ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

M.Sc. in

CONSTRUCTION TECHNOLOGY AND MANAGMENT

Assessment of Current Practice of Shoring and Scaffolding Systems in Building Construction Industry in Addis Ababa

A thesis submitted to school of graduate studies in partial fulfillment of the requirements for the degree of Master of Science in civil engineering, (Construction technology and management major)

ADVISOR:-Dr. Abraham Assefa

Prepared By:-Eyerusalem Kelemework

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By

Eyerusalem Kelemework

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Approved by Board of Examiners

Dr. Abraham Assefa	Abraham Assefa	01/06/17
Advisor	Signature	Date
Yibeltal Temesgen	[signature]	19/05/2017
External Examiner	Signature	Date
Ephraim Senbetta	Ephraim Senbetta	24/5/2017
Internal Examiner	Signature	Date
Chairman	Signature	Date

Dr. Agizew Nigussie
Dean, School of Civil & Environmental Engineering

DECLARATION

This thesis is my original work, and has not been presented for a degree in any other university and all sources of material used for the thesis have been duly acknowledged.

Candidate

Name ____

Signature ____

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Abbreviations

OHSA	Occupational Safety and Health Administration
EBCS	Ethiopian Building Codes and Standards
ILO	International labor Organization

Interpretation of Terms

Scaffolding- A temporary structure built to provide access and working platforms in elevated areas; the process of erecting scaffolds

Shoring- A temporary structure built to support form work and fresh concrete or recently built structures which have not developed full design strength; also called Prop, Tom, Post, and strut. ; The process of erecting shores

Supported scaffoldings- A type of scaffolding built from base upward and the platforms are supported by legs, outrigger beams, poles, uprights, posts, frames, or similar rigid support.

H-Frames - Manufactured metal frames used for construction of shoring and scaffoldings

Tube and coupler- Metal tubing or pipe with special couplers that connect the uprights and various members used for construction of shoring and scaffolding systems**.**

Adjustable steel prop- Metal tubing with adjustable pins on them used for construction of shoring and scaffolding systems

Posts- Elements of shoring and scaffolding that insure the structure stands upright and transfer the entire weight of the structure to the ground; also called standards or uprights.

Ledgers- Elements of shoring or scaffolding that are horizontal and connected to the vertical tubes or posts to hold the structure firmly; also called runner.

Transoms- Elements of shoring or scaffolding placed on ledgers at right angles to give the structure more strength; also called bearer.

Joists- A comparatively narrow beam with closely spaced arrangements found directly under slab formwork sheeting in shoring construction

Stringer- A secondary flexural member used to support joists and transfer the weight of the supported structure to the posts in shoring system.

Eucalyptus wood metal combination- A combination of eucalyptus wood and metal used for construction of shoring and scaffolding

Abstract

The demand of shoring and scaffolding systems for the construction of the new high-rise buildings in Addis Ababa is very high. Shoring and scaffoldings are usually constructed using Eucalyptus wood but currently the use of metal is emerging around Addis Ababa building projects. However, despite the short comings of the traditional Eucalyptus wood shoring and scaffolding, due to the level of development of the construction industry it still dominates the building construction industry. Recent concerns about safety, increasing height of buildings, operating cost and flexibility constraints are now requiring innovation in shoring and scaffolding systems in Addis Ababa. In order to make these necessary changes possible first there should be a clear understanding of the current practice of shoring and scaffolding systems. This study was conducted by selecting forty-four G+5 and higher building projects around Addis Ababa that are under construction during the study period. Site observation and questionnaires were conducted in the projects to get relevant data which helps to achieve the objectives of this thesis. The research findings indicated that Eucalyptus wood metal combination and Eucalyptus wood were the most frequently used materials for construction of shoring and scaffoldings, respectively. Capacity of a company, availability of shoring and scaffolding material in the company, and initial cost of the material were identified to be the top three influencing factors considered in selection of both shoring and scaffolding systems. Moreover, the pattern of the chosen material and geometry of the building and activity related factors such us, type of the slab, method of slab concrete construction, maximum floor height, degree of repetition of the work, expected floor cycle construction duration, height of the building and expected duration of work on the constructed scaffolding systems were also the other critically influencing factors. The research also indicated that speed of construction of metal shoring and scaffolding are faster than eucalyptus wood, and the initial cost of H-frame is higher than Eucalyptus wood, however, the life cycle cost of Eucalyptus wood shoring is higher than H- frame shoring. The average meter square cost of Eucalyptus wood shoring was found to be 34.4 birr/m^2 or 47 % higher than H-frame shoring considering 4 times and 20 times life use of each material, respectively. Regarding safety of the shoring and scaffolding materials, buildings which were using Eucalyptus wood for both shoring and scaffolding systems have contributed the most to construction injuries occurring in the selected projects. A total of 10 or 42% of the incidents out of the 24 incidents, and 2 or 33% of the fatality out of 6 occurred in building projects using Eucalyptus wood for both shoring and scaffolding systems.

