresh and hardened concrete. This proportioning is governed by the performance of concrete in two states known as plastic (fresh) state and the hardened state. If the plastic concrete is not workable, it can't be placed and compacted. The compressive strength of the hardened concrete is considered to be an index of many factors known as quality and quantity of cement, water and aggregates, mixing, placing, compaction, and curing (Temple et al 2015 and Kamran et al 2015).

The main aspects to consider mix design is workability in fresh state, strength, and durability on the hardened state of concrete. The ultimate aim of the concrete mix design is to produce the most economical combinations of concrete materials to satisfy the performance requirements of the

specified value. The mix design can be designed in two ways known as nominal concrete mix and design concrete mix shown in figure 2.4 (Temple et al 2015).

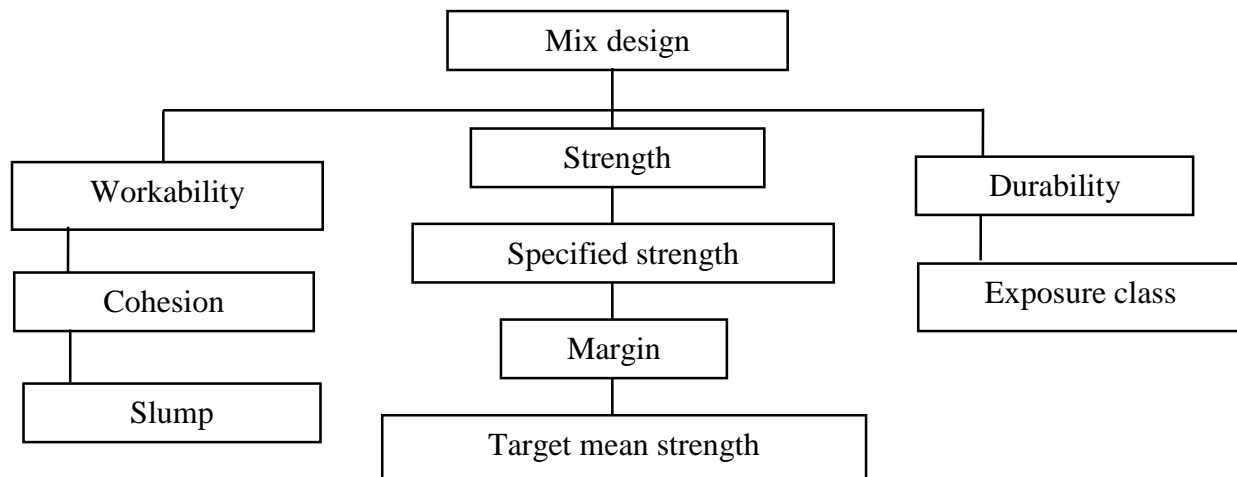


Figure 2.4 The main aspects to be considered in mix design (Temple et al 2015).

#### A. Nominal concrete mix

The nominal concrete mix is low-grade concrete mixes that are used for small and unimportant works. In this method, fine aggregate quantity is fixed irrespective of cement and coarse aggregate proportions. Hence, the quality of concrete mix will be varied, the required strength of the produced concrete may not be obtained and the water-cement ratio is not specified. Therefore grades of concrete prepared by nominal mix design are M20 and below but for a high grade of concrete design concrete mix is preferred (Kamran et al 2015).

#### B. Design concrete mix

The designed concrete mix does not contain any specified ranges in proportions. But the design is done according to the requirements of concrete strength. So we can achieve the desirable properties of concrete either in the fresh stage or in the hardened stage. The properties of fresh concrete-like workability, setting time, and the properties of hardened concrete like compressive strength and durability are attained surely by this method. Utilization of additives other than the basic ingredients for a certain condition is essential to improve the properties of concrete on the fresh and harden state (Temple et al 2015). By using a design concrete mix anyone can design various grades of concrete from as low as M10 grade to higher grades such as M80, M100, and above. The workability requirements of each mix can also meet using this method from zero to 150 mm slump.

Each mix is tested in a laboratory after hardens by using a trial mix to verify the requirement (Temple et al 2015).

However, a good design mix becomes a poor design mix with poor materials, the wrong situation, the wrong time, and the wrong place. Poor design mix could be due to some classified issues such as design proportion issues, material issues, and external issues (weather, placement method, forms). Design proportion issues mean that cementations too low or too high, incorrect aggregate ratio and specific gravities, air content too low or too high, under or over yield. And also material issues mean cement (strength, water demand, and setting time) is inappropriate, aggregates (grading, durability, and shape) and admixtures compatibility are not on behave of specification due to those factors poor quality concrete is produced. So to avoid poor concrete design mix we must know the chemical and physical properties of concrete ingredients, follow recommended guidelines for mix proportioning, do not use untested mix designs, and maintain correct yield (Franz 2008).

#### **2.4.4.3. Assembling the mold components**

Collect the mold components into the required workplace and then check the level and flatness of the base mold before assembling for casting. In this time the only things it must be considered is to ensure the dimension of the mold within the specified tolerance and also check the squareness of the mold form. As shown in figure 2.5, molds of adequate stiffness have been used and installed as per the issued drawings (Shreyanka, S and Ashwin, M 2018).



a) Assemble the mold components



b) Check the mold form

*Figure 2.5 Assembling and check the mold form (Shreyanka, S and Ashwin, M 2018).*

As Larsen and Toubro (2016) defined as molds for precast reinforced concrete elements shall be of steel and concrete. During the design of the molds for various elements, special importance should be given to easy de-molding and assembly of the various parts. At the same time, rigidity and strength and water tightness of the mold are also important taking into consideration forces due to the pouring of green concrete and vibration.

#### **2.4.4.4. Mold cleaning and preparation**

The mold should be clean and free from any derbies and old mortars by using remover or scaling bars known as forming oil or mold release agents evenly over the mold surface shown in Figure 2.6. Whereas casting concrete without cleaning or removing those bad derbies causes difficulty to de-molding due to strong surface contact between casting concrete and mold then it leads to damage or failure of finished components due to strongly dismantling of stiffly assembled mold components. Besides that, less quality surface precast component is produced and it may lead to strength and durability problem through transportation mechanism because of forming crack due to highly striking the mold for dismantling. Not only producing fewer quality components but it affects the use of full or design period of the mold components (Larsen and Toubro 2016).



a) Application of mold releasing agent



b) Mold cleaning

*Figure 2.6 Take care of molds prior to casting (Larsen and Toubro 2016).*

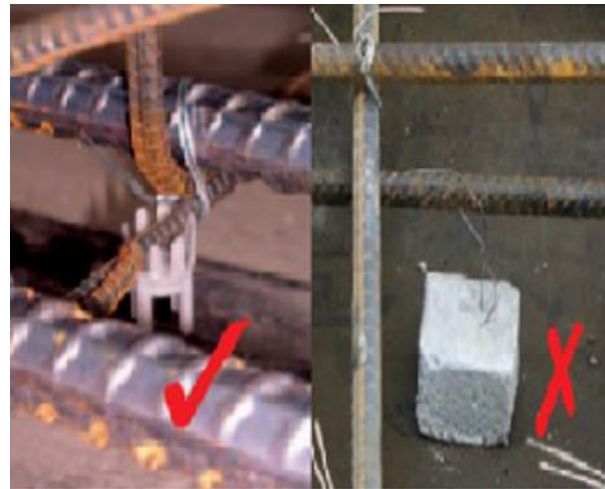
#### **2.4.4.5. Fixing of re-bars and spacer fitting**

Fixing of mechanical fittings is prepared accurately in this stage and check such fixtures placed on the required tolerance. There are a lot of things it must be considered in this stage such as check the sizes of reinforcement bars, check the spacing and lap length of the rebar's in accordance with

the specified drawing, ensure re-bars correctly positioned, properly secured cast in fitting, insert lifting hooks, welding should be carried out and ensure a sufficient number of spacers placed and secured within the correct size to achieve the required concrete cover during casting shown in figure 2.7 (Larsen and Toubro 2016).



a) Check rebar spacing and lap length



b) Spacer placing

Figure 2.7 Check the mechanical and electrical Fittings (Shreyanka and Ashwin 2018).

#### 2.4.4.6. Concrete casting

Larsen and Toubro (2016) defines, there are a lot of things that should be considered on the entire casting process of precast reinforced concrete ribbed beams such as (1) Precast reinforced concrete ribbed beams should be produced on horizontal/vertical stiffly assembled molds; (2) Prior to casting check the mold components properly treated with mold release agent; (3) Check the reinforcement bars shall be kept in position and properly place a sufficient number of spacers within the correct size; (4) High-quality concrete shall be transported from the batching plant to the manufacturing yard and pour such concrete into the properly assembled molds by different pouring methods; (5) During casting table vibrators should be used to achieve the best compaction. Thereafter the top surface of the casted reinforced concrete shall be finished with a hand-operated trowel which gives smooth finish; (7) After casting all exposed surfaces shall be covered with a tarpaulin avoid vaporization; (8) Then after the casted components shall be de-mold once the strength meets the design requirements and shifted the units into the stockyard; (9) Finally curing shall be carried out for the specified time period.

#### 2.4.4.7. Dismantle the mold components

It is the act of properly lifting or removing the stiffly assembled molds from previously casted concrete components ready to cure. The formal procedures of demolding include: (1) it must be ensured that all the elements should have identification mark; (2) It must be ensured that all side shutters are loosened so that the elements may be lifted without any damages; (3) Before demolding, it must be ensured that compressive strength of the cubes should meet the specified requirements; (4) lifting clamps/clutches shall be fixed to lift the ribbed components at proper positions, and (5) the elements shall be lifted carefully to the stocking area. If there is some mistake from demolding procedures, the quality of the required result is not on behave of the required anticipated standard and it leads to miss placement position, cause damage, strength and durability problem, etc. (Larsen and Toubro 2016).

#### 2.4.4.8. Curing of concrete

All of the beneficial properties of precast concrete including strength, durability, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing are enhanced through proper curing techniques. Unfortunately, the curing of precast concrete products is one of the last and perhaps most neglected steps in the manufacturing process, especially in the rapid production environment. But curing is the maintenance of satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing in order to enhance desired properties of yield high compressive strength and impermeability of concrete as shown in figure 2.8. In general, the primary aim of curing is to prevent the loss of necessary moisture during the early stage of hydration. This means it should keep the concrete saturated and it leads to decreased permeability, less plastic shrinkage, and avoids other undesirable factors (NPCA 2008).

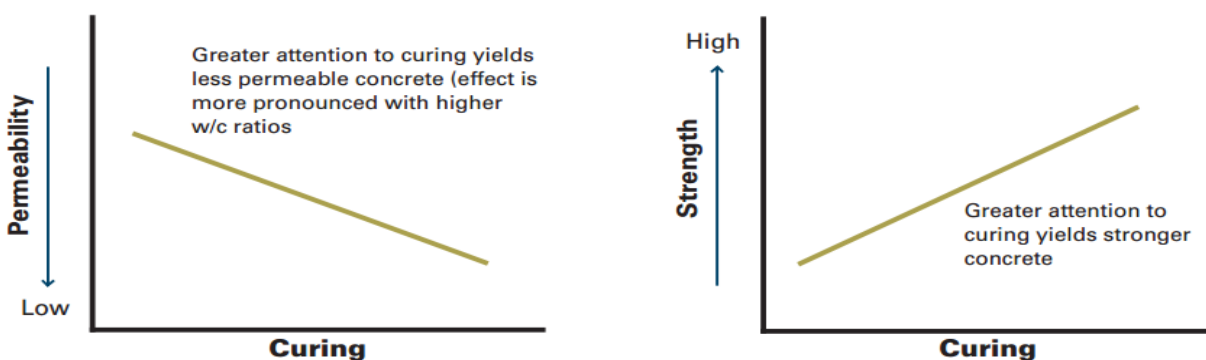


Figure 2.8 Proper curing enhances impermeability and yields strengths (NPCA 2008).

As Abebe Dinku (2018) and NPCA (2008) classification, conventional curing, and low-pressure steam curing are two of the most common methods of curing precast concrete products. Conventional curing involves the continuous saturation of the concrete surface with water for a specified length of time, starting as soon as the concrete is no longer susceptible to damage at ambient temperatures. These conditions can be achieved by draping wet burlap or cotton mats, spraying, fogging, or membrane curing. If spraying or fogging is done at intervals, the concrete must be prevented from drying between applications. When burlap or cotton mats are used, they should be kept moist. Alternate cycles of wetting and drying can cause surface crazing or cracking. For low water-cement ratios, wet curing is highly desirable. Membrane curing is another method of conventional curing using polyethylene sheeting, curing compounds, or similar material. With membrane curing, external water is not used in the curing process. This method should be used with caution for products with water-cement ratios less than 0.5, however, due to the potential for self-desiccation. This method is also not recommended for concretes containing pozzolans. Polyethylene sheeting should be at least 4mm thick and should be applied to the concrete as soon as the concrete has hardened sufficiently. Sheets should be lapped (about 18 inches) and weighted, as needed. All exposed surfaces, including exposed edges and joints, must be protected against moisture evaporation. Curing compounds should be sprayed uniformly on surfaces as soon as the water shine disappears but when the surface is still moist enough to ensure adequate performance (1-3 hours after concrete placement). Curing compounds should be stirred or agitated as needed before spraying. Curing compounds should be applied in two directions (vertically and horizontally) to ensure full coverage and should not be thinned or otherwise modified. Curing compounds are available in clear and colored (white) formulations. Colored formulations are easier for verifying full coverage.

Abebe Dinku (2018) specified that Low-pressure steam curing enhances moisture and temperature which are important factors that accelerating the curing process. Both result in an increased rate of hydration. The desired procedures of steam curing are: (1) Apply elevated temperatures after the initial set of fresh concrete. This is usually a period of 2 to 4 hours; (2) Apply a gradual temperature rise of not more than 40F/hr. up to a maximum temperature between 120 F and 140 F; (3) Maintain a relative humidity between 75-90% and (4) Gradually lower the temperature at a rate not to exceed

20 F per hour to avoid any thermal shock. Moisture evaporates very quickly from a hot surface and the durability to weathering and atmosphere will be detrimentally affected shown in figure 2.9. Too rapid an evaporation rate at low humidity will cause the surface to dry out and produce a concrete structure that has a permeable, poorly cured surface with relatively poor durability.

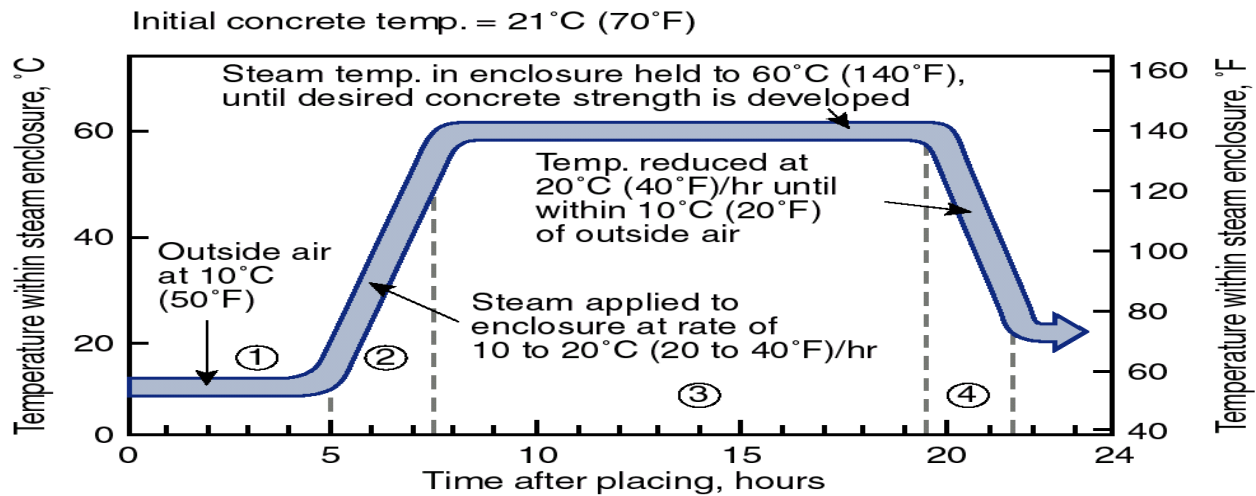


Figure 2.9 Steam curing cycle (Abebe Dinku 2018).

#### 2.4.4.9. Final inspection/ transfer to storage

This is the last stage of the precast reinforced concrete production process on the casting yards. And yet there are some considerations it must be taken in to account in this phase known as; check the conditions of the finished products, verify the critical dimension of the finished products, proper identification marking should be placed on the fabricated component, show the production location, member type, size, weight, and orientation as per shop drawing, check the elements have achieved their design concrete strength before delivery to site for erection and finally staking of the required standard finished products into the storage yard (Larsen and Toubro 2016).

Stacking of the finished components should be placed horizontally whereas in case of vertical stacking the gap between the elements should be 150 mm to 200 mm and it shall be done in such a way that longer span should be placed below that of the shorter span, also the wooden runner shall be placed perpendicular to lifting points and the elements placed over runner (Larsen and Toubro 2016).

However, implement the standard procurements of reinforced concrete ingredients, select and incorporate an efficient manufacturers/ labors, implement a standard manufacturing process, keep

and control the working condition, insure and customize the finished products are the key points of an effective precast reinforced concrete production (Shreyanka and Ashwin 2018).

## 2.5. Standardization and customization

The process of formulating, issuing, and implementing standards is called standardization. It is the process of establishing basic specifications for a set of commonly used characteristics of design, technology, size, shape, color, and performance of products or services. Product standards, engineering standards, material standards, design standards, quality standards, process standards, equipment standards, safety standards, administrative standards, etc. are some examples of standard. Standard provides requirements, specifications, guidelines, or characteristics. It can be used consistently to ensure materials, products, processes, and services to fit for specific use (Aki and Harri 2014). As shown in figure 2.10, Standardization assures all the processes are standardized, it leads to quality products, and it helps organizations to work effectively and it brings technological uniformity (www. Ddegjust.ac.in).

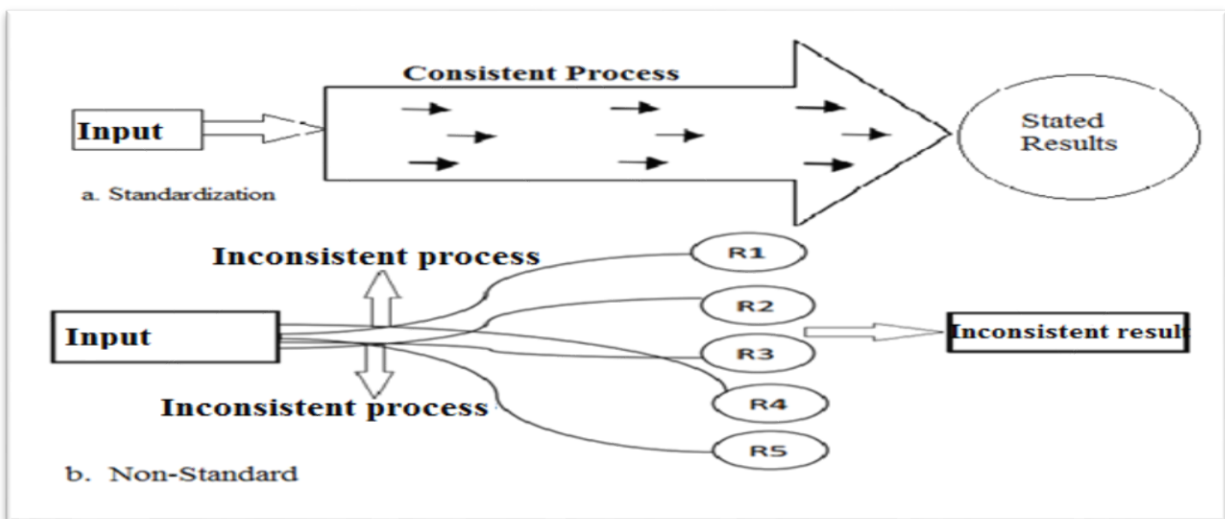


Figure 2.10 Standardized vs. Non-Standardized production process (www. Ddegjust.ac.in)

Customization is the process of product realization according to specific customer demand. Customization implies the application of standard parts maximizes the satisfaction of outspoken customers' demands at the same time and it minimalizes technical interventions in the scope of available technical equipment. The customized product can be perceived as a product modified according to the customer's needs. Customization generates higher product differentiation, which

further leads to product diversity increase and starts with negotiations with the customer on the details of the order which continue in the course of design, production, and sale of the product (Krstić et al 2015 and Aki and Harri 2014).

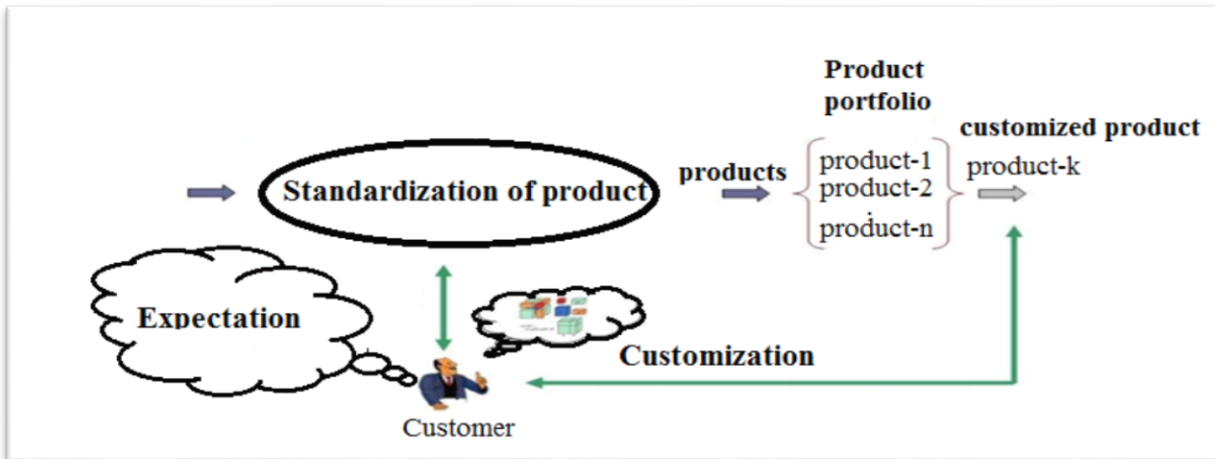


Figure 2.11 Principles of product customization (Krstić Milan.2015).

Standardized and customized products have some benefits such as it lead to increase in sale, establish higher intimacy between manufacturing enterprises and customer, represents an effective way to obtain valuable information from customers, etc. (István 2015 and Okugić et al 2013).

## 2.6. Micro and small enterprises

There is no universal definition of Micro and Small Enterprises (MSEs) because the classification of business into a large scale or small scale is subject and qualitative judgment. Accordingly, different nations such as Britain, Canada, and the USA small scale are defined in terms of annual turnover and the number of paid employees known as two million pounds or less with fewer than 200 paid employees respectively. In China, enterprises employing less than 100 workers are referred to as 'small scale sector with no sub-classification of the very small family businesses. European Commission defines MSEs based on turnover, balance sheet, and a number of employees, accordingly, a microenterprise is one with less than 2 million turnovers and less than 10 employees whereas, a small enterprise is one with less than 10 million turnovers and has not more than 50 employees. World Bank since 1976 Firms with fixed assets (excluding land) less than USD 250,000 in value are Small Scale Enterprises (Tekle Hiluf 204).

In Ethiopia, Micro and Small enterprises sector are defined both in terms of capital and number of employees. The initial investment or paid-up capital of micro-enterprises are not exceeding Birr 20,000 and excluding high tech consultancy enterprises and other high-tech establishments, whereas small enterprises are those business enterprises with a paid-up capital above Birr 20,000 and not exceeding Birr 500,000 and excluding high-tech consultancy enterprises and other high-tech establishments more presented on Table [3] (Arega et al 2016 and Tekle Hiluf (204).

Table 3 Micro and Small Enterprises definition in Ethiopia (*Tekle Hiluf 204*)

S.No	Level of Enterprise	Sector	Human power	Paid-up capital (total asset)
1	Micro-Enterprise	Industry	≤5	≤ Birr 100,000 (\$6,000 or 4500)
		Service	≤5	≤ Birr 50,000 (\$3,000 or 2,200)
2	Small Enterprise	Industry	6-30	≤ Birr 1,500.000 (\$90,000 or 70,000)
		Service	6-30	≤ 500,000 (\$30,000 or 23,000)

Micro and small enterprise (MSE) development is being one of the key focus areas of the country's development strategy. But they receive massive support from the government in the form of access to finance, market, technology, training, and working space. In Ethiopia, the government strongly believes that micro and small enterprises (MSEs) are the right solution to reduce the urban unemployment rate and hence reduce poverty (Arega et al 2016).

### 2.6.1. Contributions of micro and small enterprises

Micro and Small Enterprises (MSEs) have the potential to alleviate poverty and generate employment opportunities for unemployed people. At the same time, the sector plays a significant role in the national economy and will have a major role to play in the future. The Ethiopian private sector similar to other developing countries and the Micro and Small Enterprises (MSEs) in particular face a number of constraining variables that hamper their growth. The common problems include consultancy, working premises, credit, infrastructure, extension service, information provision, prototype development, preferential treatment, and many others, which have yet to be addressed (Hassan et al 2016).

The creation of job opportunities and expansion of economic activities are considered important development strategies in response to the impact of the financial crisis of the developing countries.

Around the world, Micro and Small Enterprises (MSEs) are increasingly seen as the creators of new jobs. The contributions of Micro and Small Enterprises (MSEs) to the national economy can be measured in terms of some interrelated issues: economic (income generation), social (poverty reduction), and political (wealth redistribution). In Ethiopia, the roles and or the contributions of Micro and Small Enterprises (MSEs) have received recognition. They are seen as a means of providing employment, alleviating poverty, ensuring food security, and private sector development (Tekle Hiluf 2014).

### **2.6.2. Micro and small enterprises in construction**

The scope of the construction industry is very vast based on the activity fragments. To accomplish such tasks and handover the entire project on the specified date within the desired quality, the construction project collaborated team players had taken a great role in the construction process with various skills and expertise. The players in the construction project are divided into primary and secondary players. The most important players in any construction project are the owner, designer, and contractor. These are the primary players of any construction project, as each of them provides different services to fulfill the project objective. The secondary players are as important as primary players, as they have power and influence on the construction process and its outcome and they cannot be controlled by the primary players. They can be divided into three layers. The first layer includes subcontractors, material suppliers, and equipment vendors. The second layer includes insurance companies, building code officials, zoning, labor unions, and some input materials and precast component manufacturers grouped within the association. The third layer includes local government, the federal government, trade association, and banks. The last two layers have no contractual connection to any of the primary layers, but they can influence the construction project on a regular basis (Azeb, G 2016).

#### **2.6.2.1. Micro and small enterprises in the Ethiopian construction industry**

In Ethiopian construction industry on the integrated housing development programs (IHDP) which includes 40/60 condominium project programs, 20/80 and 10/90 condominium projects programs launched in 2004, three levels of contractors involved in the condominium development; the housing development program office (HDPO), contractors for structural components (general contractors), and the micro and small enterprises (MSEs) which deals with components. As per

the Ethiopian building code, all contractors shall be qualified and registered for the part they perform and task responsibility for the safety and security of the building and building components they construct. In this regard, the HDPO is a management consultant rather than a contractor. But micro and small enterprises are organized to involve in the condominium buildings to manufacture precast ribbed beams, hollow concrete blocks, and appoint in plumbing and arranging electric power supply lines (Wubshet et al 2015).

## **2.7. Competency of manufacturers**

Manufacturers who have recognized the potential for prefabricated solutions will invest time and expertise in designing, testing, manufacturing, installing, and commissioning a variety of different projects well. This indicates the competency or capability characteristics of manufacturers including small and micro enterprises (SMEs) for their own specific purpose (Sam and George 2005). Competence is a physical or intellectual ability, skill, or both or a performance capacity to do as well as to know carried out under standardized conditions and judged or improved by some level or standard of performance as adequate, sufficient, proper, suitable, and qualified. In addition to that competence draws upon an underlying complex ability and needs to be observed in real-life situations (Richard and Shavelson 2010).

### **2.7.1. Classifications of competency**

Competency can be grouped into three categories known as Knowledge, Know-how/skill, and Behavior/attitude. Knowledge is everything that can be learned from educational or formative systems, training courses, and everything which involves cognitive processes (i.e. perception, learning, communication, association, and reasoning). It represents the theoretical understanding of something such as a new or updated method or procedure. Know-how/skill is related to personal experiences and working conditions. It is learned by doing, by practice, by experience. It is the practical knowledge consisting of "how to get something done". Behavior is individual characters, talents, human traits, or qualities that drive someone to act or react in a certain way under certain circumstances. In general, any kind of manufacturers including small and micro enterprises shall fulfill those three competency categories in order to produce standard or qualified components because the competency level of any manufacturers is measured by those three categorized parameters (Dario R 2016). However, one of the particular objectives of this study is to measure

the micro and small enterprise competency based on the precast ribbed beam standard manufacturing practice on the production shades and indicate its impact on the compressive strength of the produced ribbed beams.

## **2.8. Summary of knowledge gap from the literature**

The literature review covers topics in a reasonable manner, starting from the origins and importance of prefabrication, explain the types of precast system, and define the technical terms used to construct precast concrete elements, moving into details such as the standard production process of precast reinforced concrete ribbed beams starting from the procurement of raw materials up to product final storage on the factory through the micro and small enterprises. Following this, it moves into scientific literature that discusses the benefits of keeping standardization and consider customization on the production process.

In addition to giving a comprehensive view of the precast reinforced concrete ribbed beam production process, the literature review includes definitions and contributions of micro and small enterprises to alleviate poverty, reductions of the urban unemployment rate, contributions on the national economy and engagements in the Ethiopian construction industry, specifically the micro and small enterprises appointment on the integrated housing development programs in Addis Ababa.

Among all this, several types of research prepared in Ethiopia about micro and small enterprises, but most of the studies about the economic contribution of micro and small enterprises like GDP contribution, local economic development, economic growth factors, etc. In the construction industry, there are some studies about them, like the contribution of MSE contractors on the road project, the impact of MSE, and major causes of delay through MSE on 40/60 condominiums. But there is no comprehensive study has been carried out in Ethiopia about precast ribbed beam production. Furthermore, there was nothing written documents about the precast ribbed beam production process applied through the micro and small enterprise associations. The next chapter presents the methodology used for conducting the research.

### **3. RESEARCH DESIGN AND METHODOLOGY**

#### **3.1. Introduction**

The aim and purpose of this chapter are to outline the research methodology utilized for the research study, to comment on how the research was controlled and monitored, and to ensure validity and reliability of the research data and procedures associated with the subsequent analysis and presentation of the data. But the research design is prepared and completed before data collection will start.

#### **3.2. Study area description**

Addis Ababa is the capital of Ethiopia which is located between 8°55' and 9°05' North latitude and 38°40' and 38°50' East latitude in the central plateau of Ethiopia with an average elevation of 2,500 meters above sea level. The city covers an area of 540 sq.km and it has 10 sub-cities and 116 woreda Administrations. It is home to 25% of the urban population in Ethiopia; the population growth rate is 3.8 % per annum and is one of the fastest-growing cities in Africa (Asnake, M 2019). Despite the strong economic growth tends to Addis Ababa faces significant development challenges. For example, unemployment and poverty levels in Addis Ababa remain high, estimated at 23.5% and 22% respectively (World Bank Group, 2015).

Starting from the previous years the growth of the construction industry in Addis Ababa and the housing demand of the population are rapidly increasing. So the federal democratic republic of Ethiopia facilitates the integrated housing development programs in Addis Ababa by constructing different condominium apartments accessed to the population and creating job opportunity for the construction business enterprises including micro and small enterprises to manufacture different construction input prefabrication segments on the manufacturing yard and deliver it into the construction site where the structure is to be constructed (Wubshet et al 2015). From such different prefabrication components, a precast reinforced concrete ribbed beam is one part of prefabricated elements produced by micro and small enterprises in Addis Ababa. All governmental condominium housing projects such as 40/60, 20/80, and 10/90 in Addis Ababa uses precast ribbed beams manufactured by the micro and small enterprises to construct ribbed slab. So it is very

important to collect different information properly related to this research in the city of Addis Ababa.

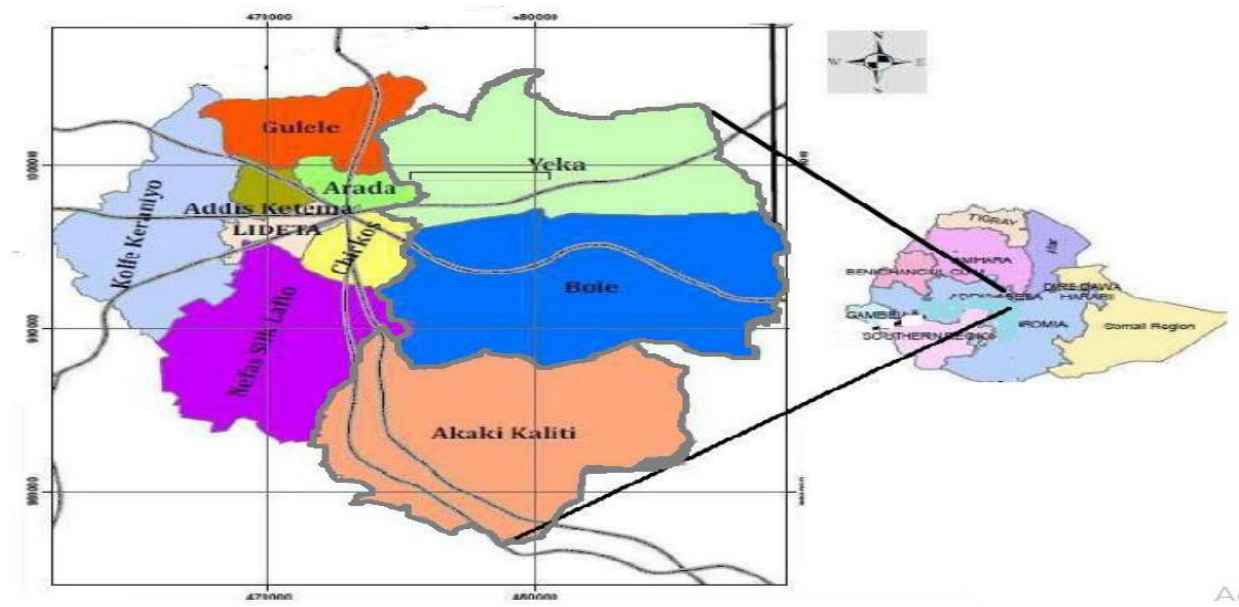


Figure 3.1 The geographic map of Addis Ababa (Asnake, M 2019).

### 3.3. Data source and collection methods

The research used both primary and secondary data collection methods as a tool to gather the necessary information. The primary data was collected by using three methods mainly through a survey in-depth interviews with the ribbed beam manufacturers (the micro and small enterprises) and the regulatory bodies (consultants and micro and small enterprise offices), on-site observations of the on-going precast ribbed beam production, and experimentations of the finished products. The second mechanism of data collection in which this research used was secondary data mainly through documentation reviews.

#### 3.3.1. Interview

Face-to-face interviews were made with the ribbed beam manufacturers to gather data about the procuring techniques of the reinforced concrete ingredients, about test investigations before and after concrete production, and about the root causes of production defects on the manufacturing shade. And also conduct interviews with regulatory bodies (professionals of micro and small enterprise offices and consultants) about their contribution, roles, and responsibilities on the ribbed beam production process.

### 3.3.2. Observation

Continuous site visits conducted on the ribbed beam production shades to record different data's about the manufacturers (MSEs) production practice starting from material selection up to final product to examine the usual production practices of the manufacturers to standard manufacturing processes, to investigate the occurrence defects and root causes during ribbed beam production on the manufacturing shade. Figure 3.2 shows, the observation parameters taken by the researcher on the manufacturing shade during a ribbed beam production.

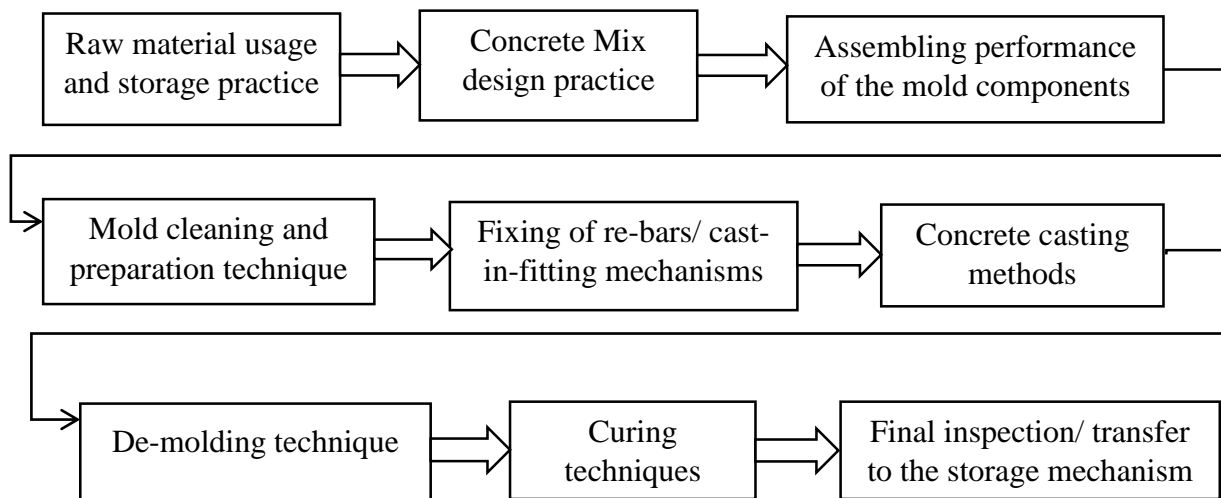


Figure 3.2 Observation process of the researcher on the ribbed beam manufacturing shade.

### 3.3.3. Experimentation

Experimentation was made on the manufacturing shades. This is a non-destructive rebound hammer test has conducted from the precast ribbed beam samples to identify the product quality compliance criteria and to show the manufacturer's production capability and the consultants' professional duty on product standard. The results of the experiment have used in evaluating 81 precast ribbed beam samples from 9 manufacturing shades and 27 manufacturing enterprises of the study area shown in Table [5].

### 3.3.4. Documentation

Documentation reviews were made from the Yeka, Bole, and Akaki Kality Subcity micro and small enterprise administrations beauro to found data's about the amount and educational backgrounds of the precast ribbed beam manufacturers to identify the scientific capability of them about precast concrete production. Review documents from contractual arrangements to obtain

information about the supervision and quality controlling roles of consultants. Review different researches and country codes including ACI, ASTM, ISO, Chain JGJ, Japan JCSE codes to understand how to take rebound hammer compressive strength test results on the concrete member and the product quality compliance criteria.

### 3.4. Sampling technique

On the Addis Ababa integrated housing development program project (IHDPP), micro and small enterprises are the main players as a client, consultant, and contractors. They are organized to manufacture precast ribbed beams, hollow concrete blocks, terrazzo tiles, and produce aggregate materials thereafter delivered such products into the government housing projects as an input. According to the Ethiopian micro and small enterprises agency (2018), 108 micro and small enterprise associations are active to manufacture precast reinforced concrete ribbed beams on the provided shades on the 10 sub-cities of Addis Ababa. From such sub-cities more than 50% of enterprises involved in Yeka, Bole, and Akaki Kality sub-cities shown in Table [4].

Table 4 Precast ribbed beam manufacturing enterprises in Addis Ababa (Ethiopian micro and small enterprise agency, 2018).

No	Sub-city	Amount
1	Akaki sub-city	26
2	Bole sub-city	26
3	Yeka sub-city	11
4	Kolfe sub-city	8
5	Gulele sub-city	7
6	Lideta sub-city	3
7	Addis sub-city	5
8	Kirkos sub-city	7
9	Neffasilk sub-city	7
10	Arada sub-city	8

On each manufacturing shades, a minimum of 13 and a maximum of 15 micro and small enterprise associations delegated by the shade agencies to manufacture precast ribbed beams. However, some manufacturers legally breach from their contract and some others leave out illegally from the

production shade to different parameters which include profitability problems, cheating, shortage of works provided by the government, etc. But some manufacturers still produced precast ribbed beams on the manufacturing shades and the researcher collect the desired data's from such active manufacturers based on systematic sampling technique and analyzed it to establish the research objective.

The researcher observed 27 micro and small enterprise precast ribbed beam manufacturers from the 9 manufacturing shades which are 3 manufacturing shades observed from Bole Subcity, 3 from Yeka, and 3 from Akaki Kality Subcity. And the researcher had taken data of a rebound hammer compressive strength test results on the precast ribbed beam member from the 27 active manufacturers' product. From each manufacturing enterprise, three precast ribbed beam samples are taken, a total of 81 precast ribbed beam samples taken for the research analysis shown in Table [5].

Table 5 Research samples taken by the researcher.

Subcity	Locations of production shades	Observed Manufacturing enterprises	Amount of ribbed beam samples taken on every enterprise	Total ribbed beam samples taken from each production shade
Bole	1. Ayat (cheffe 49)	3	3	$3*3= 9$
	2. Meri	3	3	$3*3= 9$
	3. Semmit	3	3	$3*3= 9$
Yeka	1. Karra	3	3	$3*3= 9$
	2. Abado	3	3	$3*3= 9$
	3. Deninet (W 10)	3	3	$3*3= 9$
Akaki Kality	1. Kilinto	3	3	$3*3= 9$
	2. Koyefech	3	3	$3*3= 9$
	3. Koye nefasilk	3	3	$3*3= 9$
Total	9 Production shades	27 Enterprises	81 Precast ribbed beam samples had taken	

## **4. RESULTS AND DISCUSSIONS**

### **4.1. Introduction**

Extensive data was collected through the data source and collection methods justified on the research methodology. In this chapter, government contributions on the licensing procedures of the micro and small enterprises, the amounts and educational backgrounds of ribbed beam manufacturers (micro and small enterprises), the precast ribbed beam entire production practices through the micro and small enterprises and the root causes of production defects, the roles of regulatory bodies, the manufacturer's production capability, and professional duties of consultants to the contractual arrangement, and the non-distractive rebound hammer compressive strength results of the precast ribbed beams and a such are discussed and analyzed to understand the existing situation. The findings are presented in the following subsections of this chapter.

### **4.2. Government contribution and licensing of micro and small enterprises**

The procedure followed by micro and small enterprises seeking to obtain a license to produce precast reinforced concrete rib beams is as follows:

- First, organize and form a union association on each woreda's through the coordinators on the micro and small enterprise offices by fulfilling the rule and regulations known as seeking the jobless identity cards by filling the reproach forms and approved by the volunteer village job opportunity and creative councils.
- Then the associations take short training about precast ribbed beam production for 15 days on the governmental TVT training center. The training center also transfers the list of trainers into the respective sub-city.
- Then the respective Subcity transfers the list of trainers into the respective woredas and each Woreda writes a letter into the Trade and Industry Bureau to ratify the name and legality of the association.
- The Trade and Industry Bureau sends them into the Testament and Contract agency Beureo to get consent between the associations.
- Then the associations get Tin numbers for the availability of tax.
- Then after the shade agency provides the manufacturing shade to the associations (MSEs).

- Finally, the government facilitates rental funds for the associations to facilitate the necessary production tools and equipment. Thereafter the association properly erects and fixes the production tools and equipment's on the provided shades ready to fabricate.

#### 4.3. Contributions of micro and small enterprise regulatory bodies

According to interview and documentation reviews by the researcher, the micro and small enterprise offices (delegated on the housing projects) are a facilitator to fulfill the manufacturer's need through document and market relation and support and follow- up shown in figure 4.1.