Key words: shoring and Scaffolding systems, Methods and materials, Influencing factors

Chapter One: Introduction

1.1. Background

Shores are temporary structured used for supporting structures under construction. Scaffolds are temporary elevated platforms built to facilitate the work of laborers and use of materials, mostly at higher than ground level elevations.

Shoring and scaffolding in one form or another has been used since humans moved from single story huts at ground level to taller structures. From times immemorial, shoring and scaffolding has been used in ancient Egypt to the modern world. Ancient Egypt constructed some of the most marvelous structures like the Pyramids and statues. Scholars are still baffled as to how the Egyptians built the pyramids. Some theories suggest that a series of dirt ramps and wooden scaffolding allowed each block to be hauled into place [1]. Scaffolds were also used to carve out statues around a big sized rock from the top to the bottom. The Berlin Foundry Cup depicts scaffolding in ancient Greece, early 5th century BC. Egyptians, Nubians and Chinese are also recorded as having used shoring and scaffolding like structures to build tall buildings [2]. Ancient Ethiopians also curved and erected monolithic obelisks, Lalibela rock-hewn churches, Fasil Ghebbi, castles and many more structures. The largest monolithic stelae ancient human beings ever attempted to erect survive in the town of Aksum dating between the 3rd and 4th centuries AD. The largest standing obelisk rises to a height of over 23 meters and is exquisitely carved to represent a nine-story building of the Aksumites. The largest obelisk of some 33 meters long lies where it fell, perhaps during the process of erection [58]. Nevertheless without the use of shoring and scaffolding systems curving and erecting these structures would have been impossible. Early shoring and scaffolding was made of wood and secured with rope knots [2].

In the far eastern countries like China and India, bamboo is used as scaffolding material. Many famous landmarks, notably The Great Wall of China, were built using bamboo scaffolding. Bamboo is flexible in nature yet it is strong and durable too and that gives the structures a good deal of strength. Two or more bamboo poles are bound together by ropes so that they do not slip or slide [2].

The modern shoring and scaffolding started in the early 20th century when metal fixings were introduced in place of rope. Later on, metal pipes began to be introduced instead of timber poles with standardized dimensions, allowing for the industrial interchangeability of parts and improving the structural stability of the shoring and scaffolding, which brought about a revolutionary change in the construction of very tall buildings. Metallic shoring and scaffoldings are the main pillars of the modern shoring and scaffolding business. The use of diagonal bracings also helped to improve stability, especially on tall buildings. The first frame system was brought to market in 1944 and was used extensively for the postwar reconstruction [2].

Due to the large amount of developments undertaking throughout the years, shoring and scaffoldings are found everywhere. Shoring and scaffolding play major role in building construction. They present an important part in construction especially building operations at height. Scaffolding has a variety of applications in the construction industry. It is used in new construction, alteration, routine maintenance, renovation, painting, repairing, and removal activities. Scaffolding offers a safer and more comfortable work arrangement compared to leaning over edges, stretching overhead, and working from ladders. Scaffolding provides employees safe access to work locations, level and stable working platforms, and temporary storage for tools and materials for performing immediate tasks [3].

Shores and Scaffolds are an integral part of construction operations in any field of construction especially for high-rise construction. While scaffolding is often considered to be of lesser importance within the overall project requirements, it does account for a considerable amount of labor-hours [4].

Now days there are variety of shoring and scaffolding systems are available around the world. Selecting the right type of shoring and scaffolding, which satisfies the budget, the time constraints and maintaining safety of the work place, becomes more concern around the construction industry.

Shoring and scaffoldings are usually constructed using metal tubes, Bamboo and timber in different countries. In Ethiopia shoring and Scaffoldings are usually constructed using Eucalyptus wood but currently the use of metal and Bamboo is emerging around Addis Ababa building projects. It can be understood that due to the material properties of eucalyptus wood a systematic design of eucalyptus scaffold is not available.

1.2. Statement of the problem

Nowadays, everything is about speed and all projects have to be completed within a short time frame. For multi-story buildings the traditional eucalyptus wood shoring and scaffolding systems are neither suitable nor meeting any safety parameters. Because eucalyptus wood is a natural material it has inconsistent material properties as a result systematic design of eucalyptus wood shoring and scaffolding systems are not available. It is strongly relied on the experience of the carpenter to make judgment when executing the work. Consequently it leads to uneconomical and unsafe practices. Despite these short comings, eucalyptus wood shoring and scaffolding systems have been dominating the Ethiopian construction industry. Recent concerns about safety, increasing height of buildings, operating cost and flexibility constraints are now requiring innovation in shoring and scaffolding systems In Addis Ababa.

Different literatures have been recommending replacing the traditional Eucalyptus wood shoring and scaffolding systems with currently available technology and also tried to introduce alternative shoring and scaffolding materials like bamboo [5, 6]. In order to make these necessary changes possible first there should be a clear understanding of the current practice of shoring and scaffolding systems and extensive knowledge of affecting factors in selection of scaffolding systems. There are still inadequate acknowledgements and few research studies to either understand the current practice of shoring and scaffolding systems or contractors approach how they select the existing shoring and scaffolding systems.