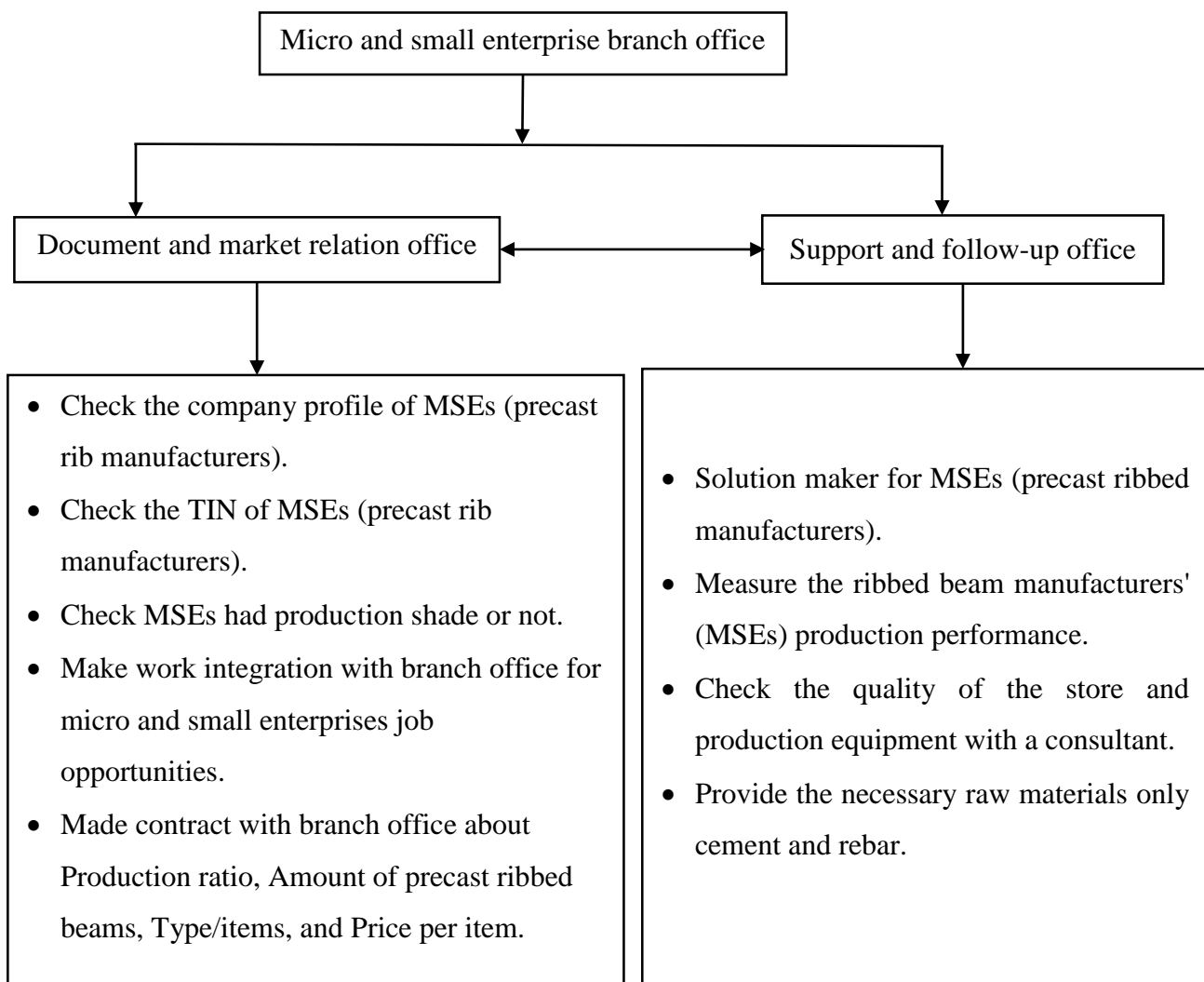


Figure 4.1 Contributions of micro and small enterprises office for the manufacturers.

#### 4.4. Educational backgrounds of precast ribbed beam manufacturers (MSEs)

It may necessary to identify the educational background of personnel before going to fabricate the precast ribbed beams on the manufacturing shade to delegate the required professionals on the manufacturing shade, to inspect and consult the entire production process, to handle the production defects, and to obtain the design value of the fabricated components. Table [6, 7, and 8] shows, the educational backgrounds of the precast ribbed beam manufacturers on Bole, Yeka and Akaki Kality Subcity from the data's recorded at July 2019 G.C. But the list of such manufacturers (enterprises) included for the discussion established since in 2005 up to 2017 G.C.

Table 6 Educational backgrounds of MSEs at Bole sub-city.

Educational background	Amount of personnel's	Percentage
Uneducated	7	5.5%
Grade 1-8	29	22.8%
Grade 9-12	54	42.5%
College	16	12.6%
University	21	16.5%
TOTAL	127	100%

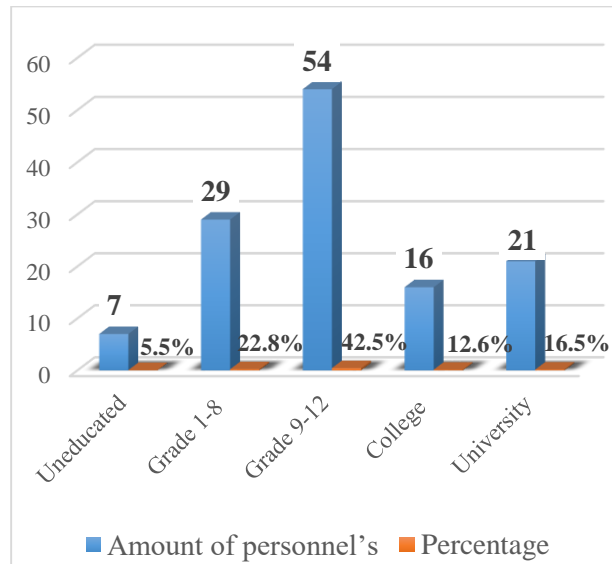


Figure 4.2 Educational backgrounds of manufacturers from Bole Subcity.

As shown the chart in figure 4.2, 42.5% of precast rib beam manufacturers (micro and small enterprises) were from Grade (9-12), 22.8% of manufactures were from Grade (1-8), 16.2% of manufactures were from university graduates by any field of specialization, 12.6% of manufacturers were from college graduates by any field of specialization and the remaining 5.5% of precast rib manufacturers were completely uneducated on Bole sub-city area.

Table 7 Educational background of MSEs at Yeka sub-city.

Educational background	Amount of personnel's	Percentage
Uneducated	0	0%
Grade 1-8	4	4.3%
Grade 9-12	24	26.1%
College	18	19.6%
University	46	50.0%
TOTAL	92	100.0%

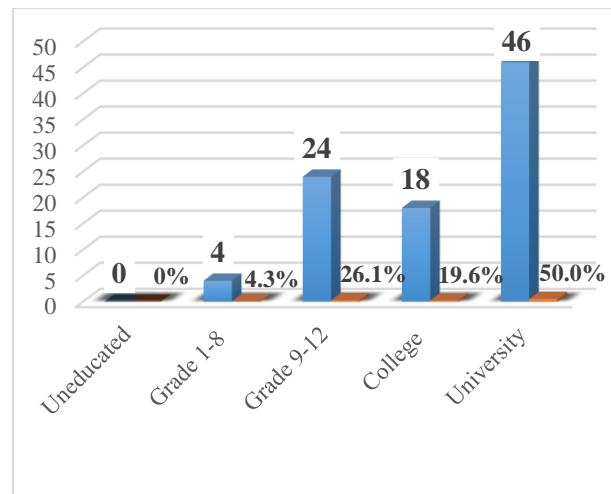


Figure 4.3 Educational backgrounds of manufacturers at Yeka Subcity.

On Yeka Subcity shown in figure 4.3, 50% of precast ribbed beam manufacturers (micro and small enterprises) involved to manufacture it from university graduates through any field of specialization, 26.1% of manufactures involved from Grade (9-12), 19.6% of manufacturers were from college graduates by any field of specialization and the remaining 4.3% was from Grade (1-4).

Table 8 Educational background of MSEs at Akaki Kality Subcity.

Educational background	Amount of personnel's	Percentage
Uneducated	0	0%
Grade 1-8	29	20.1%
Grade 9-12	52	36.1%
Collage	46	31.9%
University	17	11.8%
TOTAL	144	100.0%

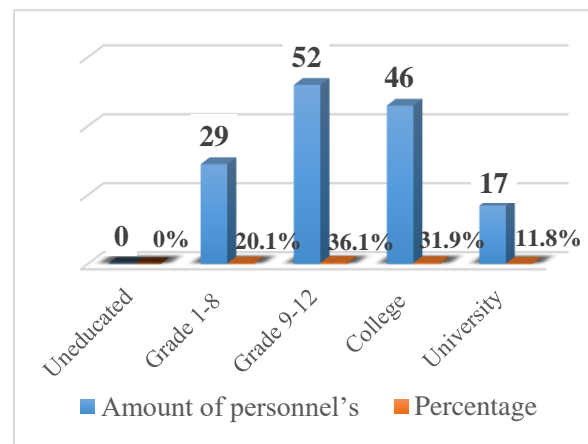


Figure 4.4 Educational backgrounds of MSEs from Akaki Kality Subcity.

As shown the chart in figure 4.4, 36.1% of manufacturers (micro and small enterprises) involved from Grade (9-12), 31.9% of them was from college graduates through any field of specialization, 20.1% of manufacturers also from Grade (1-8) and the remaining 11.8% of manufacturers involved from university graduates by any field of specialization.

Table 9 Educational backgrounds of MSEs at Bole, Yeka & Akaki Kality Subcity.

Educational background	Total amount	Total percentage
Uneducated	7	1.9%
Grade 1-8	62	17.1%
Grade 9-12	130	35.8%
College	80	22.0%
University	84	23.1%
<b>TOTAL</b>	<b>363</b>	<b>100.0%</b>

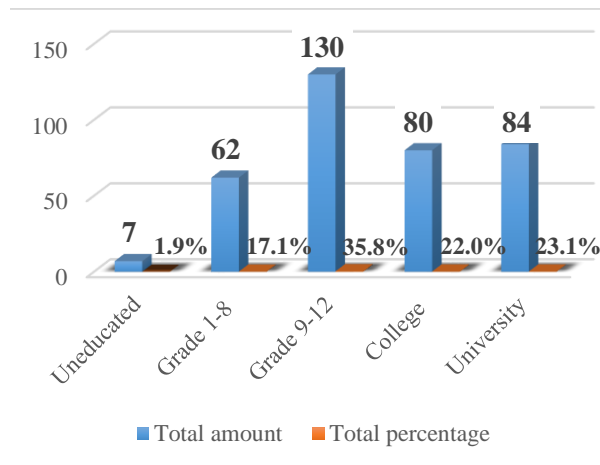


Figure 4.5 Educational backgrounds of MSE on Bole, Yeka, and Akaki Kality Subcity.

In general, 35.8% of manufacturers involved form Grade (9-12), 23.1% from university graduates through any field of specialization, 22.0% of them involved from college graduates through any field of specialization, 17.1% of manufacturers involved from Grade (1-8) and the remaining 1.9% of manufacturers are completely uneducated shown in figure 4.5.

#### 4.5. Precast ribbed beam production practices through the MSEs

The city government of Addis Ababa saving house development enterprise (AASHDE) which is the 40/60 condominium project and the Addis Ababa housing development project (AAHDP) which is 20/80 and 10/90 condominium projects are constructed through the ribbed slab. In this type of slab, a precast reinforced concrete ribbed beam is one segment of ribbed slab together hollow concrete ribbed block used for structural ribbed slab stability and live load distribution into the main beam. And yet this segment is produced in the manufacturing shades by the group of micro and small enterprise associations on the particular Subcity in Addis Ababa. But the following discussed parameter indicates the precast ribbed beam production practices applied by

the micro and small enterprise associations on the production shade starting from the raw material usage and storage practice up to the product final storage. And yet such discussed information's collected mainly through observations by the researcher and interviews of ribbed beam manufacturers on the production shade.

#### **4.5.1. Reinforced concrete raw materials usage and storage practice through MSEs**

According to the contractual arrangement signed between the City Government of Addis Ababa Saving Houses Development Enterprise (AASHDE) of the one part and the micro and small enterprises (ribbed beam manufacturers) on the other part and the Addis Ababa housing development project (AAHDP) of the one part and the micro and small enterprises (the ribbed beam manufacturers) on the other part under the annexes of the material supply list, cement and reinforcement bar is supplied by the government whereas the coarse and fine aggregate material is provided by the micro and small enterprises (precast ribbed beam manufacturers). But the handling of such materials on the manufacturing shade is the roles and responsibilities of the ribbed beam manufacturers (the micro and small enterprises) by the consultant's inspection and quality control technique.

According to the consultancy service agreement signed between the consulting architects with the city government of Addis Ababa saving house development enterprise (AASHDE) and with the Addis Ababa housing development project (AAHDP), Soil Investigation & Laboratory Testing, Construction Supervision, Contract Administration, Quality Control, and Site Work Design for 40/60 Saving Houses Construction Project and for 20/80 and 10/90 housing development project is the signature of Consulting Architects and Engineers PLC. And also routinely supervise the quality of prefabricated building elements such as hollow concrete block and precast ribbed beams on production sites which will be produced on-site or off-site (if any with different enterprises), and approve it before supplied to the project site is the responsibilities of the signature of Consulting Architects and Engineers PLC. But none of this has been seen on the site visit.

##### **4.5.1.1. Batching and storage practices of aggregate on the production shade**

According to interviews by the researcher, ribbed beam manufacturers procured the aggregate materials (both fine and coarse aggregate) from the source without doing any kinds of quality

assurance testes. The only thing considered by them is cost minimization during the procuring process.

### *I. Storage practices of aggregate*

As observed on the production shades (shown in figure 4.6 a & b), the aggregate materials stored whatever the ground on the manufacturing shades without doing any cares about it through the ribbed beam manufacturers and exposed it into different factors by the actions of environmental influences. But reinforced concrete materials needs to be stored in the ordinary condition because of some factors to may be affected such as temperature factor, humidity, ground moisture, etc.

Placing of aggregate on the uncontrolled environment may enhance mixing water and bulking of sand by the actions of surface moisture available on the aggregate and can affect the workability of concrete during production. Besides, some additional problems may occur on the plastic and harden states of concrete such as bleeding and segregation during casting, plastic shrinkage crack, capillary pore, and transportation mechanism through porous media on the existed crack.



a) Storage practice of fine aggregate



b) Storage practice of coarse aggregate

*Figure 4.6 Storage practices of aggregate on the ribbed beam manufacturing shades (picture taken by the researcher).*

Regular supervision and quality control is the role and responsibilities of the consultants on the manufacturing shades according to the contractual arrangement signed between the parties. But as observed and interviews by the researcher, (1) inefficient routine supervision and quality controlling practice by consultants, (2) shortage of sufficient place in the manufacturing shades, and (3) manufacturer’s lack of appropriate knowledge about the impacts of inadequate material

storage on products are the causes of keeping aggregate materials inadequate in the manufacturing shades by the micro and small enterprises.

## II. *Batching practices of aggregate*

According to literature reviews, concrete prefabrication requires material standard, measuring/batching standard, quality standard, and process standard (consistent production process) to provide stated results. But as observed by the researcher (shown in figure 4.7 on the picture (a) & (b)), most ribbed beam manufacturers utilized the aggregate materials over the required specification batching through gage box for concrete production. Incorrectly utilized aggregate materials for concrete production results a significant effect on quality. Applied overestimated amount of coarse aggregate may produce less binding concrete due to minimum mortar proportional unit by volume whereas utilized over amount of fine aggregate may led to produce harsh concrete.

According to interviews and observations by the researcher, inefficient inspection and quality controlling practice by consultants, manufacturers lack of appropriate knowledge about aggregate proportioning for a specified concrete strength, the absence of standard production document available on the production shades to govern manufacturers, and concrete mix design implementation problems are the causes being utilized over estimated amount of aggregate materials on the manufacturing shades.



a) Over batching of fine aggregate



b) Batching and grading of coarse aggregate

*Figure 4.7 Batching practice of aggregate on the precast ribbed beam manufacturing shades (picture taken by the researcher).*

Most manufacturers used the recycled coarse aggregate for a ribbed beam production by crashing the waste broken ribbed beams through hammer on the manufacturing shade shown in figure 4.7 on the picture b). Because (1) most ribbed beam manufacturers had not required knowledge about gradation and how it affect the quality of concrete, (2) the aggregate materials were purchased by the manufacturers according to the contractual arrangement, (3) manufacturer's lack of knowledge about where and when the required types and gradation of coarse aggregate used, (4) concrete mix design implementation problem in the manufacturing shades due to the consultant's inefficient supervision and control practices, and (5) most ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person assigned to accomplish the tasks and such are the critical causes of the problem.

#### **4.5.1.2. Batching and storage practices of cement on the production shade**

##### *I. Storage practices of cement*

*"According to [ACI 304R-00] all cement should be stored in weather tight and on properly ventilated structures to prevent absorption of moisture"*. But as observed by the researcher, most ribbed beam manufacturers had store cement without keeping a standard requirement. As shown in figure 4.8, it was store into the ground without making wood battens, with no proper ventilation and packed it randomly with different tools, unnecessary dirt's, clothes, woods, electric cables, metals, plastics, mold lubricant chemicals on the stores at the manufacturing shades. Such practice can facilitate to decrease the cement specified store period by the actions of a chemical reaction between cement substances specially tri-calcium aluminate (C3A) with moisture. Besides that, the quality of cement will have the chance to deteriorate before use it and enhance wastes of cement on the manufacturing shades.

As observed by the researcher, (1) manufacturers (MSEs) lack of knowledge about the factors that affect the properties of cement on the store, (2) consultants inefficient supervision practice on the production shades, (3) manufacturers (MSEs) lack of knowledge about the inadequate storage practice can affect the quality of cement and the concrete quality too and (4) the absence of standard production documents available in the manufacturing shades to govern the manufacturers to handle cement on the store properly and a such are the causes of the problem.



*Figure 4.8 Cement storage practice on the ribbed beam manufacturing shade through MSEs (picture taken by the researcher).*

## *II. Batching practices of cement*

As observed, most manufacturers had taken cement randomly from the store without considering the sequential indent period. But it should be recorded at the time of packing on the store to remember the expiration date before use it. In most production shades, cement was not recorded at the time of delivery into the manufacturing shades by the ribbed beam manufacturers. Besides that, manufacturers couldn't know the cement was expired or not during production.

The recommended proportioning of concrete ingredients for a ribbed beam production is 1:2:3 and the design strength of the concrete to be produced is C-25Mpa. But as observed by the researcher, most ribbed beam manufacturers applied additional cement over the recommended one bag by using hand shovel for each mix during concrete production shown in figure 4.9 on picture (b). But applied extra cement over the estimated standard will produce high mortar concrete related to the volumetric ratios of both fine and coarse aggregate available for concrete production. If so, plastic shrinkage crack will have the chance to occur in the plastic state of concrete by the actions of exothermic reaction between cement and mixing water.



a) Batching of cement on transit mixer



b) Applied extra cement on the same mix

Figure 4.9 Consumption of extra cement by the rib manufacturers on the production shades (picture taken by the researcher).

Therefore, the consumption of cement utilized by the ribbed beam manufacturers was high due to; (1) cement provided by the government on the manufacturing shade according to the contractual arrangement and yet manufacturers applied cement without any care, (2) manufacturers lack knowledge about the effects of utilizing over estimated amount of cement on strength and durability of concrete, (3) manufacturers misunderstanding concept about cement (most manufacturers believed that applied over the estimated amount of cement can improve the desired compressive strength of concrete), (4) consultants inefficient monitoring practice on the manufacturing shades, and (5) most ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person assigned to accomplish the tasks.

#### 4.5.1.3. Usage and storage practices of rebars on the production shades

##### *I. Storage practices of reinforcement bar*

As observed by the researcher, the storage practices of the reinforcement bar was inconvenient on the manufacturing shade through the precast ribbed beam manufacturers (the micro and small enterprise groups). Because it was placed outside the shade on the uncontrolled environment into the unnecessary ground condition on the manufacturing shade without considering moisture impact by the manufacturers shown in figure 4.10. Therefore, in most production shade rebars were corrode and utilize as it is through the manufacturers for a ribbed beam production. Such

practice may cause a troubling effect on the qualities of the reinforcement bars and the durability of the produced ribbed beams through different factors like bond effect between rebars with concrete and it led to corrosion crack.



*Figure 4.10 Reinforcement bar storage practice on the manufacturing shade through MSEs (picture taken by the researcher).*

Therefore, in most production shades like fine and coarse aggregate rebars stored out of the manufacturing shade on the uncontrolled environment without given special protection from the environmental factors. Because of (1) shortage of sufficient places available to stored rebars properly on the manufacturing shade provided by the shade agencies, (2) manufacturers (MSEs) lack of appropriate knowledge about how much weathering impact affects the properties of reinforcement bars and the durability of ribbed beams, (3) the absence of standard production documents available in the manufacturing shade to govern the manufacturers to handle the reinforcement bars properly, and (4) the consultant's inefficient regular supervision and quality controlling practice on the manufacturing shades.

## II. Reinforcement bar utilization practice

As observed by the researcher, rebars utilized inaccurately by the ribbed beam manufacturers (a group of micro and small enterprise associations) on the production shades. As shown in figure 4.11 on picture (a) and (b), most manufacturers cutting the rebar folds wrongly to minimize their effort and time without giving a special consideration about reinforcement bar wastage. Besides that, wastes of reinforcement bar available on the production shades due to; (1) the consultants inefficient routine monitoring practice, (2) rebars procured and provided by the government into the manufacturing shades according to the contractual arrangement beside manufacturers utilized it without any care, (3) most manufacturers had not given considerations about the financial deficits of the government through the rebars wastage, and (4) most ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person assigned to accomplish the tasks.



a) Inaccurate rebars cutting practice



b) Reinforcement bars wastage

Figure 4.11 Reinforcement bar utilization practice on the ribbed beam production shades (picture taken by the researcher).

### 4.5.1.4. Type and utilization practice of water on the manufacturing shades

It is very important to consider the quality and quantities of mixing water during concrete production. Because the utilization of mixing water over the specified quantity can affect the workability of concrete on the plastic state and it may lead to producing capillary concrete. But it recommends utilizing the amount of mixing water based on the concrete mix design calculation,

besides, to check the quality of water through laboratory tests to fabricate the target quality components.

As observed by the researcher, most manufacturers (MSEs) utilized mixing water purchased from the sellers and accumulated through the existed pool on the production shade without identifying the quality of it. As shown in figure 4.12 on picture (a), a lot of waste materials such as re-bars, broken blocks, plastics, grown and dead plants occurred over and around the existing pool water utilized for ribbed beam production on the manufacturing shade. But on Yeka Subcity at Karra production shade, manufacturers utilized discharge water for concrete production resulted from the surrounding society to fabricate precast ribbed beams. As shown in figure 4.11 on the picture (b), the collection of dirt's wasted from the society such as plastics, clothes, household ruins, and existing plants was found over and around the discharge water. Such practice may affect the workability of concrete on the plastic state, strength, and durability on the hardened state besides the algae's and aggressive chemicals that may be involved in the water.



a) The existed pool water



b) Discharge water from the society

*Figure 4.12 The type of water used for ribbed beam production on the manufacturing shades (picture taken by the researcher).*

According to interviews and observations by the researcher, (1) the absence of adequate water provided by the government on the manufacturing shade, (2) inefficient supervision and quality controlling practice by the consultants on the manufacturing shades, (3) manufacturers (MSEs) lack of knowledge about which type and requirements of water available for concrete production,

and (4) most ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person assigned to accomplish the tasks are the causes of utilized inadequate mixing water for concrete production.

#### 4.5.2. Concrete mix design practice

According to literature reviews, the mix design can be designed in two ways known as nominal concrete mix and design concrete mix. But as observed by the researcher on the manufacturing shade, the mix design was designed and implemented through a nominal mix. This means any requirements of concrete ingredients were prescribed before going to mix through the transit mixer rather than investigate the desired properties of such ingredients.

According to the contractual arrangement, the target strength of the concrete manufactured by the ribbed beam manufacturers had C-25Mpa using 1:2:3 volumetric batching ratios through the gauge box as a prescription standard. However, most ribbed beam manufacturers batching the aggregate materials (both fine and coarse aggregate) over the prescription standard through gage box, add mixing water without considering the desired quality and quantities, applied high cement content over the specified one bag for one mix, and the mixing process applied by the manufacturers will without considering the mixing period through transit mixer shown in figure 4.13.



a) Over batching of sand



b) Applied extra cement



c) Application of mixing water

*Figure 4.13 Concrete mixing practice on the ribbed beam production shade through the MSEs (picture taken by the researcher).*

According to interviews and observations by the researcher, (1) manufacturers lack of knowledge and technical performances about a standard concrete mixing process, (2) concrete mix design applied through nominal mix rather than design mix, (3) absence of a standard ribbed beam

production manuals on the manufacturing shade to govern the manufacturers, (4) consultants inefficient routine supervision and quality controlling practice on the manufacturing shades, and (5) most ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person assigned to accomplish the tasks are the causes of batching and mixing concrete ingredients out of the prescription standard on the production shades.

#### **4.5.3. Mold handling and assembling practices on the ribbed beam production shades**

Standard mold handling and assembling practice are necessary to provide a standard dimension and sharpness edge precast components. Unless the desired components may not achieve the anticipated designed value.

##### **4.5.3.1. Mold handling practice**

As observed, most ribbed beam manufacturers were handling the mold components improperly on the manufacturing shades. As shown in figure 4.14, the mold components placed wrongly wherever the ground on the manufacturing shades without consider corrosion by the action of moisture and placed with different waste materials of broken HCB, plastics, piece of woods, dust, etc. Besides that, the fixing points of the mold components had broken, the depreciation value of the mold components can increase before attaining the payback value.



*Figure 4.14 Mold handling practices on the manufacturing shade through the MSEs (picture taken by the researcher).*

According to interviews and observations, (1) manufacturers lack of knowledge and technical skills to handle the mold components properly in the manufacturing shade, (2) manufacturer's lack of knowledge about the effective mold handling technique can improve the durability of the mold components, (3) the absence of standard ribbed beam production documents on the manufacturing shade to govern manufacturers, (4) the consultant's inefficient regular supervision practice on the production shades, and (5) most ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person assigned to accomplish the tasks are the causes of wrongly handling the mold components on the manufacturing shades.

#### 4.5.3.2. Mold assembling practice

Even though check the level and flatness of the ground where the assembled molds to be placed, check the dimension of the mold within the specified tolerance, ensure the squareness of the mold and mold of adequate stiffness as per the issue of drawings are the necessary parameters to be considered during the mold assemblage on the manufacturing site. But none of this has been considered on the manufacturing shade during the ribbed beam production.

As shown in figure 4.15 on picture (a), the length of the mold was longer as compared to the design length of the produced ribbed beams. Because the standard length of the mold was 6m whereas the required lengths of the ribbed beam were 5.53m, 4.23m, and 4.18m according to the structural design requirements of the buildings. Besides that, the water-cement was flowed away from the casted concrete during consolidation through table vibrator shown in picture (b) and had been produced harsh edged ribbed beams on the manufacturing shades shown in picture (c).



a) Production mold



b) Flow of water-cement



c) Harsh edged ribbed beam

*Figure 4.15 Mold standardization and its impact on the provided component (picture taken by the researcher).*

As observed (shown in figure 4.16 on the picture a), the stiffness of the mold affected mainly by the improper mold handling and de-molding techniques through the ribbed beam manufacturers on the production shades. Besides that, edges/fixing points of the assembled molds had broken and fitted improperly. Hence mortar units (water-cement) have been wasted away from the casted concrete on the assembled mold during consolidation through table vibrator shown in picture (b).



a) Mold stiffness problem



b) Wastes of mortar

*Figure 4.16 Mold stiffness problem and its impact on concrete (picture taken by the researcher).*

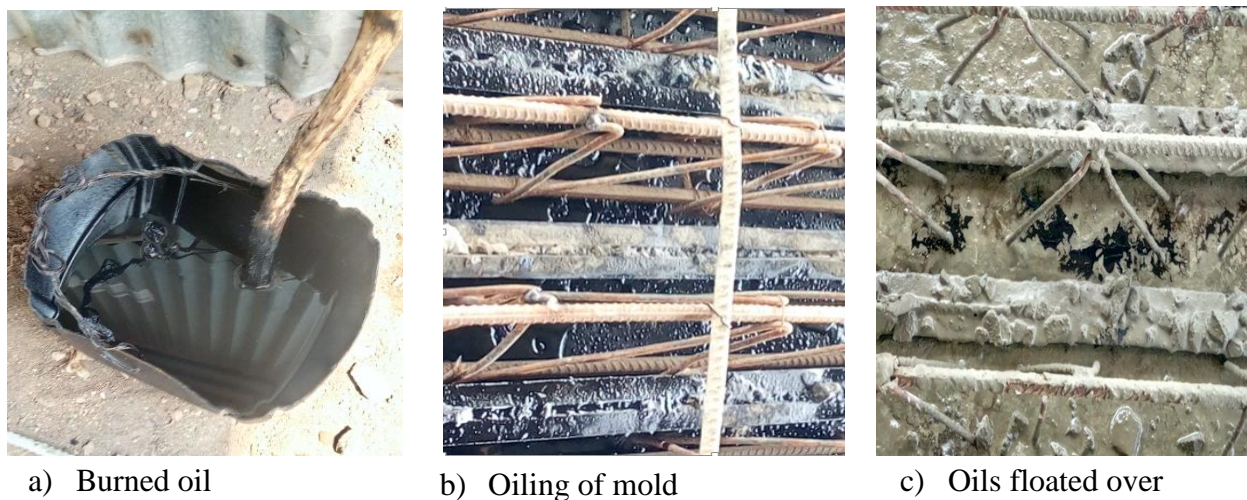
According to interviews and observations by the researcher, (1) design inflexibility of the mold components related to the design behavior of the ribbed beams, (2) mold standardization problem, (3) improper mold handling and de-molding practices, (4) the consultant's inefficient regular supervision and quality control practices, and (5) most ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person assigned to accomplish the tasks and such are the main causes of the occurrence defects during mold assemblage on the manufacturing shades.

#### **4.5.4. Mold cleaning and preparation practices on the ribbed beam production shades**

Before cast the concrete, the mold components must be washed and remove the derbies of the old mortars and prepared it by using recommended mold oils within the prescription standard. As observed, most ribbed beam manufacturers clean and prepared the mold components improperly

before going to cast the concrete. They cast concrete without removing the derbies of the old mortars from the assembled mold and lubricate it through burned oils without any standard measurement based on the manufacturer's permission.

As shown in figure 4.17, a ribbed beam manufacturer's utilized excess burned oils for mold preparation without any prescription standard according to the well of manufacturers. Thereafter insert the fixing rebars before dry the lubricated molds and cast the concrete sequentially shown in picture (b). Besides that, the burned oil contact with the fitted rebars on the assembled mold and mixed with concrete then after bleeding it over the casted concrete during vibration shown in figure (c). Therefore it is not good to utilize burned oils for mold preparation even excess amount over the desired specification. Because it may occur chemical reactions between the aggressive elements in the concrete particle and on the burned oils in addition to affect the bond between the concrete and the reinforcement bars.



*Figure 4.17 Mold cleaning and oiling practice on the manufacturing shade through the MSEs (picture taken by the researcher).*

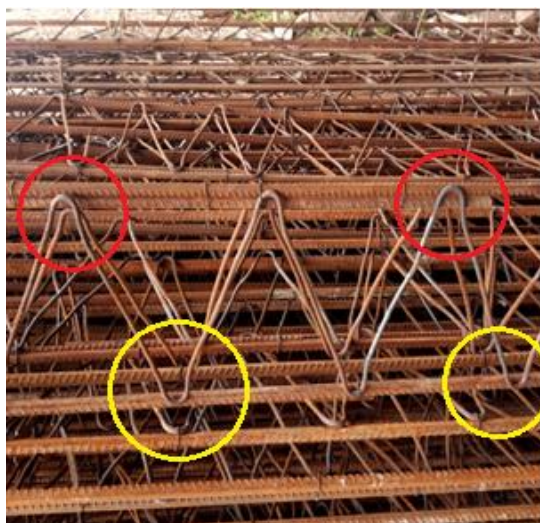
According to interviews and observations by the researcher, (1) manufacturers lack of knowledge about the impacts of utilizing the excess amount of burned oils, (2) the absence of standard ribbed beam production manuals available to guide the manufacturers, (3) the consultant's inefficient regular supervision and quality controlling practices on the production shades, and (4) most ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person

assigned to accomplish the tasks are the causes of cleaning and preparing the mold components improperly on the manufacturing shades.

#### 4.5.5. Rebar fixing and cast in fitting practices on the ribbed beam production shades

As observed by the researcher, most ribbed beam manufacturers were fixing the reinforcement bar incorrectly through the black wire without keeping the required specification, they call it damma in Amharic on the manufacturing shades shown in figure 4.18 on picture (a). Such practice may cause precast ribbed beam shear failure and enhance tensile deflection by the actions of flexural force applied on the slab. During a ribbed beam production, manufacturers had been cast the concrete on the previously assembled/prepared molds without fitting spacers to provide a standard concrete cover shown in picture (b).

However, the pouring of concrete without fitted a spacer properly may cause a significant problem on the strength and durability of the final product (precast ribbed beam). Because it may produce a non-standard concrete cover and the provided cover might be mortar based on the actions of vibration impact, in addition to that, the thickness of the cover might be smaller as compared to the recommended standard. Yet, it is desired to provide a standard concrete cover to prevent concrete components from external factors alike transportation mechanism applied through porous media.



a) Fixing or rebar



b) Fitting rebars without placing spacer

Figure 4.18 Fixing of rebars and cast in fitting practice on the manufacturing shades by MSEs (picture taken by the researcher).

According to interviews and observations by the researcher, (1) manufacturers lack of knowledge about the impacts of fixing rebar and fitting spacer properly on the strength and durability of the concrete, (2) consultants inefficient routine supervision and quality controlling practice on the manufacturing shade, (3) the absence of standard ribbed beam production manuals available on the manufacturing shades to govern and guide manufacturers, and (4) most ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person assigned to accomplish the tasks and a such are the causes of producing precast ribbed beams without fixing rebars and fitting spacers properly on the manufacturing shades.

#### **4.5.6. Concrete casting practices on the ribbed beam production shades**

Even though concrete prefabrication practice requires standard professional expertise and calibrated production machinery with proper concrete casting procedures to provide the optimal design components. It has been observed that ribbed beam manufacturers had not plenty of professional performances to mix, place and consolidate the concrete, the production tools and equipment's had not mechanized rather it was manual to mix, place and consolidate the concrete and had no production documents available to show and govern the ribbed beam manufacturers about concrete casting procedures.

In addition to that, most ribbed beam manufacturers (MSEs) laid a concrete wherever the ground after it was mixed through a transit mixer without considering contaminations through organic matter. Besides that, the concrete particles separated apart, which is water-cement particles isolated from the coarser particle and tends to bleed and segregation shown on picture (a). Thereafter, it was placed randomly into the assembled molds by the manufacturers using hand shovel shown on picture (b) in figure 4.19. Such practice is difficult to yield material separation between coarse aggregate and mortar particles because of the free space on the mold may field by the free mortar through vibration impact.



a) Putting of concrete on the unsafe ground



b) Random placing of concrete on the mold

*Figure 4.19 Concrete casting practices on the ribbed beam production shades (picture taken by the researcher).*

As observed, ribbed beam manufacturers followed the following procedures to consolidate the casted concrete through table vibrator. (1) Rebar's were fixed and fitted into the previously assembled molds, (2) Then by using labor-intensive movable equipment's and chain blocks the final entire component ware moved and placed on table vibrator, (3) Then ribbed beam manufacturers had placed the fresh concrete randomly on the assembled mold, and (4) Finally consolidate the placed concrete according to the manufacturer's permission without considering the recommended vibration time shown in figure 4.20.



a) Lifting and moving of the entire mold component



b) The mold component on the table vibrator



c) Vibrate the casted concrete

*Figure 4.20 Concrete vibration procedure on the ribbed beam production shade (picture taken by the researcher).*

According to interviews and observations by the researcher, (1) manufacturer’s incapability (lack of knowledge and technical skills) to mix, place and consolidate the concrete, (2) consultants inefficient supervision and quality controlling practice on the manufacturing shades, (3) the absence of well-prepared ribbed beam production manuals available on the production shades to lead and govern the manufacturers, and (4) most ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person assigned to accomplish the tasks and a such are the causes of casting concrete improperly by the ribbed beam manufacturers on the production shades.

#### **4.5.7. Mold dismantling practices on the ribbed beam production shade**

Notwithstanding mold dismantling had its standard disassembling procedures to pull apart the assembled molds from the casted component without any failure. As observed, ribbed beam manufacturers had not applied a standard disassembling process adequately on the manufacturing shades. Because they dismantle the mold components improperly through striking it's forcefully from the casted concrete by using any kind of divot steel or rebar's shown in figure 4.21. But such practices may cause any failure or damage on the casted concrete and rebar's weld due to the provisions of extra force applied to it.



*Figure 4.21 Mold dismantling practice on the production shades (picture taken by the researcher).*

According to interviews and observations by the researcher, (1) the absence of contemporary mold dismantling tools on the production shades, (2) manufacturer’s lack of knowledge and technical skills to dismantle the mold components properly, (3) the absence of well-prepared ribbed beam production manuals available on the shade to lead and govern the manufacturers, (4) consultants inefficient regular supervision and quality controlling practices on the production shades, and (5) ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person assigned to accomplish the tasks and a such are the causes of dismantling the mold components improperly by the ribbed beam manufacturers in the production shades.

#### **4.5.8. Curing practice on the precast ribbed beam production shades**

As observed, most ribbed beam manufacturers had been stored the final products (precast ribbed beams) wherever the ground outside the manufacturing shades and exposed it into direct sunlight ready to cured shown in figure 4.22. Besides that, a high rate of evaporation may occur by the actions of temperature from sunlight in addition to the hydration of cement react with water. Therefore proper curing shall be necessary to obtain the required components.

Based on the information through interviews from the consultant representatives and the ribbed beam manufacturers, the precast ribbed beams had cured properly to the required specification for 28 days. But routinely observed by the researcher on the production shades, manufacturers had cured the final components (precast ribbed beams) by sprinkling water according to the manufacturer's will rather than the desired curing specification. Which means they cured once a day and leave it the next day regarding the will of the manufacturers.



*Figure 4.22 The place where ribbed beams cured on the production shade (picture taken by the researcher).*

Generally, the curing practices of the ribbed beam manufactures were irregular by sprinkling insufficient water without the standard requirement due to; (1) the manufacturers lack of knowledge about the impacts of curing on the strength and durability of concrete, (2) the consultant's inefficient supervision and quality controlling practice on the manufacturing shades, (3) the absence of well-prepared ribbed beam production manuals provided from the concerned body to guide and govern the manufacturers about the type and procedures of curing, and (4) ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person assigned to accomplish the tasks.

#### **4.5.9. Product final inspection and storage practices on the ribbed beam production shade**

According to the literature review, final inspection and product storage are the last stages of the precast reinforced concrete production process. Therefore the finished products must be attested to their critical dimension, verify and place identification marks, check the required design compressive strength, and properly stored the place were free from any contamination before delivering it into the construction site to fix and assemble. But none of this has been seen on the site visit. Because the ribbed beam manufacturers had stored the finished component (precast ribbed beams) outside the production shades and delivered such components into the contractors

for assemblage on the construction site without doing any kind of final inspection and quality controlling techniques by the consultants.

As shown in figure 4. 23, the finished products (precast ribbed beams) stored wherever the ground randomly near and over the existed river it takes a public discharge from the surrounding society and also stored with wastes of broken hollow concrete blocks shown in picture (a) and (b) respectively. Stored the finished product properly free from any action is necessary unless it may cause different contamination due to the ground moisture and weathering impact and tends to fail before going to attain the desired requirement.



a) Beams stored over the existed public drain.



b) Beams stored with wasted materials.

*Figure 4.23 Precast ribbed beam storage practice on the production shade.*

According to interviews and observations by the researcher, (1), the manufacturers lack of knowledge about the consequences of inadequate storage practice in product standard, (2) the consultant's inefficient routine supervision and quality controlling practice on the production shades, (3) the absence of well-prepared ribbed beam production manuals provided from the concerned body to guide and govern the manufacturers and (5) ribbed beam manufacturers (MSEs) outsourced the key activities of them into a non-trained person assigned to accomplish the tasks and a such are the causes of precast ribbed beams stored improperly on the manufacturing shades.

#### 4.6. Compressive strength of precast ribbed beams manufactured by MSEs

The researcher defines the compressive strength of the precast ribbed beams by using a rebound hammer test on the selected manufacturing shades at Bole, Yeka, and Akaki Kality Subcity to ACI 228.1R, EN13791: 2003, ASTM C 805, ISO 1920-7, China: JGJ T-23, and Japan: JCSE-G504 codes. Besides, the researcher had taken three precast ribbed beam samples randomly from the stocks of the manufacturing enterprises for the test. And yet 30 points of rebound value had taken from each sample (precast ribbed beams) which is, 10 impacts from sample preliminary span (PS), 10 impacts from sample mid-span (MS), and 10 impacts from sample end spans (ES) to get the accurate sample strength (S.S) shown in figure 4.24. According to the contractual arrangement signed between the micro and small enterprises in one part and the micro and small enterprise office on the other part, the required strength of the produced precast ribbed beam should be C-25Mpa.

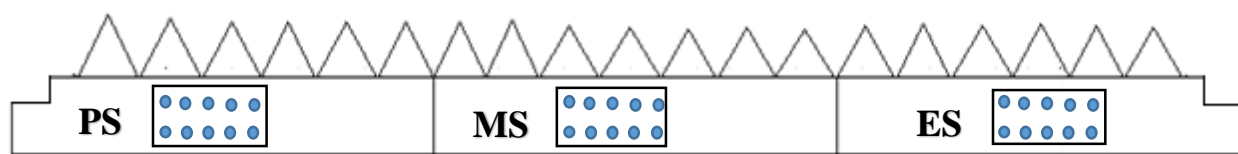


Figure 4.24 Hammer test rebounding technique taken by the researcher.

##### 4.6.1. Strength of precast ribbed beams produced on Bole Subcity manufacturing shades

The researcher had taken data of compressive strength rebound values on the precast ribbed beam samples from Ayat 49, Semmit, and Merri manufacturing shades shown on Table [10-15].

##### A. Compressive strength of precast ribbed beams on Ayat 49 production shade

Table 10 Rebounding values of ribbed beams on Ayat 49 manufacturing shade

Ayat 49 shade (3 active manufacturers involved)	Manufacturing enterprise 1 (3 month production period)									Manufacturing enterprise 2 (3 month production period)									Manufacturing enterprise 3 (45 day production period)								
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)		
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES
	21	20	16	18	17	20	18	16	17	23	22	18	21	18	21	20	18	20	15	20	20	17	17	16	17	16	22
	16	21	18	15	19	20	16	16	17	22	21	17	19	19	23	19	17	18	20	21	21	19	20	19	18	16	21
	19	19	19	19	18	17	21	17	16	21	20	16	17	20	21	21	15	17	17	21	19	16	20	20	17	19	20
	15	18	20	18	20	15	19	15	19	23	21	18	21	16	20	18	20	19	19	19	17	15	18	18	16	20	21
	17	17	22	17	16	18	18	18	18	21	19	19	19	15	19	22	19	20	21	22	18	18	18	22	16	18	19
	18	20	19	19	22	17	21	19	18	19	18	20	20	18	20	21	20	16	19	18	20	18	17	21	16	19	18
	21	16	18	16	18	20	22	20	20	25	20	17	24	17	21	18	22	17	20	19	19	17	21	19	18	17	16
	15	17	20	19	17	19	20	17	19	19	21	18	22	20	22	23	21	22	16	19	16	16	20	19	19	20	17
	19	18	21	20	16	17	20	20	17	21	20	19	18	21	20	22	20	20	15	17	20	19	19	17	17	21	20
	18	21	17	17	20	16	21	18	16	24	18	20	20	18	21	19	16	21	18	19	22	18	21	20	16	18	19
<b>Average</b>	17.9	19	19	18	18.3	17.9	20	18	17.7	22	20	18.2	20	18	20.8	20	18.8	19	18	20	19	17.3	19.1	19.1	17	18	19.3
<b>S.S</b>	18.5			18.0			18.3			20.0			19.7			19.4			18.9			18.5			18.2		
<b>N.S</b>	18.3									19.7									18.5								

Study on the production process of the precast reinforced concrete ribbed beam through the micro and small enterprises in Addis Ababa: “A case study on Bole, Yeka and Akaki kality Subcity”

As shown in Table [10], a maximum of 3months, a minimum of 45days fabricated precast ribbed beam samples had taken by the researcher for a rebound hummer compressive strength test on Ayat 49 manufacturing shade. And yet the researcher found a maximum of 19.7Mpa and a minimum of 18.3Mpa average compressive strength results. Which is below the required strengths C-25Mpa shown on the Table [11] and quality control chart in figure 4.25.

Table 11 Variation of average sample strength from the required strength.

Sample Strength (Mpa)	18.5	18.0	18.3	20.0	19.7	19.4	18.9	18.5	18.2
Required Strength (Mpa)	25	25	25	25	25	25	25	25	25
Variation (V )	-6.5	-7.0	-6.7	-5.0	-5.3	-5.6	-6.1	-6.5	-6.8

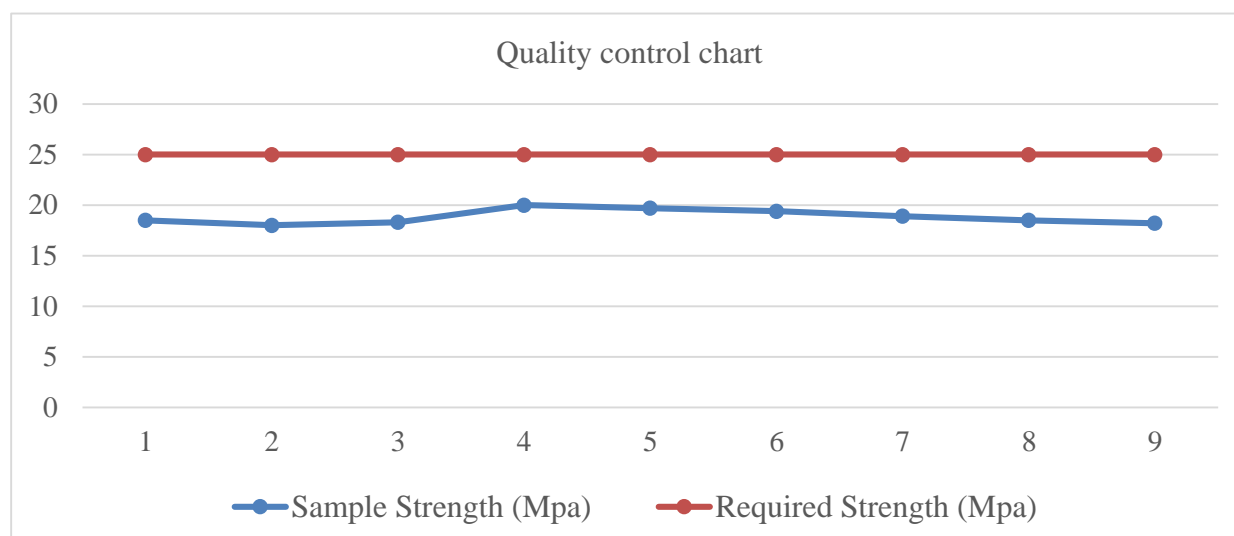


Figure 4.25 Moving average sample strength from the required strength.