1.3. Research objective

The objectives of this research work are following.

- To assess methods and materials used in erecting shoring and scaffolding systems in building construction projects around Addis Ababa.
- To identify critical factors for selection of shoring and scaffolding systems in building construction projects around Addis Ababa
- To make comparison of cost, time, safety, operation and application of the eucalyptus wood with currently available shoring and scaffolding materials around Addis Ababa.

1.4. Scope of the research

This research focused only on shoring and supported scaffolding systems used in building construction projects in Addis Ababa. The research mainly focused on shoring which are used in slab and beam concrete construction, and supported scaffolding systems, which are built from the base upwards to provide temporary access and working platforms on elevated areas. It doesn't include related issues like form work.

Chapter Two: Literature Review

2.1. Introduction

The purpose of this chapter is carrying out a detail literature review about shoring and scaffolding system in construction of building projects. A review of journals, thesis, books, codes, standards and relevant websites are carried out to develop this chapter

2.2. Building Construction

High rise buildings have always fascinated the minds of people since the start of its construction in the ancient times. The construction of such buildings began in the ancient times for defensive purposes or religious purposes. But in the modern era construction of such project began in nineteen century for the purpose of either residential or administrative and then it became to meet the requirements of hotels and other touristic needs as well.

Developments in building construction and in construction industries have a significant role in the overall development of a country. In most developing countries construction activities constitutes 6-9% of the GDP and have great contribution in fixed capital formation as infrastructure and public utilities are required for economic development. It is also the major source of job opportunity especially in developing countries like Ethiopia.

In common with other developing countries, demographic changes in Ethiopia are resulting in massive migrations of people from villages to urban areas. The capital city of Ethiopia, Addis Ababa is facing severe overpopulation. To solve the housing problem the government has embarked on one of Africa's biggest state-housing projects, built and transferred 144,460 units between the year 2005 and 2015 [57]. At the same time, infrastructure developments such as health bureaus, universities and schools are expanding throughout Ethiopia. Construction in Ethiopia is on a constant rise and construction sites can be seen everywhere in Addis Ababa. On the other hand scarcity of land supply encourages the construction of multi-story buildings. Construction of multi-story buildings requires effective use of temporary structures to provide safe access and support for the workers, materials, equipment and for the built structure as well.

2.3. Temporary Structure

Temporary structures are those structures that are erected and used to aid the construction of a permanent project. They are used to facilitate the construction of buildings, bridges, tunnels, and other above and below-ground facilities by providing access, support, and protection for the facility under construction, as well as to assure the safety of the workers and the public [9]

In addition to new construction projects, temporary structures are also a major component in maintenance, repair and inspection works [9]. Some of the different types of temporary works are:

- concrete formwork construction,
- scaffolding,
- False work /shoring,
- cofferdams,
- underpinning,
- diaphragm/slurry walls,
- earth-retaining structures, and
- dewatering construction.

A temporary structure in construction affects the safety of the workers on the job and the general public and there is also the relationship of the temporary structure to the finished structure. Structures form the interface between design and construction. Most permanent structures simply could not be built without temporary structures [9].

Losses in time and money will occur if the temporary structures are not planned and coordinated with the same degree of thoroughness as the permanent structures. Temporary structures can be the most expensive part of some construction projects. Designing cost-effective solutions to temporary structure problems could easily be the competitive advantage a contractor has over others [9].

2.4. Shoring and Scaffolding

Shoring is a temporary structure used for support of excavations, formwork, and unsafe structures or for recently built structures which have not developed full design strength. They are also called Prop, Tom, Post, and strut. Shoring is subjected to heavy loads for example concrete weight in formwork.

Scaffolding is a temporary structure erected to support access or working platforms. Scaffolds are commonly used in construction work to have a safe and stable work platform when work cannot be done at ground level or on a finished floor. Scaffoldings are used to support light to moderate loads of labors, small construction material and equipment for safe working space. They are usually attached to buildings with ties and only one bay wide

2.5. Types of Scaffoldings

There are many different types of scaffolding and the precise names and terminology tend to vary from place to place, but in general the main categories are set based on how the structure interacts with the building it's up against, how it's constructed, and the type of weight it can support. All have some inherent dangers, manufacturers and users usually have to adhere to a number of best practices in order to stay safe. Based on how scaffoldings are constructed they can be classified as follows:

2.5.1 Supported Scaffolding

Supported scaffoldings are built from the base upwards, and will normally be used wherever possible. It is the most commonly used form of scaffolding in construction work and on most other forms of work where elevation is required. Extra support may be required if the scaffolding will be long or required to take a lot of weight. Supported scaffolding can be left in position for longer periods of time, making it especially useful in those situations where permanent access may be needed to elevated positions [3]. Different forms of supported scaffolding are available, and each will serve a very specific purpose and used in specific circumstances.The most common types of supported scaffolds are the following:

Tube and coupler scaffolds**:** are built from tubing connected by coupling devices. Due to their strength, they are frequently used where heavy loads need to be carried, or where multiple platforms must reach several stories high. Their versatility, which enables them to be assembled in multiple directions in a variety of settings, also makes them hard to build correctly [3].

Figure 2.1 Tube and coupler scaffolding [4]

The three basic elements of scaffolding are standards, ledgers and transoms. The tubes used to construct the scaffolds are also known as the standards or uprights. They run throughout the entire structure and ensure that it stands upright. They also transfer the entire weight of the structure to the ground on a square base plate so as to spread the load. Ledgers are the tubes that are horizontal and connecting to the vertical tubes to hold the structure firmly. Transoms are placed on the ledgers at right angles to give the structure more strength. All these different components ensure that the structure is strong and firm to hold weight and ensure safety [3]. Standard couplers or clamps are used to connect these elements together to form a complete scaffold. Figure 2-2 shows the typical elements in such configurations [4].

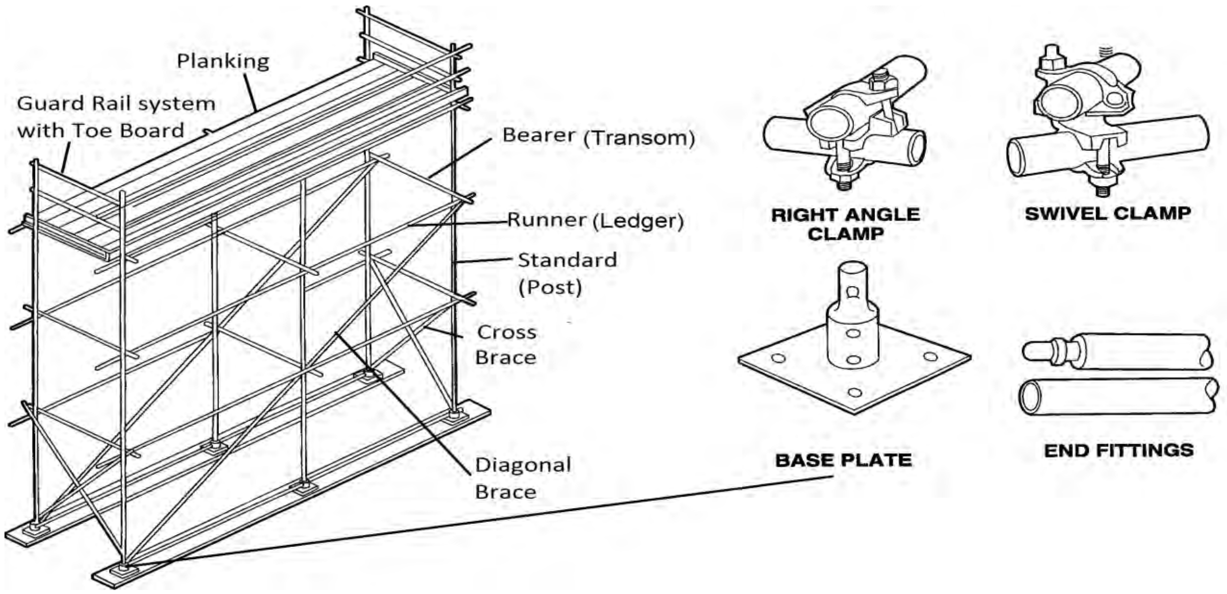

Figure 2.2 Typical tube and coupler scaffolding [4]

***Frame or fabricated scaffolding*:** Fabricated frame scaffolds are the most common type of scaffold because they are versatile, economical, and easy to use. [3] However, such scaffolds suit mostly residential or other kinds of symmetrical construction where a single configuration would be repeatedly used. Framed scaffolds are also used in industrial projects depending on the type of situation as they are far easier to construct and take down than a normal tube and clamp scaffold which in turn saves considerable resources [4]. Figure 2-3 shows a typical framed configuration and Figure 2-4 shows different types of frames used [9].

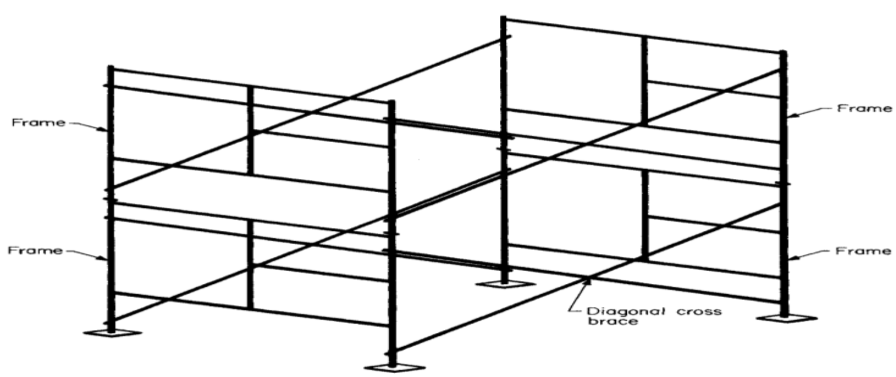

Figure 2.3 Typical framed configurations [4]