B. Compressive strength of precast ribbed beams on semmit production shade

Table 12 Rebounding values of ribbed beams on Semmit manufacturing shade.

Semmit shade(3 active manufacturers involved)	Manufacturing enterprise 1 (4 month production period)									Manufacturing enterprise 2 ( 33 day production period)									Manufacturing enterprise 3 ( 2 month production period)																	
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)											
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES						
43	49	51	37	35	40	50	49	51	21	18	20	19	16	15	20	21	19	38	41	39	49	41	46	39	35	41										
39	43	52	42	37	45	51	47	47	20	17	20	18	19	18	17	21	17	42	37	35	47	45	45	38	33	40										
38	42	45	41	39	42	53	50	42	22	19	22	21	17	20	23	17	16	44	35	37	41	42	41	36	38	45										
44	39	49	45	37	40	48	48	46	24	20	19	17	20	19	20	19	18	39	31	31	48	44	48	45	34	38										
48	38	38	44	35	37	49	45	47	20	21	17	19	18	18	18	16	21	38	37	39	39	37	39	44	30	37										
43	44	36	48	43	32	41	38	40	19	20	18	16	17	16	16	22	20	37	37	38	37	39	45	49	29	32										
48	50	37	53	40	33	39	34	48	24	16	16	21	20	19	22	21	20	47	35	40	41	37	40	48	28	41										
49	49	43	47	47	42	39	50	49	20	18	20	22	21	17	19	20	19	48	38	41	44	38	41	50	35	41										
50	44	45	42	51	41	37	41	41	20	17	21	18	19	20	18	18	19	44	32	38	45	45	37	37	33	39										
51	45	39	38	48	40	46	40	43	21	19	22	22	17	18	22	19	16	46	41	37	51	41	39	36	37	35										
Average	45.3	44	44	44	41.2	39.2	45	44	45.4	21	19	19.5	19	18	18	20	19.4	19	42.3	40	38	44.2	40.9	42.1	42.2	33	38.9									
S.S	44.4			41.4			45.0			19.7			18.6			19.1			39.9			42.4			38.1											
N.S	43.6									19.1									40.1																	

As shown on Table [12], the researcher had taken 4-month ages of three samples (precast ribbed beams) from the manufacturing enterprise one, 2 months of three samples from the manufacturing enterprise two, and 33 days of three samples from the manufacturing enterprise three on semmit manufacturing shade to registered a rebound value. Yet, ages of all samples had over 28 days and the researcher founds 43.6Mpa and 40.1Mpa average compressive strength from the manufacturing enterprises one and three respectively over the required design strength whereas 19.1Mpa average compressive strength provided from the manufacturing enterprises two below the required design strength shown on Table [13] and quality control chart in figure 4.26.

Table 13 Variation of average sample strength from the required strength.

Sample Strength (Mpa)	44.4	41.4	45.0	19.7	18.6	19.1	39.9	42.4	38.1
Required strength (Mpa)	25	25	25	25	25	25	25	25	25
Variation (V )	19	16	20	-5	-6	-6	15	17	13

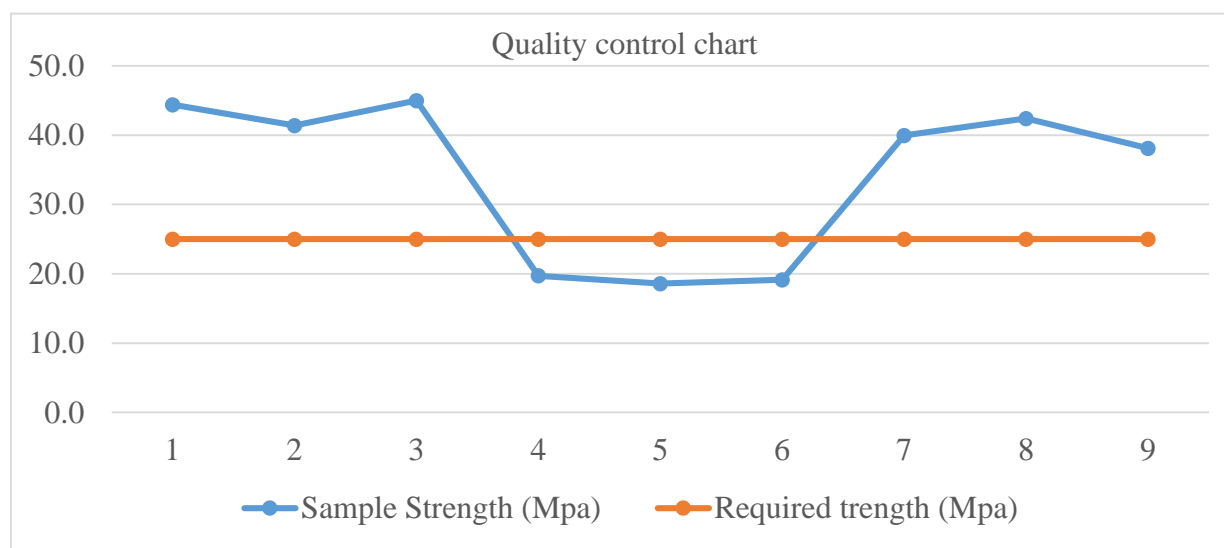


Figure 4.26 Moving average sample strength from the required strength.

C. Compressive strength of precast ribbed beams on merri production shade

Table 14 Rebounding values of ribbed beams on Merri manufacturing shade.

Merri shade(3 active manufacturers involved)	Manufacturing enterprise 1 (54 day production period)									Manufacturing enterprise 2 (47 day production period)									Manufacturing enterprise 3 (3 month production period)								
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)		
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES
16	19	22	21	22	16	20	21	17	20	22	22	21	22	23	19	16	14	17	15	22	20	24	16	19	18	18	
15	21	20	16	21	18	21	19	22	22	21	21	20	23	23	15	16	17	15	15	20	21	21	15	18	18	19	
17	18	21	17	20	19	16	20	21	17	18	21	22	21	21	15	15	15	17	19	21	16	20	17	20	18	20	
19	16	23	16	20	20	17	18	21	15	22	18	23	18	20	18	17	16	19	17	22	15	23	15	16	16	21	
20	17	20	16	21	21	15	17	21	17	21	19	16	18	24	14	18	19	20	16	23	18	23	14	18	15	22	
18	21	19	18	20	22	22	20	18	16	19	20	18	17	20	15	18	18	21	18	20	17	19	18	14	17	19	
15	18	18	19	19	19	21	21	19	15	20	20	17	19	22	16	16	18	19	20	21	19	18	17	20	14	19	
19	16	18	20	19	16	18	19	20	14	21	18	20	20	22	19	15	17	20	19	19	17	20	16	16	18	20	
21	20	21	17	18	18	17	20	17	20	20	18	22	21	21	20	17	15	15	17	18	16	20	17	17	17	22	
20	19	20	21	17	17	22	18	18	18	19	20	19	20	20	18	18	15	17	16	23	17	19	17	20	16	20	
Average	18	18.5	20.2	18.1	19.7	18.6	18.9	19.3	19.4	17.4	20.3	19.7	19.8	19.9	21.6	16.9	16.6	16.4	18	17.2	20.9	17.6	20.7	16.2	17.8	16.7	20
S.S	18.9			18.8			19.2			19.1			20.4			16.6			18.7			18.2			18.2		
N.S	19.0									18.7									18.3								

As shown on Table [14], the researcher had taken ages of 54 days precast ribbed beam three samples from the manufacturing enterprise one, 47 days of three samples from the manufacturing enterprise two, and 3 months of three ribbed beam samples from the manufacturing enterprise three on Merri manufacturing shade. Yet, the average strengths of such samples obtained by the researcher are 19Mpa, 18.7Mpa, and 18.3Mpa respectively below the required strength of C-25Mpa shown on Table [15] and quality control chart in figure 4.27.

Table 15 Variations of average sample strength from the required strength.

Sample Strength (Mpa)	18.9	18.8	19.2	19.1	20.4	16.6	18.7	18.2	18.2
Required strength (Mpa)	25	25	25	25	25	25	25	25	25
Variation (V)	-6	-6	-6	-6	-5	-8	-6	-7	-7

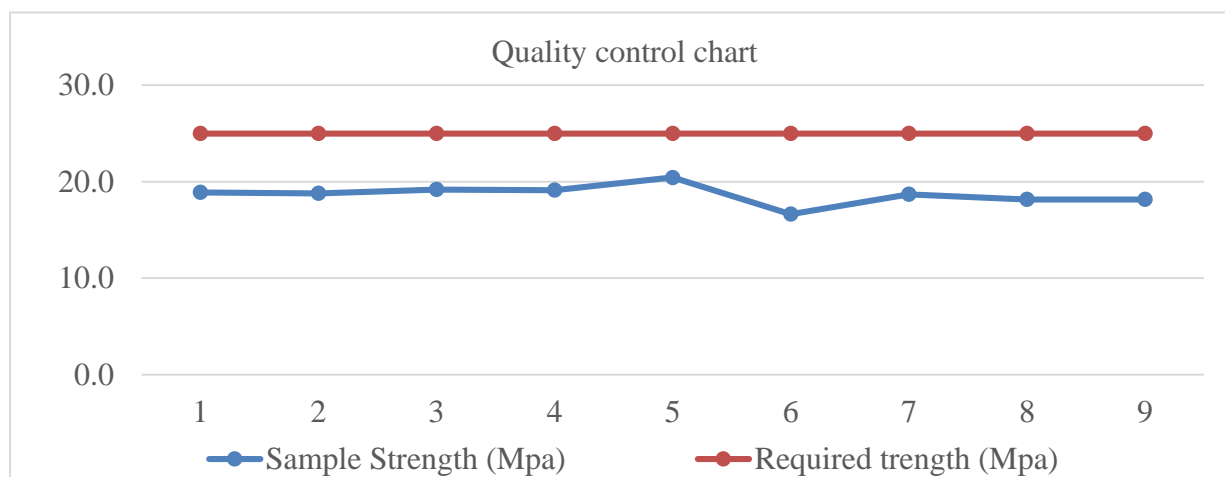


Figure 4.27 Moving average sample strength related to the required strength.

#### 4.6.2. Strength of precast ribbed beams produced on Yeka Subcity manufacturing shades

The researcher had taken data of compressive strength rebound values on the precast ribbed beam samples from Karra, Abado, and Deninet manufacturing shades shown in Table [16-21].

##### A. Compressive strength of precast ribbed beams on karra production shade

Table 16 Rebounding values of ribbed beams on Karra manufacturing shade.

Karra shade (3 active manufacturers involved)	Manufacturing enterperise 1 (5month production period)									Manufacturing enterperise 2 (4month production period)									Manufacturing enterperise 3 (2.5month production period)														
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)								
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES			
35	38	43	31	42	39	38	38	44	26	19	19	23	22	16	17	22	18	26	23	16	20	22	20	16	17	19							
30	25	45	27	45	35	35	32	43	19	19	16	28	23	19	15	21	18	29	22	15	21	21	23	19	21	19							
34	28	39	41	39	41	41	41	49	18	22	17	19	20	20	20	24	21	20	20	19	20	19	19	22	16	18							
40	32	35	37	38	37	49	48	45	17	21	19	30	17	22	30	20	16	18	18	18	19	18	18	15	22	22							
39	45	41	40	44	42	45	44	51	21	18	22	17	19	18	16	24	17	18	19	18	18	20	21	19	20	21							
44	43	35	48	35	44	42	45	49	25	17	24	21	18	19	25	19	22	20	17	17	17	16	22	17	20	20							
29	34	29	28	33	35	29	39	38	21	16	23	18	16	17	24	23	21	26	18	16	19	21	16	16	19	18							
29	32	30	30	39	38	28	37	44	19	21	17	22	22	20	17	20	23	31	16	15	21	17	17	22	16	16							
35	37	41	35	36	33	35	48	41	17	21	23	23	17	21	20	18	20	22	20	18	22	19	17	21	20	20							
41	28	42	30	44	46	42	39	43	18	24	22	15	20	16	21	22	22	22	23	21	21	18	16	17	17	19							
Average	35.6	34.2	38	34.7	39.5	39	38.4	41.1	44.7	20.1	19.8	20.2	21.6	19.4	18.8	20.5	21.3	19.8	23.2	19.6	17.3	19.8	19.1	18.9	18.4	18.8	19.2						
S.S	35.9			37.7			41.4			20.0			19.9			20.5			20.0			19.3			18.8								
N.S	38.4									20.2									19.4														

As shown in Table [16], the researcher had taken 5months of precast ribbed beam three samples from the manufacturing enterprise one, 4months of such from the manufacturing enterprise two, and 2.5months of such samples from the manufacturing enterprise three for a rebound value strength test on Karra manufacturing shade. Yet, the average strength of such components obtained from the manufacturing enterprise one is 38.4Mpa over the required strength, 20.2Mpa, and 19.4Mpa average strengths obtained from the manufacturing enterprise two and three respectively below the target required strength. Which is, the manufacturing enterprise ones had produced over qualified precast ribbed beam components whereas the remaining two had manufactured under qualified components concerning the target designed strength C-25Mpa shown on Table [17] and quality control chart in figure 4.28.

Table 17 Variations of average sample strength from the required strength.

Sample Strength (Mpa)	35.9	37.7	41.4	20.0	19.9	20.5	20.0	19.3	18.8
Required strength (Mpa)	25	25	25	25	25	25	25	25	25
Variation (V )	11	13	16	-5	-5	-4	-5	-6	-6

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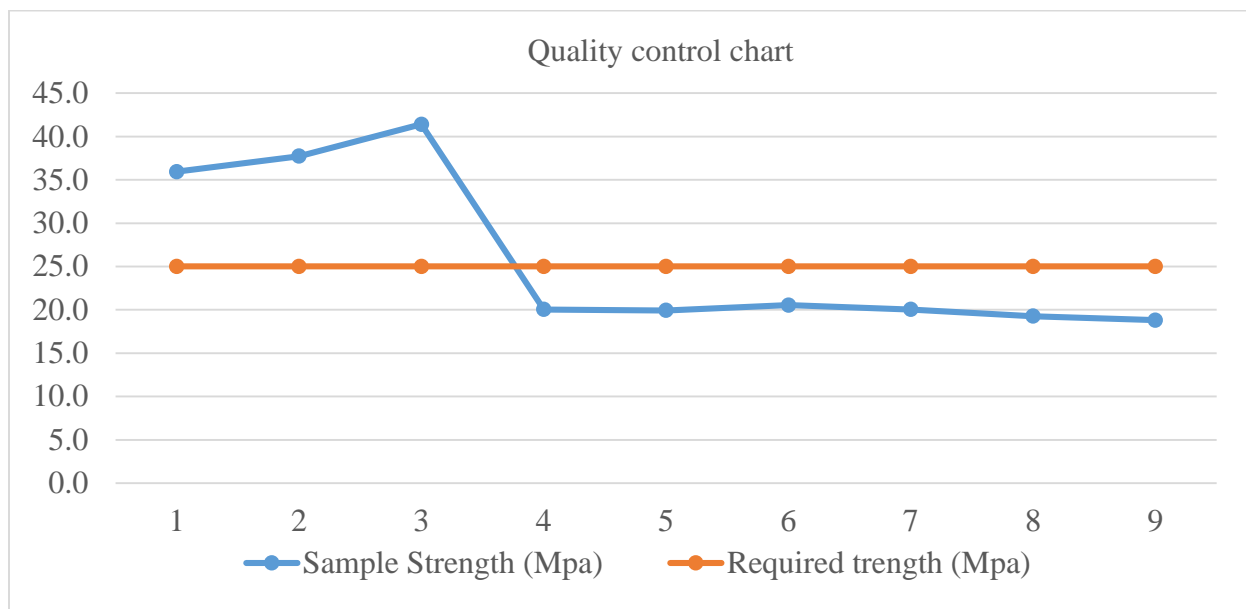


Figure 4.28 Moving average sample strength related to the required strength.

B. Compressive strength of precast ribbed beams on Abado production shade

Table 18 Rebounding values of ribbed beams on Abado manufacturing shade.

Abado shade (3 active manufacturers involved)	Manufacturing enterprisise 1 (3month production period)									Manufacturing enterprisise 2 (3month production period)									Manufacturing enterprisise 3 (1.5month production period)																			
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)													
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES								
21	19	22	21	23	19	18	22	19	21	20	22	19	16	20	16	22	17	18	19	24	24	19	22	20	22	19	18	19	24	24	19	22	20	22	19			
20	16	21	20	16	22	17	16	17	22	20	20	17	20	20	17	22	19	19	19	20	22	18	19	21	21	21	21	21	21	21	21	21	21	21	18			
22	17	24	20	18	19	16	21	18	21	19	18	22	17	18	23	19	19	22	18	19	21	23	18	19	19	19	19	19	19	19	19	19	19	19	17			
17	22	20	24	20	20	22	19	17	20	16	18	21	19	19	19	20	22	19	20	20	19	23	19	17	21	21	21	21	21	21	21	21	21	21	21	21		
19	20	18	19	19	22	21	17	22	19	21	19	19	16	16	18	21	20	20	20	22	20	21	20	20	19	22	22	22	22	22	22	22	22	22	22	22		
20	21	19	20	17	18	18	19	20	24	21	20	18	22	18	22	23	16	22	21	22	24	20	23	16	20	20	20	20	20	20	20	20	20	20	20	20	20	
21	16	22	24	18	16	19	16	21	20	18	20	23	20	22	19	18	22	21	17	19	19	18	18	18	18	22	23	23	23	23	23	23	23	23	23	23	23	
22	19	20	21	22	21	24	21	19	21	17	18	24	19	20	22	19	18	19	19	18	21	20	19	22	19	20	20	20	20	20	20	20	20	20	20	20	20	20
24	20	18	22	17	20	23	19	20	17	19	17	21	18	21	16	22	19	23	18	20	20	23	22	19	23	19	19	19	19	19	19	19	19	19	19	19	19	19
19	19	19	21	23	17	16	20	22	21	20	19	20	17	18	24	20	19	19	21	19	19	21	21	24	20	22	22	22	22	22	22	22	22	22	22	22	22	22
Average	21	19	20	21	19	19	19	20	21	19	19	20	18	19	20	21	19	20	19	20	21	21	20	20	21	20	20	20	20	20	20	20	20	20	20	20	20	20
S.S	19.9			20.0			19.3			19.6			19.3			19.8			19.9			20.6			20.2													
N.S	19.7									19.6									20.2																			

As shown in Table [18], the researcher had taken 3months of precast ribbed beam three samples from the manufacturing enterprise one and two respectively and had taken 45days of such three samples from the manufacturing enterprise three for a rebound value strength test on Abado manufacturing shade. Yet, all manufacturing enterprises had produced such components below the required target strength. Which is, all manufacturing enterprises that are involved in Abado

manufacturing shade had produced under qualified precast ribbed beam components to the target designed compressive strength (C-25Mpa) shown on Table [19] and quality control chart in figure 4.29.

Table 19 Variations of average sample strength from the required strength.

Sample Strength (Mpa)	19.9	20.0	19.3	19.6	19.3	19.8	19.9	20.6	20.2
Required strength (Mpa)	25	25	25	25	25	25	25	25	25
Variation (V )	-5	-5	-6	-5	-6	-5	-5	-4	-5

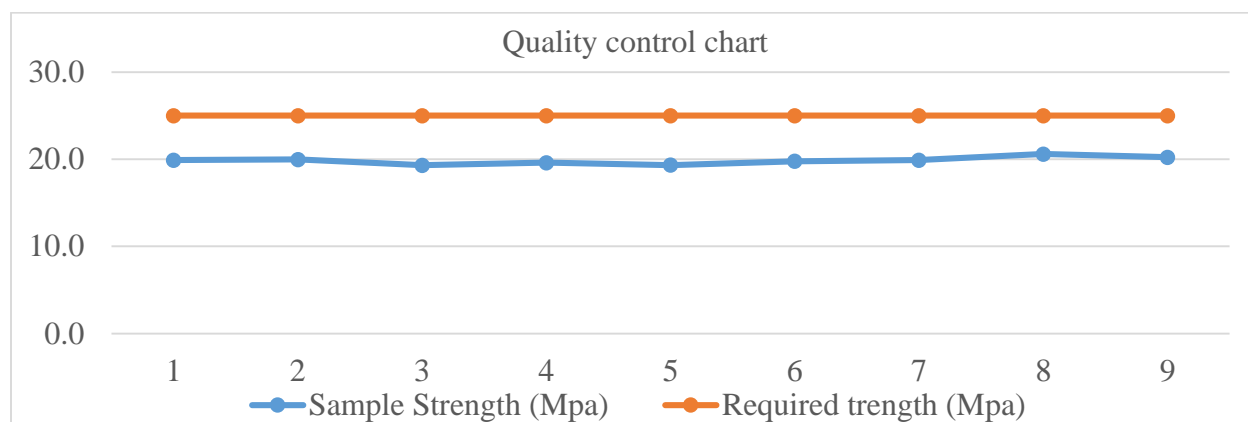


Figure 4.29 Moving average sample strength related to the required strength.

C. Compressive strength of precast ribbed beams on Deninet production shade

Table 20 Rebounding values of ribbed beams on Deninet manufacturing shade.

Deninet shade (3 active manufacturers involved)	Manufacturing enterprise 1 (45day production period)									Manufacturing enterprise 2 (43day production period)									Manufacturing enterprise 3 (45day production period)											
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)					
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES
	19	22	21	24	19	23	21	23	19	29	35	39	53	38	36	49	42	29	22	19	22	26	16	18	18	21	24			
	23	21	22	23	19	21	19	21	21	40	33	38	41	45	38	50	31	35	24	18	21	19	18	19	22	22	20			
	22	19	20	19	20	20	18	20	22	39	39	45	43	47	39	35	39	37	21	17	23	17	21	21	21	19	16			
	23	20	19	23	22	19	22	22	18	42	41	38	46	38	42	36	33	34	22	16	19	24	20	20	24	18	19			
	20	19	23	23	23	18	21	21	19	50	45	44	41	42	51	38	51	42	21	22	17	19	22	23	21	23	22			
	21	20	21	22	19	20	23	19	17	27	42	41	46	41	45	44	49	40	26	20	16	24	19	20	19	20	20			
	19	21	20	21	18	21	24	18	22	39	44	46	34	46	41	52	44	39	24	19	18	23	20	21	18	19	20			
	21	23	19	18	20	19	22	22	20	27	47	37	36	40	39	49	42	37	23	22	22	23	18	18	20	19	23			
	22	21	19	24	22	21	25	20	19	44	38	40	40	42	37	50	41	45	26	20	20	24	23	16	22	22	19			
	23	19	18	22	21	18	20	21	21	28	36	41	43	43	36	37	39	44	21	19	18	21	20	22	24	20	20			
Average	21.3	20.5	20.2	21.9	20.3	20	21.5	20.7	19.8	36.5	40	40.9	42.3	42.2	40.4	44	41.1	38.2	23	19.2	19.6	22	19.7	19.8	20.9	20.3	20.3			
S.S	20.7			20.7			20.7			39.1			41.6			41.1			20.6			20.5			20.5					
N.S	20.7									40.6									20.5											

As shown in Table [20], a researcher had taken 45days of precast ribbed beam three samples from the manufacturing enterprise one and three respectively, and had taken 43days of such three

samples from the manufacturing enterprise two for a rebound value strength test on Deninet manufacturing shade. Yet, the average strength of such components obtained from the manufacturing enterprise two is 40.6Mpa over the required strength, 20.7Mpa, and 20.5Mpa average compressive strengths obtained from the manufacturing enterprise one and three respectively below the required strength. Which is, the manufacturing enterprise two had produced over qualified precast ribbed beams components whereas the remaining two manufacturing enterprises had produced under qualified components to the target compressive strength (C-25Mpa) shown on Table [21] and quality control chart in figure 4.30.

Table 21 Variations of average sample strength from the required strength.

Sample Strength (Mpa)	20.7	20.7	20.7	39.1	41.6	41.1	20.6	20.5	20.5
Required strength (Mpa)	25	25	25	25	25	25	25	25	25
Variation (V )	-4	-4	-4	14	17	16	-4	-5	-5

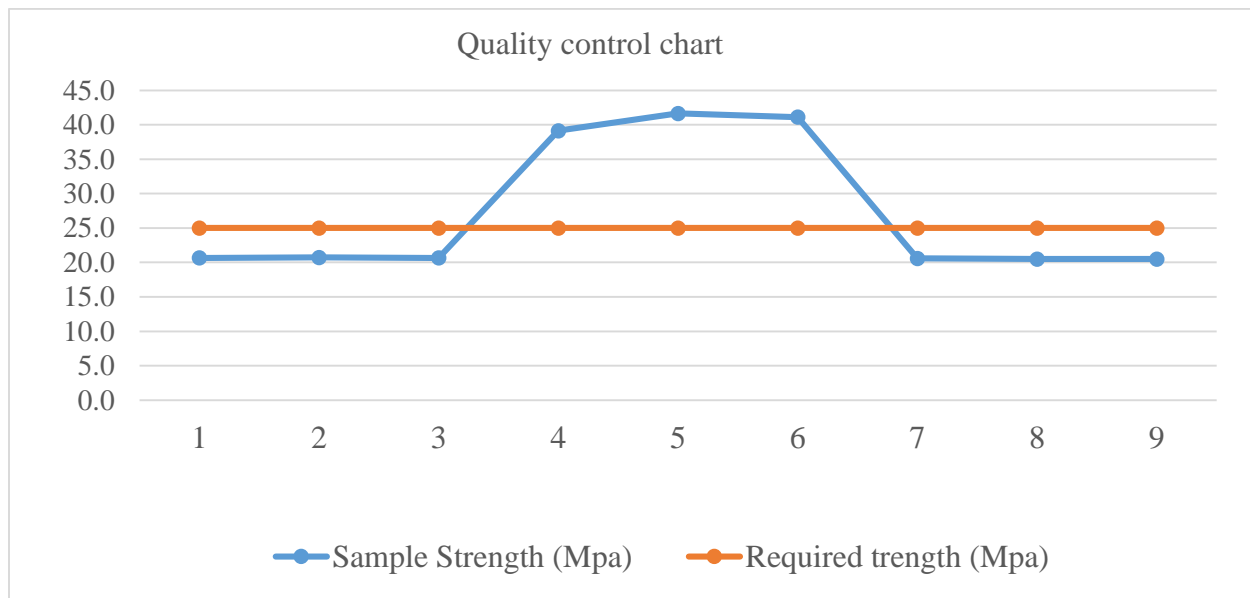


Figure 4.30 Moving average sample strength related to the required strength.

#### 4.6.3. Strength of ribbed beams produced on Akaki Kality Subcity production shades

The researcher had taken data of compressive strength rebound values on the precast ribbed beam samples from Kilinto, Koyefech, and Koye neffasilk manufacturing shades on Akaki Kality Subcity shown on Table [22-28].

A. Compressive strength of precast ribbed beams on Kilinto production shade

Table 22 Rebounding values of ribbed beams on Kilinto manufacturing shade.

Kilinto shade (3 active manufacturers involved)	Manufacturing enterperise 1 ( 2.5month production period)									Manufacturing enterperise 2 ( 1.5month production period)									Manufacturing enterperise 3 ( 3.5month production period)								
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)		
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES
	18	15	20	21	20	14	18	17	15	14	16	18	19	18	20	14	20	16	22	22	14	20	15	16	22	14	22
	16	14	20	22	21	14	17	15	14	15	16	18	19	15	21	14	19	15	23	18	14	20	14	16	20	14	19
	16	17	19	17	23	16	18	15	14	15	17	17	21	15	18	15	18	16	24	22	15	21	14	15	23	15	16
	15	16	15	19	22	15	18	20	16	19	15	15	21	15	19	18	18	14	20	22	16	22	16	14	23	15	21
	17	14	17	18	20	15	16	21	14	16	14	20	22	16	20	18	19	17	20	20	17	19	15	15	24	15	20
	15	14	18	20	19	17	15	20	18	15	19	21	18	14	19	19	17	17	19	24	14	19	17	20	20	19	15
	19	15	14	19	20	18	19	19	17	20	20	21	17	17	16	15	19	16	18	24	15	17	18	17	19	17	18
	16	17	16	22	16	20	17	18	15	19	20	17	19	17	20	16	20	18	20	23	15	18	14	18	18	17	18
	17	16	15	18	17	14	17	20	19	17	20	14	22	18	15	15	21	15	21	20	19	20	15	19	22	15	19
	14	15	19	14	18	15	15	17	19	18	18	16	20	18	14	17	22	16	22	22	19	22	20	17	24	16	17
Average	16.3	15.3	17.3	19	19.6	15.8	17	18.2	16.1	16.8	17.5	17.7	19.8	16.3	18.2	16.1	19.3	16	20.9	21.7	15.8	19.8	15.8	16.7	21.5	15.7	18.5
S.S	16.3			18.1			17.1			17.3			18.1			17.1			19.5			17.4			18.6		
NS	17.2									17.5									18.5								

A researcher had taken 2.5months of precast ribbed beam three samples from the manufacturing enterprise one, 1.5months of such three samples taken from the manufacturing enterprise two, and 3.5months of three samples taken from the manufacturing enterprise three on Kilinto manufacturing shade. Yet, a maximum of 18.5Mpa obtained from the manufacturing enterprise three and a minimum of 17.2Mpa from the manufacturing enterprise one also found 17.5Mpa from the manufacturing enterprise two Table [22]. Which is, all manufacturing enterprises had produced under qualified precast ribbed beam components to the required designed strength shown on Table [23] and quality control chart in figure 4.31.

Table 23 Variations of average sample strength from the required strength.

Sample Strength (Mpa)	16.3	18.1	17.1	17.3	18.1	17.1	19.5	17.4	18.6
Required strength (Mpa)	25	25	25	25	25	25	25	25	25
Variation ( V )	-9	-7	-8	-8	-7	-8	-6	-8	-6

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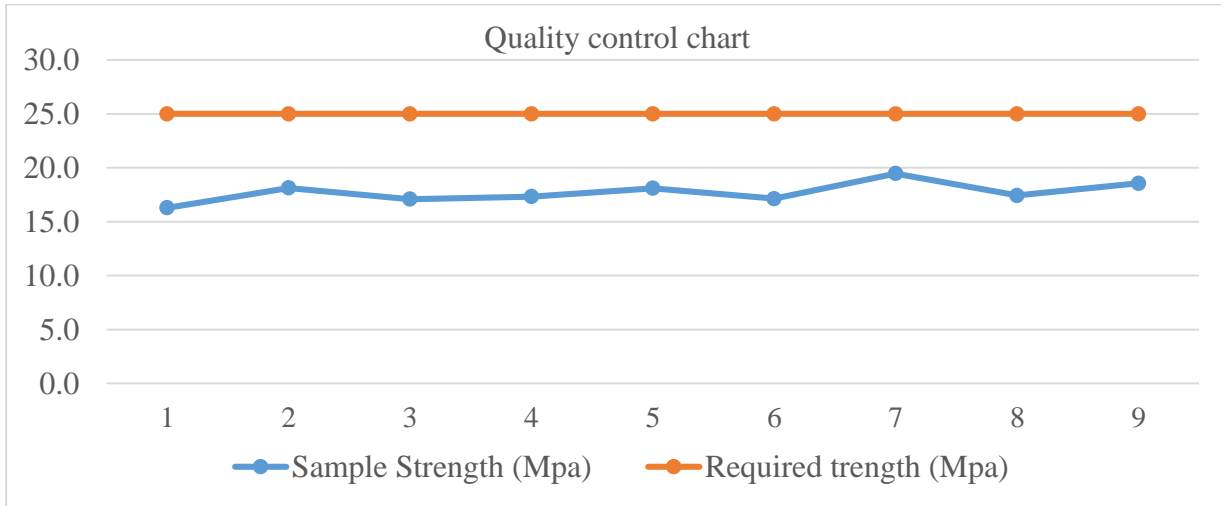


Figure 4.31 Moving average sample strength related to the required strength.

B. Compressive strength of precast ribbed beams on Koyefech production shade

Table 24 Rebouncing values of ribbed beams on Koyefech manufacturing shade.

Koye fech shade (3 active manufacturers involved)	Manufacturing enterperise 1 (4month production period)									Manufacturing enterperise 2 (4month production period)									Manufacturing enterperise 3 (2.5month production period)										
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)				
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS
22	23	20	15	18	16	23	21	15	18	16	18	22	23	24	21	21	21	22	15	16	22	20	14	20	16	22			
17	22	22	18	15	17	23	21	19	18	16	17	24	20	20	22	20	19	21	15	16	21	20	15	15	18	21			
16	24	19	18	14	18	24	23	18	15	16	19	22	18	20	15	20	18	23	14	15	23	19	13	17	17	18			
17	19	20	18	14	15	20	18	20	20	14	22	22	21	18	19	23	17	21	16	19	22	18	19	15	18	22			
15	19	23	15	16	16	19	20	21	21	19	20	21	20	19	20	18	18	20	17	20	15	20	15	20	16	19			
19	17	20	17	14	15	18	20	17	20	15	19	20	21	16	18	19	20	24	15	21	19	20	15	21	19	21			
18	18	19	19	15	17	22	19	17	19	19	21	20	15	22	21	20	15	19	14	20	16	21	16	20	15	20			
22	20	19	18	17	18	22	21	15	19	20	21	21	17	20	23	22	16	18	18	18	17	15	14	19	18	21			
18	19	18	20	14	22	19	20	14	17	21	15	19	15	18	18	21	23	20	20	15	20	14	17	19	17	22			
23	19	15	20	19	20	20	18	22	15	15	19	21	20	17	21	18	20	19	19	14	15	19	20	18	20	19			
Average	18.7	20	19.5	17.8	15.6	17.4	21	20.1	17.8	18.2	17.1	19.1	21.2	19	19.4	19.8	20.2	18.7	20.7	16.3	17.4	19	18.6	15.8	18.4	17.4	20.5		
S.S	19.4			16.9			19.6			18.1			19.9			19.6			18.1			17.8			18.8				
N.S	18.7									19.2									18.2										

As shown in Table [24], a researcher had taken 4months of precast ribbed beam three samples from the manufacturing enterprise one and two respectively, and had taken 2.5months of such samples from the manufacturing enterprise three on Koyefech manufacturing shade for rebound hammer compressive strength test. Yet, the researcher obtains a maximum of 19.2Mpa and a minimum of 18.2Mpa average compressive strength from the manufacturing enterprise two and three respectively whereas 18.7Mpa average strength obtained from the manufacturing enterprise one. Which is, all manufacturing enterprises had produced underqualified precast ribbed beams to

the required average compressive strength (C-25 Mpa) shown on Table [25] and quality control chart in figure 4.32.

Table 25 Variations of average sample strength from the required strength.

Sample Strength (Mpa)	19.4	16.9	19.6	18.1	19.9	19.6	18.1	17.8	18.8
Required strength (Mpa)	25	25	25	25	25	25	25	25	25
Variation (V)	-6	-8	-5	-7	-5	-5	-7	-7	-6

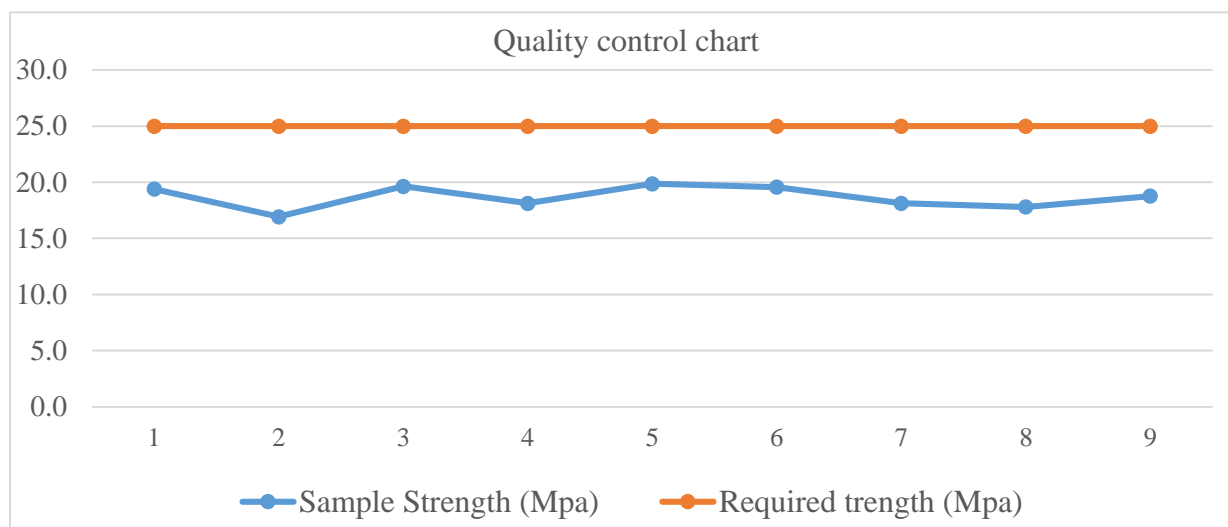


Figure 4.32 Moving average sample strength related to the required strength.

### C. Compressive strength of precast ribbed beams on Koye neffasilk production shade

Table 26 Rebounding values of ribbed beams on Koye neffasilk manufacturing shade.

Koye neffasilk shade (3 active manufacturers involved)	Manufacturing enterprise 1 (1.5month production period)									Manufacturing enterprise 2 (2month production period)									Manufacturing enterprise 3 (4month production period)																																			
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)																													
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES																								
	15	15	17	22	17	23	19	22	15	20	22	20	15	22	14	22	20	21	17	22	18	20	21	23	15	20	18	16	13	14	20	19	20	19	18	14	19	21	18	17	16	16	17	18	20	20	20	22	21	17	20	14	21	18
	15	17	18	23	19	16	20	20	19	15	23	20	19	17	17	19	16	18	18	23	21	17	20	19	16	19	16	16	15	17	20	21	14	17	18	20	18	20	19	15	16	18	18	23	21	17	20	19	16	19	16			
	16	15	17	20	21	14	17	18	20	18	20	17	15	28	15	20	15	16	19	21	22	17	16	19	16	17	17	16	14	16	20	20	20	20	18	18	18	19	16	17	16	17	16	17	17	16	17	17						
	13	14	16	15	20	20	20	18	18	18	19	16	20	15	18	17	20	15	16	21	22	21	15	22	17	17	21	17	14	16	15	20	20	20	18	18	18	19	20	13	18	15	17	16	15	20	16	17	21	17	21	18	19	19
	15	18	15	19	15	19	22	15	16	17	20	15	16	15	16	22	19	17	17	20	17	18	19	20	13	18	15	17	16	15	20	16	17	21	17	21	16	18	18	18	16	17	20	17	19	18	19	19	18	18	21	18	19	19
	15	18	17	16	18	18	18	14	20	20	17	14	17	20	16	16	18	20	18	18	20	21	21	18	15	21	19	19	15	17	22	18	19	17	16	17	15	21	20	21	21	15	17	16	21	19	18	21	17	21	17	16	20	18
	19	15	17	22	18	19	17	16	17	15	21	20	21	21	15	17	16	21	19	18	21	17	21	17	16	20	18	17	14	18	21	22	20	22	15	15	18	20	17	18	18	14	23	20	15	21	20	16	16	17	21	15	18	20
Average	15.8	15.5	16.4	19.8	18.5	18.6	19.5	17.3	17.5	17.6	20.1	17.5	17.6	18.8	15.8	19.3	17.9	18.2	18.3	20.2	19.8	18.6	18.5	20	15.5	19	18.1																											
S.S	15.9			19.0			18.1			18.4			17.4			18.5			19.4			19.0			17.5																													
N.S	17.7									18.1									18.7																																			

As shown on Table [26], the researcher had taken 1.5months of precast ribbed beams three samples from the manufacturing enterprise one, 2months of such three samples taken from the manufacturing enterprise two, and 4months of such samples taken from the manufacturing enterprise three for a rebound hummer compressive strength test on Koye neffasilk manufacturing shade. Yet, the researcher obtains a maximum of 18.7Mpa and a minimum of 17.7Mpa average compressive strength from the manufacturing enterprise three and one respectively whereas 18.1Mpa average compressive strength found from the manufacturing enterprise two. Which is, all manufacturing enterprises had produced under qualified precast ribbed beams components to the required average compressive strength (C-25Mpa) shown on Table [27] and quality control chart in figure 4.33.

Table 27 Variations of average sample strength from the required strength.

Sample Strength (Mpa)	15.9	19.0	18.1	18.4	17.4	18.5	19.4	19.0	17.5
Required Strength (Mpa)	25	25	25	25	25	25	25	25	25
Variation (V )	-9	-6	-7	-7	-8	-7	-6	-6	-7

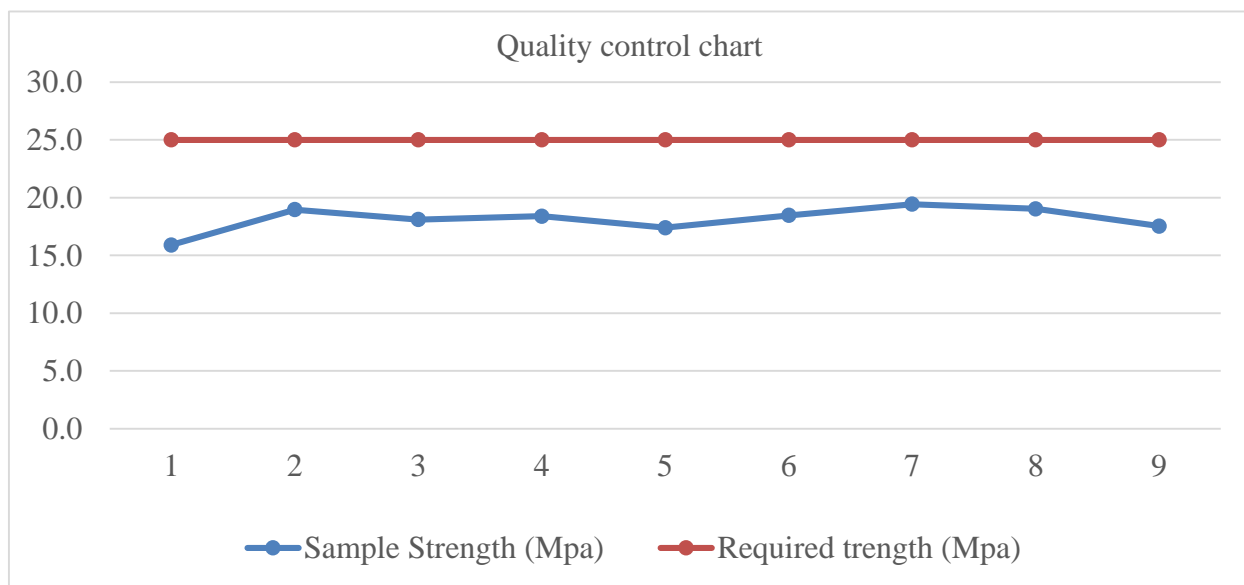


Figure 4.33 Moving average sample strength related to the required strength.

As ACI 228.1R states, the average compressive strength ( $\bar{X}$ ) of samples should be greater from the target characteristic strength. EBCS-2, 1995 also states that,

$$\bar{X} \geq f_{ck} + k_1 \dots \dots \dots 4.6a, \quad k_1 \text{ should be } 1, 2, 3, 4$$

However, from the total 81 samples taken 85.2% of precast ribbed beams had an average strength of  $15.9 \leq \bar{X} \leq 20.7\text{Mpa}$  which is below the target compressive strength C-25Mpa whereas the remaining 14.8% of precast ribbed beams had an average strength of  $35.9 \leq \bar{X} \leq 45\text{Mpa}$  which is over from the target strength. Therefore, the average compressive strengths of the total samples are evaluated by using  $\pm 2$  SD from the target (C-25Mpa) to measure the quality compliance criteria of the precast ribbed beam components. But all precast ribbed beam components are not satisfied or archive the desired requirement based on the quality compliance criteria analyzed through  $\pm 2$  SD shown in figure 4.34.