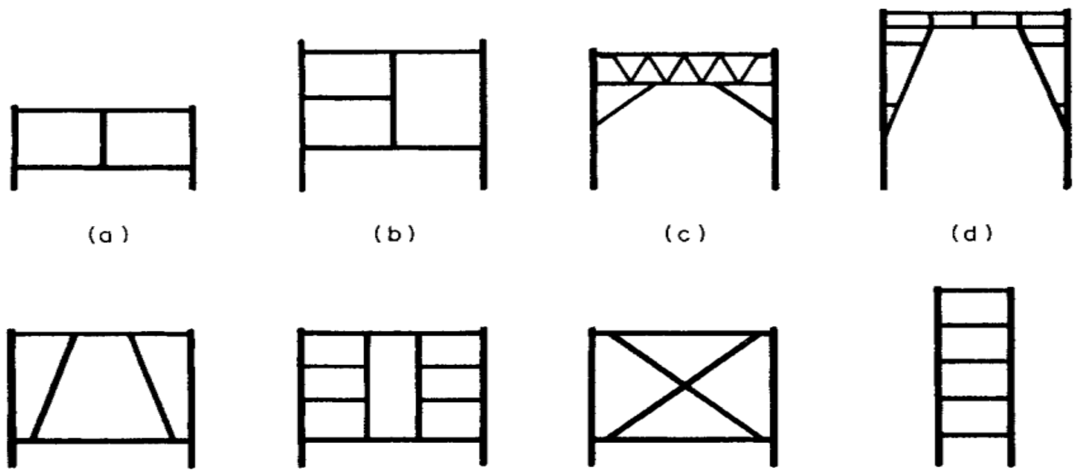

Figure 2.4 Different types of frames

Systems scaffold: Systems scaffolds or all around scaffolds can be applied to a wide variety of rectangular, dome or circular configurations [13]. It's not as adjustable as a tube and clamp; however, they are comparatively quicker to set up and take down. Figure 2-5 shows a typical system scaffold. [13]

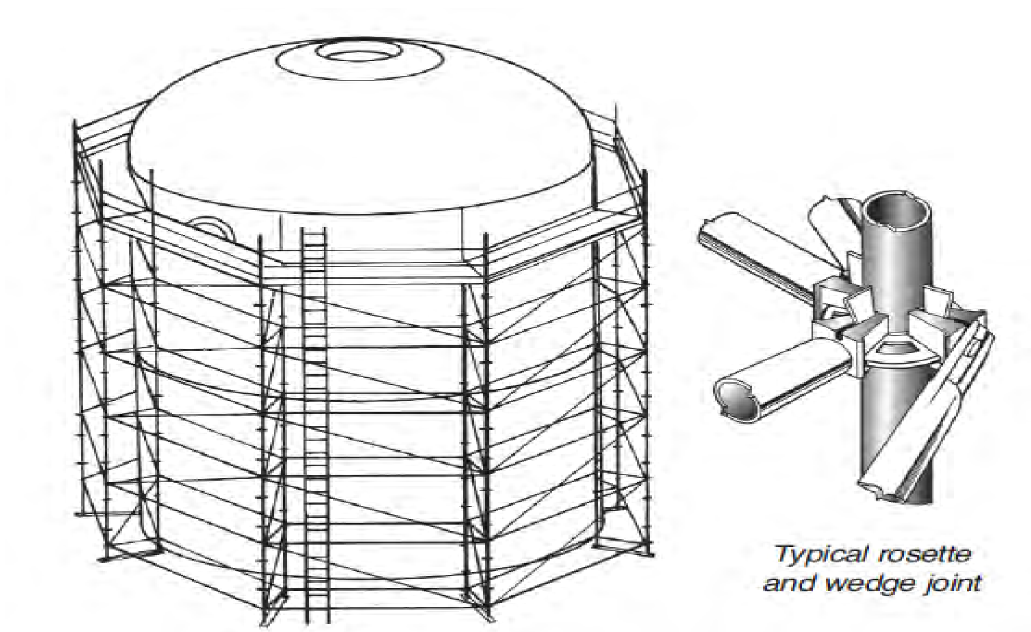

Figure 2.5 System scaffold [4]

2.5.2 Suspended Scaffolding

Suspended scaffolding is typically suspended from a roof or other tall construct. It is most commonly used when it is not possible to construct a base, or where access to upper levels may be required, and the building of scaffolding from floor to the required level would be impractical. The suspended scaffolding is high-efficiency modern overhead operation equipment capable of replacing a traditional scaffold and being reused [3]. Generally, the suspended scaffolding can be divided into two kinds: manual and electric. It is widely applied to the outer wall construction, curtain wall installation and outer wall cleaning and maintenance in high rise and it can be also applied to large tanks, bridges, dams and other engineering operations [3].

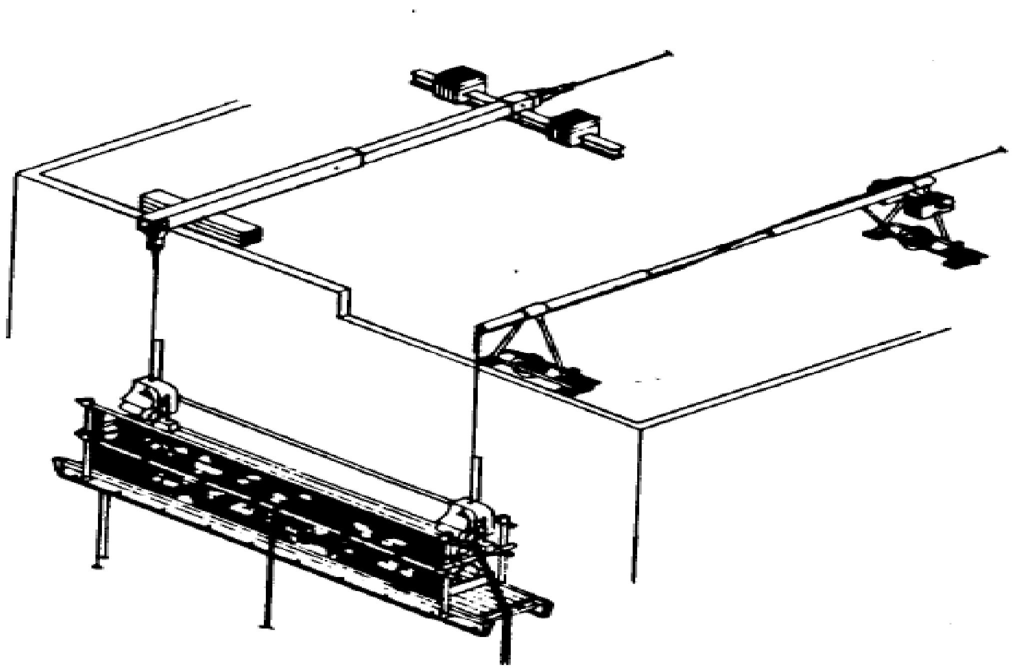

Figure 2.6 Suspended scaffolding [3]

2.5.3 Mobile Scaffolding

There are a number of factors to consider when deciding whether to use static or mobile scaffolding. Ease of access is one such consideration, along with the amount of movement on the scaffolding itself. Where possible, scaffold contractor should rely on the use of a single scaffolding structure, or a number of structures, because mobile units, while perfectly safe when well-constructed and used properly, do pose more of a hazard than mobile constructs. Most scaffolding is considered semi-permanent. Once used, it can be taken apart and moved to another location before it is constructed again [3].Figure 2.7 shows typical mobile scaffolding

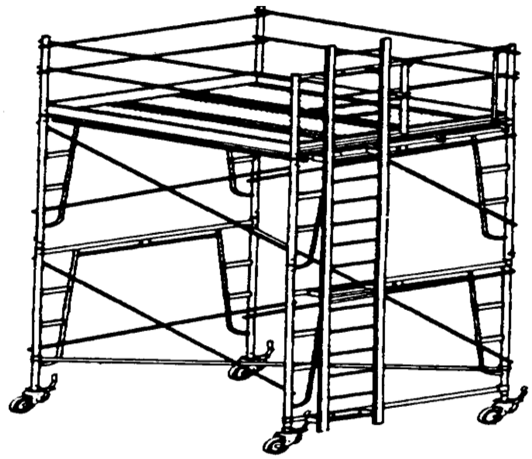

Figure 2.7 Manually propelled mobile scaffolding [3]

2.5.4 Aerial Lifts

Aerial lifts should be used where workers need to be able to access a number of levels in order to be able to complete a construction. For example, if building work is being completed on the outside of a multi-story property and both workers and materials will be needed to work outside two or more floors, at different times, then an aerial lift will make it easier and safer to lift even large amounts of material, and multiple workers to the levels required [3].

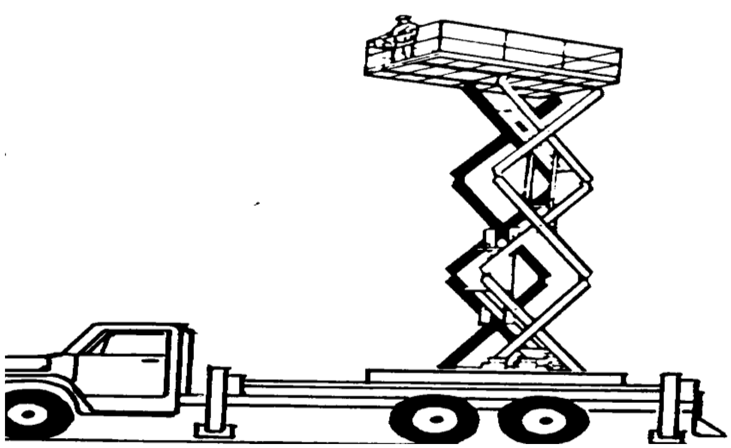

Figure 2.8 Truck mounted Aerial lifts [3]

2.6. Shoring and Supported scaffolding materials

Materials for shoring and scaffoldings have undergone a big change due to the increase in safety precautions and cost effectiveness in construction projects especially for high rise buildings. Universally shoring and Scaffolding materials vary from place to place but the common accepted and used types of shoring and scaffolding materials are timber, bamboo, metal, aluminum or a combination between any of these materials.