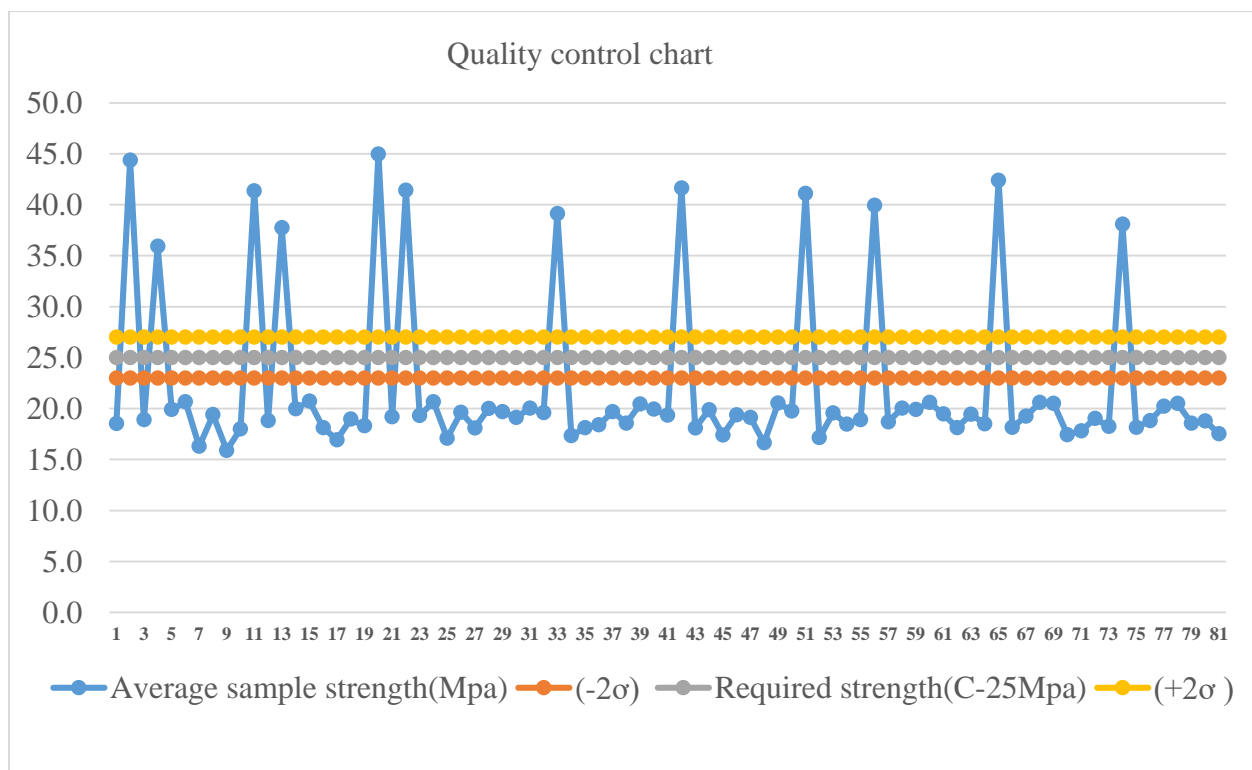


Figure 4.34 Moving average sample strength from the target by  $\pm 2\sigma$ .

## 5. CONCLUSIONS AND RECOMMENDATIONS

### 5.1. Conclusions

It was observed in this research that the production process of precast ribbed beams through the micro and small enterprise associations in Addis Ababa Bole, Yeka, and Akaki Kality Subcity is not standardized. The manufacturing process that should be followed to produce this component is not lead and guided by the standard manufacturing process rather it was made according to the manufacturer's permission.

Besides an extensive production defect had seen during the production process starting from material selection up to product final storage due to the manufacturers lack of knowledge and technical skills, the consultant's inefficient regular supervision and quality controlling technique, the absence of well-prepared precast ribbed beam production documents available on the manufacturing shades, and all most all ribbed beam manufacturers (MSEs) outsourced the key activities of them illegally into a non-trained person assigned to accomplish the task.

Handling and use of reinforced concrete ingredients and production equipment are in the manufacturing shade are very poor. In addition, batching of materials, mixing, placing, and curing practices of the manufacturers are inefficient. Routinely supervise the quality of precast ribbed beams on production site and approved it before supplied to the project site is the roles of the consulting architects and engineers according to the contractual arrangement while the supervision and quality controlling aspect are too weak that the specifications prepared on the production process and the approval tests required by them.

According to this research, all precast ribbed beam samples couldn't satisfy the standard requirement set by the standard. 85.2% of precast ribbed beam samples had an average compressive strength of between 15.9 to 20.7Mpa below the target required compressive strength. The remaining 14.8% of precast ribbed beam samples had an average compressive strength of between 35.9 to 45Mpa over from the target compressive strength (C-25Mpa). This indicates that precast ribbed beam manufacturers (micro and small enterprise associations) had poor production

capability and consultants had not applied their professional duty into the ground set on the contractual arrangement.

As the results obtained in this research shown, the educational backgrounds of all most all manufacturers had not related to the precast ribbed beam production process. However, government regulatory bodies (micro and small enterprise office) agreed to contract with them to procure and provide the aggregate materials into the manufacturing shade for ribbed beam production.

## **5.2. Recommendations**

Based on the research findings the following recommendations drawn-out.

- Reinforced concrete ingredients should be stored properly and utilized according to the standard requirement.
- Concrete mix design practice should be implemented.
- Mold components should mechanized and handle it properly.
- Well-prepared precast ribbed beam production documents should be provided by the regulatory bodies and concerned professionals to guide and govern manufacturers during fabrication.
- Consultants should be implemented regular supervisions and conduct tests of reinforced concrete ingredients before using it and make quality inspections of the final product before delivering it into the project site.
- Manufacturers should minimize wastes of reinforced concrete materials.
- Manufacturers should follow standard concrete casting procedures during precast ribbed bema production on the manufacturing shades.
- Manufacturers should be stored on the final products on the available place properly on the manufacturing shade.
- Manufacturers should consider safety and health practice on the manufacturing shade and utilize personal protective equipment to protect themselves from physical injuries.

### **5.3. Suggestions for future work**

1. Investigate wastes of reinforced concrete materials on the precast ribbed beam production shades.
2. Economic feasibilities of precast ribbed beam production through the micro and small enterprise associations on the production shades.
3. Benefit-cost analysis of precast rib beam production tools and equipment.
4. Assess impacts of precast rib beams on the assemblage in 40/60, 20/80, and 10/90 governmental housing projects.
5. Investigate the factors that limit concrete prefabrication technology in Ethiopia.

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## Appendix

### Appendix 1: structural interview schedule

#### 1.1. Some interview equations with precast ribbed beam manufacturer’s (MSEs)

##### 1. General profile of the respondents (MSEs)

1.1. Name of your enterprise\_\_\_\_\_

1.2. Year of establishment\_\_\_\_\_

1.3. Location\_\_\_\_\_

1.4. Educational status\_\_\_\_\_

1.5. Field of specialization\_\_\_\_\_

##### 2. Questions for precast ribbed beam production

2.1. Are you procuring reinforced concrete materials from the source in to your factory?

A. Yes                      B. No

2.2. If no, who is\_\_\_\_\_

2.3. If yes, what type of materials? And how? Please specify how to procure raw materials from source

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2.4. Different studies conduct that entire procuring process of raw material includes: receiving, inspecting and accepting of the procured raw materials. Do you think you follow this procedure?

A. Yes                      B. No

2.5. If your answer is yes, what is your material inspection mechanism or what quality assurance test would you take? Please specify

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2.6. Before you going to casting a reinforced concrete ribbed beam, are you investigate the properties of concrete ingredients?

- A. Yes            B. No

**If your answer is yes**

2.7. What test did you prepare from cement? Please specify

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2.8. What test did you prepare from aggregate? Please specify

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2.9. What test did you prepare from rebar? Please specify

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2.10. What is the compressive strength of your precast ribbed beam? Please specify

3. Questions about precast ribbed beam production defect and its cause

3.1. As a manufacturer what are your challenges during production to fabricate the required standard precast ribbed beam?

3.2. Sometimes you manufacture precast ribbed beam below the required standard and rejected by consultants. Why?

- |  |                            |
|--|----------------------------|
| A. Lack of technology                    | F. Transporting problem    |
| B. Quality of materials                  | G. Casting problem         |
| C. Implementation of concrete mix design | H. vibrating problem       |
| D. Batching problem                      | I. moulding/oiling problem |
| E. Mixing problem                        | J. lack of knowledge       |
|  | K. others please specify   |

3.3. Most of the time what production defect is happening?

1.2. Some interview questions with regulatory bodies in charge (consultants and MSEO) to control the production process.

1. General profile of the respondents

1.1. Name \_\_\_\_\_

1.2. Position \_\_\_\_\_

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1.3. Organization\_\_\_\_\_

1.4. Address\_\_\_\_\_

1.5. Educational status?

A. BSc      B. MSc      C. Others, specify\_\_\_\_\_

1.6. Field of specialization\_\_\_\_\_

1.7. How long have you work in this sector?

A. 0-5 years      B. 6-10 years      C. >10 years

2. As regulatory body representatives, what are your contribution, role and responsibilities on micro and small enterprises in order to produce standard result? Please specify

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3. Several literatures revealed that standardization is the process of formulating, issuing and implementing standards. Because standard provides requirements, specifications, guidelines or characteristics.

3.1. As regulatory body delegate, do you have standards/manual documents about precast ribbed beam production?

A. Yes      B. No

3.2. If yes, what standard?

- |                          |                             |
|--------------------------|-----------------------------|
| 1. Product Standards     | 6. Process Standards        |
| 2. Engineering Standards | 7. Equipment Standards      |
| 3. Material Standards    | 8. Safety Standards         |
| 4. Design Standards      | 9. Administrative Standards |
| 5. Quality Standards     | 10. Others please specify   |

3.3. If not, how to monitor and what action or measures would you taken on micro and small enterprises during the entire production process of precast ribbed beams?

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\_\_\_\_\_ As a regulatory body, could you involve during the production process of precast rib beam within manufacturers (MSEs) in the factory?

- A. Yes      B. No

3.4. If your answer is yes, why? And what production problem or defects did you seen most of the time? Please justify your answer

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3.5. Who provide the precast reinforced concrete ribbed beam raw materials in to production site or factory?

- A. Clients      B. MSEs

3.6. If your answer is A, what physical and chemical tests would you conduct?

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3.7. Is there any coincidence you reject the manufacturers product?

- A. Yes      B. No

If your answer is yes through what mechanism you reject their product? And as a regulatory body what do you think the causes of the failure? Please specify

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**Appendix 2: Educational back ground of micro and small enterprises.**

Appendix 2.1: Educational background of Yeka Subcity micro and small enterprises those are currently manufacturing precast reinforced concrete rib beams in the city of Addis Ababa.

በየካ ክ/ከተማ ጥ/አ/አ/ል/ጽ/ቤት በበጥቃቅን ማኑፋክቸሪንግ ዘርፍ የተሰማሩ አዳሪና ነባር ኢ/ዞች መረጃ መሰብሰቢያ ቅጽ																
ተ.ቁ	የኢንተርፕራይዙ ስም	ወረዳ	የተደራጁ በት ዓ.ም	የተሰማራባት ግ/ዘርፍ	የአባላት ብዛት						የትምህርት ደረጃ				የኢንተርፕራይዙ አይነት በትርጓሜ ጥቃቅን/አነስተኛ	
					ሲቋቋም የነበረ አባላት			ወቅታዊ የአባል ብዛት								
					ወ	ሴ	ድ	ወ	ሴ	ድ	ማን እና	ከ1-8	ከ9 - 12	ከሌጅ ወይም ዩኒቨርሲቲ		ድምር
1	ብርሃኑወንድሙ እና ዳደሾቻቸው ኮንስትራክሽን ህ/ሽ/ማህበር	12	2008	ፕሪካስት	4	1	5	4	1	5			2	3	5	ጥቃቅን
2	ሰላማዊት፣ዮናስ እና ዳደሾቻቸው ኮንስትራክሽን ስራ ህ/ሽ/ማህበር	12	2008	ፕሪካስት	2	3	5	2	3	5		1	1	3	5	ጥቃቅን
3	ሞገስ ደበበ እና ዳደሾቻቸው የኮ/ሰ/ህ/ሽ/ማ	10	2004	ፕሪካስት	3	1	4	3	1	4			2	2	4	አነስተኛ
4	የሐንስ እና የወዳት ኮንስትራክሽን ስራ ሽ/ማ	10	2002	ፕሪካስት	2	1	3	2	1	3			3		3	አነስተኛ
5	ሞላ፣ መላኪ እና ዳደሾቻቸው ብሎኬት እና ፕሪካስት ማምረት	6	1997	ብሎኬት እና ፕሪካስት ማምረት	16	0	16	6	0	6	0	0	5	1	6	አነስተኛ
6	ጥረት በስራ ኮንስትራክሽን ህ/ሽ/ማ	7	2004	ብሎኬት ማምረት እና ፕሪካስት	7	5	12	3	2	5			3	2	5	አነስተኛ
7	ቴዎድሮስ ሀገስ እና ዙፋን ኮንስትራክሽን	11	2006	ብሎኬትና ፕሪካስት ማምረት	2	1	3	2	1	3			1	2	3	አነስተኛ
8	ፀጋ ቢኒየምና ሃኖክ ኮንስትራክሽን	11	2004	ብሎኬትና ፕሪካስት ማምረት	10		10	3		3			1	2	3	አነስተኛ
9	ሰላማዊትና ላዎይሽ እና ዳደሾቻቸው	11	2004	ብሎኬትና ፕሪካስት ማምረት	7		7	2	2	4			2	2	4	አነስተኛ
10	መንግስትቴግሮማ እና ዳደሾቻቸው የግ/ግ/አምራች ህ/ሽ/ማህበር	12	2008	ፕሪካስት	5	0	5	5	0	5	0	0	3	2	5	አነስተኛ
11	ሳሙኤል ዊንታ እና ፍሰሐ ኮንስትራክሽን ስራ የህብረት ሽርክና ማህበር	13	4/7/2005	ብሎኬትና ፕሪካስት ማምረት	2	1	3	2	1	3				3	3	አነስተኛ

Study on the production process of the precast reinforced concrete ribbed beam through the micro and small enterprises in Addis Ababa: “A case study on Bole, Yeka and Akaki kality Subcity”

Appendix 2.2: Educational background of Bole Subcity micro and small enterprises those are currently manufacturing precast reinforced concrete rib beams in the city of Addis Ababa.

በቦሌ ክ/ከተማ አስተዳደር በጥ/አ/ኢ/ል/ፅ/ቤት የተደራጁ ኢ/ዞች ዝርዝር መረጃ																		
ተ.ቁ	የኢንተርፕራይዙ ስም	ክ/ከተማ	ወረዳ	የተደራጁ በት ዓ.ም	የተሰማራቦት ግ/ዘርፍ	የአባላት ብዛት						የትምህርት ደረጃ					የኢንተርፕራይዙ አይነት በትርጓሜ ጥቃቅን/አነስተኛ	
						ሲቆቆም የነበረ አባላት			ወቅታዊ የአባል ብዛት			ማንበብ እና መጻፍ	የትምህርት ደረጃ					
						ወ	ሴ	ድ	ወ	ሴ	ድ		ከ1-8	ከ9-12	ዲፕሎማ	ዲግሪ		ድምር
1	ሰው ለሰው ከንስትራክሽን	ቦሌ	9	2004	ፕሪካስት	18	1	19	3	3	6			4	2		6	አነስተኛ
2	ሀይወት ገነት ና ዳደ	ቦሌ	9	2005	ፕሪካስት	3	10	13	1	5	6		4		2		6	ጥቃቅን
3	ታምራት ቶሌራና ዳደ	ቦሌ	9	2004	ፕሪካስት	13		13	3		3			1	2		3	አነስተኛ
4	ገነት ድረባ	ቦሌ	9	2009	ፕሪካስት	6	1	7	6	1	7					7	7	አነስተኛ
5	ወ/የሀገን ፋሲካና ዳደቶቻው	ቦሌ	9	2008	ፕሪካስት	4	2	6	3	2	5			1	2	2	5	አነስተኛ
6	ሸጋ ሁለገብ	ቦሌ	9	2004	ፕሪካስት	8	10	18	2	4	6			1	2	3	6	አነስተኛ
7	ነጋሽ ይሄይስና ዳደቶቻቸው	ቦሌ	9	2004	ፕሪካስት	15	5	20	4	0	4		1	2		1	4	አነስተኛ
8	Feye Tefera and friends	ቦሌ	11	2009	ፕሪካስት				4	4	8		2	5	1		8	አነስተኛ
9	A.B.C.M Precast	ቦሌ	11	2004	ፕሪካስት				3	1	4	1	3	3			7	አነስተኛ
10	Eyob fiyori and friends	ቦሌ	11	2009	ፕሪካስት				2	3	5			1	1	3	5	አነስተኛ
11	woley habtom and friends	ቦሌ	11	2009	ፕሪካስት				7	0	7			5		2	7	ጥቃቅን
8	ሚኒሊክ፣ብዙአየሁ እና ዳ.	ቦሌ	12	2007	ፕሪካስት								1	2	1		4	ጥቃቅን
9	ዩቲሮን ፕሪካስት	ቦሌ	12	2004	ፕሪካስት								2	1	1		4	ጥቃቅን
10	አበበ ሰጥአርጌና ዳደ	ቦሌ	15	2008	ፕሪካስት								2	3			5	ጥቃቅን
11	መገርሳ ጥላሁንና ዳደ	ቦሌ	15	2008	ፕሪካስት							1		3			4	ጥቃቅን
12	ደሳለኝ አደራእና ዳደ	ቦሌ	15	2008	ፕሪካስት							1	1	2			4	ጥቃቅን
13	ዘርአይ አማኑኤልእና ዳደ	ቦሌ	15	2008	ፕሪካስት								2	3			5	ጥቃቅን
14	አወል አብዱሳ እና ዳደ	ቦሌ	15	2008	ፕሪካስት									2			2	ጥቃቅን
15	ተስፋዬ መንገሻእና ዳደ	ቦሌ	15	2008	ፕሪካስት							1	1			3	5	ጥቃቅን
16	ወንድወሰን ጀግማ እና ዳደ	ቦሌ	15	2007	ፕሪካስት							1	1	3			5	ጥቃቅን
17	ሙኤዝ ትዝታ እና ዳደ	ቦሌ	15	2007	ፕሪካስት									3	2		5	ጥቃቅን
18	ጎይቶም ራሄል እና ዳደ	ቦሌ	15	2007	ፕሪካስት								1	2			3	ጥቃቅን
19	ሆዴተስፋለም እና ዳደ	ቦሌ	15	2008	ፕሪካስት							1	1	2			4	ጥቃቅን
20	ሀብታሙ ኤደን እና ዳደ	ቦሌ	15	2007	ፕሪካስት								3	2			5	ጥቃቅን
21	ተስፋዬ ብርሃኑ እና ዳደ	ቦሌ	15	2007	ፕሪካስት							1	1	2			4	ጥቃቅን
22	ሀብታሙ YONAS ENA GUADEGNOCHU	ቦሌ	15	2007	ፕሪካስት							0	3	1			4	ጥቃቅን

Appendix 2.3: Educational background of Akaki Kality Subcity micro and small enterprises those are currently manufacturing precast reinforced concrete ribbed beams in the city of Addis Ababa.

በአቃቂ ቃላት ክ/ከተማ በጥ/አ/ኢ/ል/ጽ/ቤት በማኑፋክቸሪንግ ዘርፍ በ2011 ዓ.ም. በተደረገው የኢ/ኛ ምዝገባ የተለዩ በአነስተኛ የዕድገት ደረጃ ላይ የሚገኙ ኢ/ኛዎች ኘሮፋይል																
ተ.ቁ	የኢንተርፕራይዙ ስም	ወረዳ	የተደራጀ በት ዓ.ም	የተሰማራበት ግ/ዘርፍ	የአባላት ብዛት						የትምህርት ደረጃ				የኢንተርፕራይዙ አይነት በትርጓሜ ጥቃቅን/አነስተኛ	
					ሲቋቋም የነበረ አባላት			ወቅታዊ የአባል ብዛት			የትምህርት ደረጃ					
					ወ	ሴ	ድ	ወ	ሴ	ድ	ማግብብ እና መፃፍ	ከ1-8	ከ9-12	ከሌጅ ወይም የሚከተሉት ደረጃዎች		ድምር
1	ብርክቲ ፀሀይ ና ዳደኞቻቸው	4	2004	ፕሪክስት	2	3	5	0	2	2		-	-	1	ጥቃቅን	
2	ናሁሰናይ ማቲዮስ ዳደኞ	4	2004	ፕሪክስት	8	1	9	6	1	7		-	1	3	ጥቃቅን	
3	አለማየሁ ደረጃ ናዳደኞ	4	2004	ፕሪክስት	6	0	6	6	0	6		-	-	3	ጥቃቅን	
4	አበዱል አሀመድ፤ ጋዲሳና ዳደኞ	4	2004	ፕሪክስት	10	0	10	4	0	4		-	1	3	ጥቃቅን	
5	እሸቱ ደረጃ እና ዳደኞቻቸው ፕሪክስት ማምረቻ ህ/ሽ/ማ	9	2008	ፕሪክስት	5	0	5	5	0	5	0	0	5	0	ጥቃቅን	
6	ብሩክ ታደላ እና ዳደኞቻቸው ፕሪክስት ስራ ህ/ሽ/ማ	9	2010	ፕሪክስት	5	0	5	5	0	5	0	0	2	3	ጥቃቅን	
7	ሸዋት ምሩፅ ዳደኞቻቸው የብ/ማ/ህ/ሽ/ማ	9	2009	ፕሪክስት	2	3	5	2	3	5	0	0	2	2	1	ጥቃቅን
8	መላኩ ትዕግስት እና ዳደኞቻቸው የፕሪ/ህብ/ሽ/ማ	9	2007	ፕሪክስት	4	2	6	4	2	6	0	0	1	5	ጥቃቅን	
9	ሰይፈዲን፣ታዲዮስ እና ዳደኞቻቸው ፕሪክስት ማምረት ህ/ሽ/ማ	9	2008	ፕሪክስት	9	1	10	9	1	10	0	5	3	2	ጥቃቅን	
10	ብርሀኑ፣ፀጋዬ እና ዳደኞቻቸው ፕሪክስት ማምረት ህ/ሽ/ማ	9	2007	ፕሪክስት	8	1	9	8	1	9	0	5	3	1	ጥቃቅን	

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11	ለከተለው እና ዳይጅቻቸው ፕሪክስት ማምረት ህ/ሸ/ማ	9	2008	ፕሪክስት	4	0	4	4	0	4	0	1	2	1	ጥቃቅን	
12	አዲስ፡ሀይለጊዮርጊስ እና ዳይጅቻቸው ፕሪክስት ማምረት ህ/ሸ/ማ	9	2006	ፕሪክስት	8	0	8	8	0	8	0	1	5	3	ጥቃቅን	
13	አለም እሸት፡ሀብታሙ እና ዳይጅቻቸው ፕሪክስት ማምረት ህ/ሸ/ማ	9	2005	ፕሪክስት	5	2	7	5	2	7	0	3	2	2	ጥቃቅን	
14	ገብረ፡ገ/ሙድህን እና ዳይጅቻቸው ፕሪክስት ማምረት ህ/ሸ/ማ	9	2007	ፕሪክስት	5	0	5	5	0	5	0	0	3	2	ጥቃቅን	
15	ዛፍነህ ፣አገላይ እና ዳይጅቻቸው ፕሪክስት ማምረት ህ/ሸ/ማ	9	2006	ፕሪክስት	13	0	13	13	0	13	0	6	5	2	ጥቃቅን	
16	ዳንኤል፡አንዳልካቸው ዳይጅቻቸው ፕሪ/ማም/ሀ/ሸ/ማ	9	2008	ፕሪክስት	2	0	2	2	0	2	0	0	0	2	ጥቃቅን	
17	አሸናፊ፡ፅጌ እና ዳይጅቻቸው ፕሪክስት ማምረት ህ/ሸ/ማ	9	2006	ፕሪክስት	3	1	4	3	1	4	0	2	1	1	ጥቃቅን	
18	አብራር፡ሰዒድ እና ዳይጅቻቸው ፕሪ/ማም/ሀ/ሸ/ማ	9	2005	ፕሪክስት	8	2	10	8	2	10	0	4	4	2	ጥቃቅን	
19	ተስፋለም፡ኤርሚያ እና ዳይጅቻቸው ፕሪክስት ማምረት ህ/ሸ/ማ	9	2006	ፕሪክስት	9	0	9	9	0	9	0	0	6	3	ጥቃቅን	
20	አንዷ አለም ፤ሚካኤል ዳይጅቻቸው	4	2004	ፕሪክስት				2	0	2				1	አነስተኛ	
21	አንዷ አለም ፤ሚካኤል ዳይጅቻቸው	4	2004	ፕሪክስት				2	0	2				1	አነስተኛ	
22	ታደሰ አንዳለማው	4	2005	ፕሪክስት	2	0	2	1	0	1				1	አነስተኛ	
23	ዋህድ ሁለገብ የግንባታ ግብዓት	4	2004	ፕሪክስት	3	1	4	1	1	2			1	1	አነስተኛ	
24	ዲ.ዋይ.ኢ የግንባታ ግብዓት	4	2004	ፕሪክስት	4	0	4	2	1	3				1	2	አነስተኛ
25	ታደሰ፤ደገፋ ናዳይጅቻቸው	4	1997	ፕሪክስት	12	0	12	12	0	12				2	6	አነስተኛ
26	ሙሉ ተሰማ እና ዳይጅቻቸው የግ/ግብ/አም/ሀ/ሸ/ማ	9	2004	ፕሪክስት	3	1	4	3	1	4	0	2	2	0	አነስተኛ	
27	ቢቂላ ታምራት እና የፕሪክስት ማምረት ህ/ሸ/ማ	9	2008	ፕሪክስት	5	0	5	5	0	5	0	2	3	0	አነስተኛ	

### Appendix 3: Rebound hammer compressive strength test data

Appendix 3.1: Compressive strength of precast ribbed beam data from Bole subcity on Ayat 49, Merri, and semmit manufacturing shades.