2.6.1 Timber

The use of shoring and scaffolding made of timber or wooden beams have a history dating back several thousand years. In Ethiopia eucalyptus wood is widely used for construction of shoring and scaffoldings. Eucalyptus is the species widely distributed and used in different parts of the world. The total numbers of eucalyptus species are estimated to be more than 700, native to Australia and neighboring countries. Its rapid growth and adaptability to a range of conditions has made it preferable than any other exotic species grown in Ethiopia [8]. About 70 species of Eucalyptus are available in Ethiopia, most of which are widely spread in many regions of the country, mainly in central highlands where higher population density [15]. Thanks to their capacity of rapid growth and good mechanical qualities they can be used as building material [16]. Eucalyptus wood can be constructed in different shapes and sizes to support formwork for in-situ concrete construction or to provide temporary access and working platforms in elevated areas.

Figure 2.9 Eucalyptus Wood scaffolding in Addis Ababa around 22

2.6.2 Bamboo

Bamboo has been used for centuries as scaffolding in Asian countries, despite the competition with many metal scaffolding systems, remains one of the most preferred system in both China and Hong Kong.

China is reported to have both the largest and fastest growing bamboo sector, involving more than ten million bamboo farmers, providing 35 million jobs and generating a market value of over $10.5 billion [22]. Other countries with significant bamboo resources and bamboo exports include Vietnam, Indonesia, Thailand, and the Philippines. India has a large bamboo resource, estimated at about 9 million hectares (or about 30 Percent of global total), that as of 2008 only contributed about 4 percent of the global market [39].

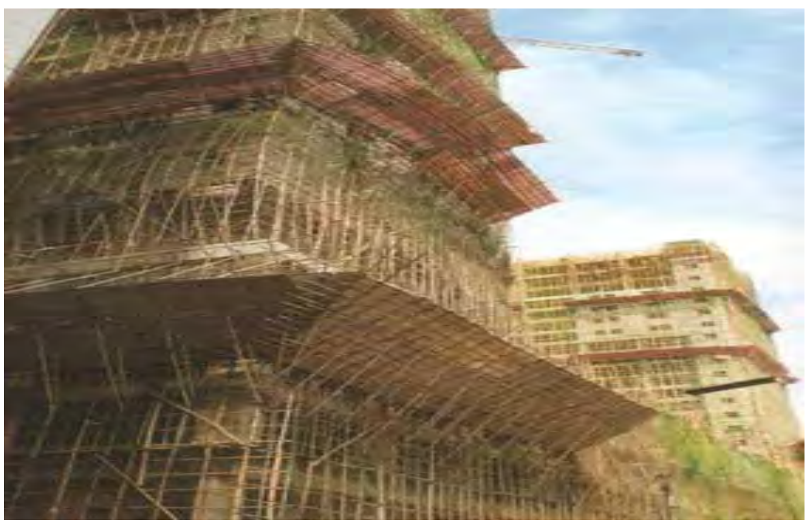

Figure 2.10 Bamboo Scaffoldings in Hong Kong [21]

In many African countries, notably Nigeria, bamboo scaffolding is still used in small scale construction in urban areas. In rural areas, the use of bamboo scaffolding for construction is common. In fact, bamboo is an essential building and construction commodity in Nigeria [20].

Bamboo scaffolds can be constructed in different shapes to follow any irregular architectural features of a building within a comparatively short period of time. In general, bamboo scaffolds are mainly used to provide access of workers to different exposed locations to facilitate various construction and maintenance process [20]. Bamboo used in scaffolding is strong, flexible and light weight. Unlike steel, however, it is a natural material and thus it is not uniform in terms of strength, weight and density. Calculating the total weight of bamboo scaffolding and projecting its live load and maximum bearing load are more difficult than steel [20].

2.6.3 Metal

Metal shoring or Scaffolding refers to shoring or scaffoldings with metal components as structural skeleton, which is commonly used as false work to support formwork for in-situ concrete construction or as working platforms at the building envelope.

Introduced in the mid-1950s, the basic lightweight tube shoring and scaffolding, with the three main components tubes, couplers and boards, became the standard and has revolutionized the shoring and scaffolding industry. The tubes are made of either of steel or aluminum. These materials are used in countless projects all over the world. However aluminum scaffolds are being out of dated due to their higher cost [22].

Metal commonly used in shoring systems can withstand heavier live loads and dead loads during construction of the upper deck. Fixed-angle steel couplers and rotational couplers fix the vertical members to the bracing [22].

Metal shoring and scaffolding are now popular because it has the advantages of easy fabrication, installation and dismantling, mainly due to their uniform mechanical properties and good corrosion resistance. However, the overall cost is much higher than any natural material such us timber and bamboo scaffolds. Usually, hollow section metal tubes with thinner walls are used to reduce self-weight. The hollow steel sections are either hot-dip galvanized or paint coated tubes [22].