#### A. Rebound hammer test information’s from Ayat 49 manufacturing shade

Ayat 49 shade (3 active manufacturers involved)	Manufacturing enterprise 1 (3 month production period)									Manufacturing enterprise 2 (3 month production period)									Manufacturing enterprise 3 (45 day production period)											
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)					
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES
	21	20	16	18	17	20	18	16	17	23	22	18	21	18	21	20	18	20	15	20	20	17	17	16	17	16	22			
	16	21	18	15	19	20	16	16	17	22	21	17	19	19	23	19	17	18	20	21	21	19	20	19	18	16	21			
	19	19	19	19	18	17	21	17	16	21	20	16	17	20	21	21	15	17	17	21	19	16	20	20	17	19	20			
	15	18	20	18	20	15	19	15	19	23	21	18	21	16	20	18	20	19	19	19	17	15	18	18	16	20	21			
	17	17	22	17	16	18	18	18	18	21	19	19	19	15	19	22	19	20	21	22	18	18	18	22	16	18	19			
	18	20	19	19	22	17	21	19	18	19	18	20	20	18	20	21	20	16	19	18	20	18	17	21	16	19	18			
	21	16	18	16	18	20	22	20	20	25	20	17	24	17	21	18	22	17	20	19	19	17	21	19	18	17	16			
	15	17	20	19	17	19	20	17	19	19	21	18	22	20	22	23	21	22	16	19	16	16	20	19	19	20	17			
	19	18	21	20	16	17	20	20	17	21	20	19	18	21	20	22	20	20	15	17	20	19	19	17	17	21	20			
	18	21	17	17	20	16	21	18	16	24	18	20	20	18	21	19	16	21	18	19	22	18	21	20	16	18	19			
<b>Average</b>	17.9	19	19	18	18.3	17.9	20	18	17.7	22	20	18.2	20	18	20.8	20	18.8	19	18	20	19	17.3	19.1	19.1	17	18	19.3			
<b>S.S</b>	18.5			18.0			18.3			20.0			19.7			19.4			18.9			18.5			18.2					
<b>N.S</b>	<b>18.3</b>									<b>19.7</b>									<b>18.5</b>											

#### B. Rebound hammer test information’s from semmit manufacturing shade

Semmit shade(3 active manufacturers involved)	Manufacturing enterprise 1 (4 month production period)									Manufacturing enterprise 2 (33 day production period)									Manufacturing enterprise 3 (2 month production period)											
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)					
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES
	43	49	51	37	35	40	50	49	51	21	18	20	19	16	15	20	21	19	38	41	39	49	41	46	39	35	41			
	39	43	52	42	37	45	51	47	47	20	17	20	18	19	18	17	21	17	42	37	35	47	45	45	38	33	40			
	38	42	45	41	39	42	53	50	42	22	19	22	21	17	20	23	17	16	44	35	37	41	42	41	36	38	45			
	44	39	49	45	37	40	48	48	46	24	20	19	17	20	19	20	19	18	39	31	31	48	44	48	45	34	38			
	48	38	38	44	35	37	49	45	47	20	21	17	19	18	18	18	16	21	38	37	39	39	37	39	44	30	37			
	43	44	36	48	43	32	41	38	40	19	20	18	16	17	16	16	22	20	37	37	38	37	39	45	49	29	32			
	48	50	37	53	40	33	39	34	48	24	16	16	21	20	19	22	21	20	47	35	40	41	37	40	48	28	41			
	49	49	43	47	47	42	39	50	49	20	18	20	22	21	17	19	20	19	48	38	41	44	38	41	50	35	41			
	50	44	45	42	51	41	37	41	41	20	17	21	18	19	20	18	18	19	44	32	38	45	45	37	37	33	39			
	51	45	39	38	48	40	46	40	43	21	19	22	22	17	18	22	19	16	46	41	37	51	41	39	36	37	35			
<b>Average</b>	45.3	44	44	44	41.2	39.2	45	44	45.4	21	19	19.5	19	18	18	20	19.4	19	42.3	40	38	44.2	40.9	42.1	42.2	33	38.9			
<b>S.S</b>	44.4			41.4			45.0			19.7			18.6			19.1			39.9			42.4			38.1					
<b>N.S</b>	<b>43.6</b>									<b>19.1</b>									<b>40.1</b>											

C. Rebound hammer test information’s from Merri manufacturing shade

Merri shade(3 active manufacturers involved)	Manufacturing enterperise 1 ( 54 day production period)									Manufacturing enterperise 2 ( 47 day production period)									Manufacturing enterperise 3 ( 3 month production period)											
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)					
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES
	16	19	22	21	22	16	20	21	17	20	22	22	21	22	23	19	16	14	17	15	22	20	24	16	19	18	18			
	15	21	20	16	21	18	21	19	22	22	21	21	20	23	23	15	16	17	15	15	20	21	21	15	18	18	19			
	17	18	21	17	20	19	16	20	21	17	18	21	22	21	21	15	15	15	17	19	21	16	20	17	20	18	20			
	19	16	23	16	20	20	17	18	21	15	22	18	23	18	20	18	17	16	19	17	22	15	23	15	16	16	21			
	20	17	20	16	21	21	15	17	21	17	21	19	16	18	24	14	18	19	20	16	23	18	23	14	18	15	22			
	18	21	19	18	20	22	22	20	18	16	19	20	18	17	20	15	18	18	21	18	20	17	19	18	14	17	19			
	15	18	18	19	19	19	21	21	19	15	20	20	17	19	22	16	16	18	19	20	21	19	18	17	20	14	19			
	19	16	18	20	19	16	18	19	20	14	21	18	20	20	22	19	15	17	20	19	19	17	20	16	16	18	20			
	21	20	21	17	18	18	17	20	17	20	20	18	22	21	21	20	17	15	15	17	18	16	20	17	17	17	22			
	20	19	20	21	17	17	22	18	18	18	19	20	19	20	20	18	18	15	17	16	23	17	19	17	20	16	20			
Average	18	18.5	20.2	18.1	19.7	18.6	18.9	19.3	19.4	17.4	20.3	19.7	19.8	19.9	21.6	16.9	16.6	16.4	18	17.2	20.9	17.6	20.7	16.2	17.8	16.7	20			
S.S	18.9			18.8			19.2			19.1			20.4			16.6			18.7			18.2			18.2					
N.S	19.0									18.7									18.3											

Appendix 3.2: Compressive strength of precast ribbed beam data from Yeka subcity on Karra, Abado, and Deninet (woreda 10) manufacturing shades.

A. Rebound hammer test information’s from kara manufacturing shade

Karra shade (3 active manufacturers involved)	Manufacturing enterperise 1 ( 5month production period)									Manufacturing enterperise 2 ( 4month production period)									Manufacturing enterperise 3 ( 2.5month production period)											
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)					
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES
	35	38	43	31	42	39	38	38	44	26	19	19	23	22	16	17	22	18	26	23	16	20	22	20	16	17	19			
	30	25	45	27	45	35	35	32	43	19	19	16	28	23	19	15	21	18	29	22	15	21	21	23	19	21	19			
	34	28	39	41	39	41	41	41	49	18	22	17	19	20	20	20	24	21	20	20	19	20	19	19	22	16	18			
	40	32	35	37	38	37	49	48	45	17	21	19	30	17	22	30	20	16	18	18	18	19	18	18	15	22	22			
	39	45	41	40	44	42	45	44	51	21	18	22	17	19	18	16	24	17	18	19	18	18	20	21	19	20	21			
	44	43	35	48	35	44	42	45	49	25	17	24	21	18	19	25	19	22	20	17	17	17	16	22	17	20	20			
	29	34	29	28	33	35	29	39	38	21	16	23	18	16	17	24	23	21	26	18	16	19	21	16	16	19	18			
	29	32	30	30	39	38	28	37	44	19	21	17	22	22	20	17	20	23	31	16	15	21	17	17	22	16	16			
	35	37	41	35	36	33	35	48	41	17	21	23	23	17	21	20	18	20	22	20	18	22	19	17	21	20	20			
	41	28	42	30	44	46	42	39	43	18	24	22	15	20	16	21	22	22	22	23	21	21	18	16	17	17	19			
Average	35.6	34.2	38	34.7	39.5	39	38.4	41.1	44.7	20.1	19.8	20.2	21.6	19.4	18.8	20.5	21.3	19.8	23.2	19.6	17.3	19.8	19.1	18.9	18.4	18.8	19.2			
S.S	35.9			37.7			41.4			20.0			19.9			20.5			20.0			19.3			18.8					
N.S	38.4									20.2									19.4											

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B. Rebound hammer test information’s from Abado manufacturing shade

Abado shade (3 active manufacturers involved)	Manufacturing enterperise 1 ( 3month production period)									Manufacturing enterperise 2 ( 3month production period)									Manufacturing enterperise 3 ( 1.5month production period)											
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)					
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES
	21	19	22	21	23	19	18	22	19	21	20	22	19	16	20	16	22	17	18	19	24	24	19	22	20	22	19	20	22	19
	20	16	21	20	16	22	17	16	17	22	20	20	17	20	20	17	22	19	19	19	20	22	18	21	21	23	18	19	21	17
	22	17	24	20	18	19	16	21	18	21	19	18	22	17	18	23	19	19	22	18	19	21	23	18	19	21	17	19	21	17
	17	22	20	24	20	20	22	19	17	20	16	18	21	19	19	19	20	22	19	20	20	19	23	19	17	21	21	17	21	21
	19	20	18	19	19	22	21	17	22	19	21	19	19	16	16	18	21	20	20	20	22	20	21	20	20	19	22	20	19	22
	20	21	19	20	17	18	18	19	20	24	21	20	18	22	18	22	23	16	22	21	22	24	20	23	16	20	20	16	20	20
	21	16	22	24	18	16	19	16	21	20	18	20	23	20	22	19	18	22	21	17	19	19	18	18	18	22	23	18	22	23
	22	19	20	21	22	21	24	21	19	21	17	18	24	19	20	22	19	18	19	19	18	21	20	19	22	19	20	22	19	20
	24	20	18	22	17	20	23	19	20	17	19	17	21	18	21	16	22	19	23	18	20	20	23	22	19	23	19	19	23	19
	19	19	19	21	23	17	16	20	22	21	20	19	20	17	18	24	20	19	19	21	19	19	21	21	24	20	22	24	20	22
Average	21	19	20	21	19	19	19	19	20	21	19	19	20	18	19	20	21	19	20	19	20	21	21	20	20	21	20	20	21	20
S.S	19.9			20.0			19.3			19.6			19.3			19.8			19.9			20.6			20.2					
N.S	19.7									19.6									20.2											

C. Rebound hammer test information’s from Deninet manufacturing shade

Deninet shade (3 active manufacturers involved)	Manufacturing enterperise 1 ( 45day production period)									Manufacturing enterperise 2 ( 43day production period)									Manufacturing enterperise 3 ( 45day production period)											
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)					
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES
	19	22	21	24	19	23	21	23	19	29	35	39	53	38	36	49	42	29	22	19	22	26	16	18	18	21	24	18	21	24
	23	21	22	23	19	21	19	21	21	40	33	38	41	45	38	50	31	35	24	18	21	19	18	19	22	22	20	22	22	20
	22	19	20	19	20	20	18	20	22	39	39	45	43	47	39	35	39	37	21	17	23	17	21	21	21	19	16	21	19	16
	23	20	19	23	22	19	22	22	18	42	41	38	46	38	42	36	33	34	22	16	19	24	20	20	24	18	19	24	18	19
	20	19	23	23	23	18	21	21	19	50	45	44	41	42	51	38	51	42	21	22	17	19	22	23	21	23	22	21	23	22
	21	20	21	22	19	20	23	19	17	27	42	41	46	41	45	44	49	40	26	20	16	24	19	20	19	20	20	19	20	20
	19	21	20	21	18	21	24	18	22	39	44	46	34	46	41	52	44	39	24	19	18	23	20	21	18	19	20	18	19	20
	21	23	19	18	20	19	22	22	20	27	47	37	36	40	39	49	42	37	23	22	22	23	18	18	20	19	23	20	19	23
	22	21	19	24	22	21	25	20	19	44	38	40	40	42	37	50	41	45	26	20	20	24	23	16	22	22	19	22	22	19
	23	19	18	22	21	18	20	21	21	28	36	41	43	43	36	37	39	44	21	19	18	21	20	22	24	20	20	24	20	20
Average	21.3	20.5	20.2	21.9	20.3	20	21.5	20.7	19.8	36.5	40	40.9	42.3	42.2	40.4	44	41.1	38.2	23	19.2	19.6	22	19.7	19.8	20.9	20.3	20.3	20.9	20.3	20.3
S.S	20.7			20.7			20.7			39.1			41.6			41.1			20.6			20.5			20.5					
N.S	20.7									40.6									20.5											

Appendix 3.3: Compressive strength of precast ribbed beam data from Akaki Kality subcity on Kilinto, Koyefech, and Koye nefasilk manufacturing shades.

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A. Rebound hammer test information’s from Kilinto manufacturing shade

Kilinto shade (3 active manufacturers involved)	Manufacturing enterperise 1 ( 2.5month production period)									Manufacturing enterperise 2 ( 1.5month production period)									Manufacturing enterperise 3 ( 3.5month production period)											
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)					
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES
	18	15	20	21	20	14	18	17	15	14	16	18	19	18	20	14	20	16	22	22	14	20	15	16	22	14	22			
	16	14	20	22	21	14	17	15	14	15	16	18	19	15	21	14	19	15	23	18	14	20	14	16	20	14	19			
	16	17	19	17	23	16	18	15	14	15	17	17	21	15	18	15	18	16	24	22	15	21	14	15	23	15	16			
	15	16	15	19	22	15	18	20	16	19	15	15	21	15	19	18	18	14	20	22	16	22	16	14	23	15	21			
	17	14	17	18	20	15	16	21	14	16	14	20	22	16	20	18	19	17	20	20	17	19	15	15	24	15	20			
	15	14	18	20	19	17	15	20	18	15	19	21	18	14	19	19	17	17	19	24	14	19	17	20	20	19	15			
	19	15	14	19	20	18	19	19	17	20	20	21	17	17	16	15	19	16	18	24	15	17	18	17	19	17	18			
	16	17	16	22	16	20	17	18	15	19	20	17	19	17	20	16	20	18	20	23	15	18	14	18	18	17	18			
	17	16	15	18	17	14	17	20	19	17	20	14	22	18	15	15	21	15	21	20	19	20	15	19	22	15	19			
	14	15	19	14	18	15	15	17	19	18	18	16	20	18	14	17	22	16	22	22	19	22	20	17	24	16	17			
Average	16.3	15.3	17.3	19	19.6	15.8	17	18.2	16.1	16.8	17.5	17.7	19.8	16.3	18.2	16.1	19.3	16	20.9	21.7	15.8	19.8	15.8	16.7	21.5	15.7	18.5			
S.S	16.3			18.1			17.1			17.3			18.1			17.1			19.5			17.4			18.6					
N.S	17.2									17.5									18.5											

B. Rebound hammer test information’s from Koyefech manufacturing shade

Koye fech shade (3 active manufacturers involved)	Manufacturing enterperise 1 ( 4month production period)									Manufacturing enterperise 2 (4month production period)									Manufacturing enterperise 3 ( 2.5month production period)											
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)					
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES
	22	23	20	15	18	16	23	21	15	18	16	18	22	23	24	21	21	21	22	15	16	22	20	14	20	16	22			
	17	22	22	18	15	17	23	21	19	18	16	17	24	20	20	22	20	19	21	15	16	21	20	15	15	18	21			
	16	24	19	18	14	18	24	23	18	15	16	19	22	18	20	15	20	18	23	14	15	23	19	13	17	17	18			
	17	19	20	18	14	15	20	18	20	20	14	22	22	21	18	19	23	17	21	16	19	22	18	19	15	18	22			
	15	19	23	15	16	16	19	20	21	21	19	20	21	20	19	20	18	18	20	17	20	15	20	15	20	16	19			
	19	17	20	17	14	15	18	20	17	20	15	19	20	21	16	18	19	20	24	15	21	19	20	15	21	19	21			
	18	18	19	19	15	17	22	19	17	19	19	21	20	15	22	21	20	15	19	14	20	16	21	16	20	15	20			
	22	20	19	18	17	18	22	21	15	19	20	21	21	17	20	23	22	16	18	18	18	17	15	14	19	18	21			
	18	19	18	20	14	22	19	20	14	17	21	15	19	15	18	18	21	23	20	20	15	20	14	17	19	17	22			
	23	19	15	20	19	20	20	18	22	15	15	19	21	20	17	21	18	20	19	19	14	15	19	20	18	20	19			
Average	18.7	20	19.5	17.8	15.6	17.4	21	20.1	17.8	18.2	17.1	19.1	21.2	19	19.4	19.8	20.2	18.7	20.7	16.3	17.4	19	18.6	15.8	18.4	17.4	20.5			
S.S	19.4			16.9			19.6			18.1			19.9			19.6			18.1			17.8			18.8					
N.S	18.7									19.2									18.2											

C. Rebound hammer test information’s from kara manufacturing shade

Koye fech shade (3 active manufacturers involved)	Manufacturing enterperise 1 (4month production period)									Manufacturing enterperise 2 (4month production period)									Manufacturing enterperise 3 (2.5month production period)																																			
	Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)			Sample1 (Mpa)			Sample2 (Mpa)			Sample3 (Mpa)																													
	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES	PS	MS	ES															
	22	23	20	15	18	16	23	21	15	18	16	18	22	23	24	21	21	21	22	15	16	22	20	14	20	16	22	17	22	22	18	15	17	23	21	19	18	16	17	24	20	20	22	20	19	21	15	16	21	20	15	15	18	21
	16	24	19	18	14	18	24	23	18	15	16	19	22	18	20	15	20	18	23	14	15	23	19	13	17	17	18	17	19	20	18	14	15	20	18	20	20	14	22	22	21	18	19	23	17	21	16	19	22	18	19	15	18	22
	15	19	23	15	16	16	19	20	21	21	19	20	21	20	19	20	18	18	20	17	20	15	20	15	20	16	19	19	17	20	17	14	15	18	20	17	20	15	19	20	21	16	18	19	20	24	15	21	19	20	15	21	19	21
	18	18	19	19	15	17	22	19	17	19	19	21	20	15	22	21	20	15	19	14	20	16	21	16	20	15	20	22	20	19	18	17	18	22	21	15	19	20	21	21	17	20	23	22	16	18	18	18	17	15	14	19	18	21
	18	19	18	20	14	22	19	20	14	17	21	15	19	15	18	18	21	23	20	20	15	20	14	17	19	17	22	23	19	15	20	19	20	20	18	22	15	15	19	21	20	17	21	18	20	19	19	14	15	19	20	18	20	19
Average	18.7	20	19.5	17.8	15.6	17.4	21	20.1	17.8	18.2	17.1	19.1	21.2	19	19.4	19.8	20.2	18.7	20.7	16.3	17.4	19	18.6	15.8	18.4	17.4	20.5																											
S.S	19.4			16.9			19.6			18.1			19.9			19.6			18.1			17.8			18.8																													
N.S	18.7									19.2									18.2																																			

**Appendix 4: Observed pictures from the manufacturing shades.**

Appendix4.1: Views of raw material storage and utilization technique



Study on the production process of the precast reinforced concrete ribbed beam through the micro and small enterprises in Addis Ababa: “A case study on Bole, Yeka and Akaki kality Subcity”



Study on the production process of the precast reinforced concrete ribbed beam through the micro and small enterprises in Addis Ababa: “A case study on Bole, Yeka and Akaki kality Subcity”



Appendix 4.2: Views of concrete production and casting practice

Study on the production process of the precast reinforced concrete ribbed beam through the micro and small enterprises in Addis Ababa: “A case study on Bole, Yeka and Akaki kality Subcity”



Study on the production process of the precast reinforced concrete ribbed beam through the micro and small enterprises in Addis Ababa: “A case study on Bole, Yeka and Akaki kality Subcity”



Appendix 4.3: Views of molding, fixing rebar and casting fitting practice



Study on the production process of the precast reinforced concrete ribbed beam through the micro and small enterprises in Addis Ababa: “A case study on Bole, Yeka and Akaki kality Subcity”



Appendix 4.4: Views of final storage practice