Figure 2.11 Metal Scaffolding Work [22]

2.7. Occupational health and Safety of shoring and scaffolding works

Construction industry has been identified as one of the most hazardous industries both in developed and developing countries. In United States in year the 2014, out of 4,679 worker fatalities in private industry, 874 or 20.5% were in construction that is, every week almost 17 workers were killed in construction [24]. The estimated direct and indirect costs of fatal and nonfatal construction injuries totaled about $13 billion annually [25]. The impact is also 10 to 20 times higher in developing countries than developed countries, where the greatest concentration of the world's workforce is located and two thirds of the total construction accidents are related to scaffolding caused injuries [26]. In Ethiopia accidents related to shoring and scaffoldings occurred frequently for example nineteen young female workers died from scaffolding collapse in Bahir Dar, Broken wood scaffolding led to the tragic deaths of three construction workers in Addis Ababa around Meskel Square, a wooden scaffolding collapsed claiming the life of one laborer and injured 21 others [59] and many more accidents related to scaffolding are observed throughout the country

More often accidents can be traced to defective materials or equipment and untrained or improperly trained workers. Compliance with the manufacturer's instructions, the use of code of practices and compliance with all scaffolding standards will help ensure a safe workplace for employees [28]. Scaffolding can provide an efficient and safe means to perform work. However, unsafe shoring and scaffolding work procedures can lead to accidents, serious injuries and death. Unsafe shoring and scaffolds endanger workers in many ways. Components can break, collapse, or give way. Planks, boards, decks, or handrails can fail. Some modes of failure of shoring and scaffolding are listed below.

2.7.1. Mode of failure

Temporary structures may fail and cause accidents in various modes as shown in the figure below. The following are some of the failure modes observed from different cases and studies.

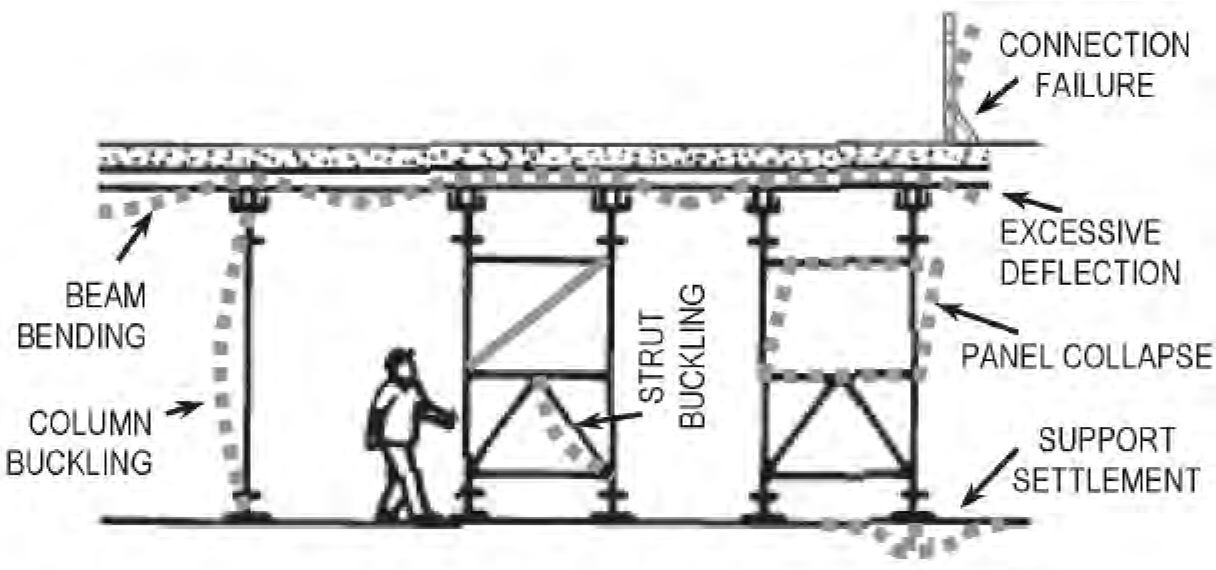

Figure 2.12 Potential failure modes of shoring [28]

4.1. Material Failure

Material failure is the most basic mode of failure, and is involved in all other modes of failure. It refers to crushing or tearing of wood fibers, yielding or cracking of metal, snapping of rope or wire. When a material fails in tension, there is usually a reduction in cross-sectional area and the particles separate. When a material fails in compression, there is some increase in cross-sectional area, and the particles crush against one another, sliding along “shear planes”. Shear failure is very rare in members, but is likely at connections, as in the lugs at bracings with frame members [28].

4.2. Component or Member Failure

Every component of temporary structures deserves care. Compression members or components can fail by buckling, even under low stress levels. In fact, most shoring and scaffolding failures have been attributed to buckling of compression members due to insufficient bracing [28].

The Experimental study on the stability of structural steel props by Samer [56] concluded that the typical failure mode of steel prop is the elastic global buckling. The elastic buckling strength of the prop was found to be sensitive to the inserted length of the upper pipe. The prop buckling capacity increases with increasing the inserted length. Figure 2.13 shows Geometric properties of the tested steel props.

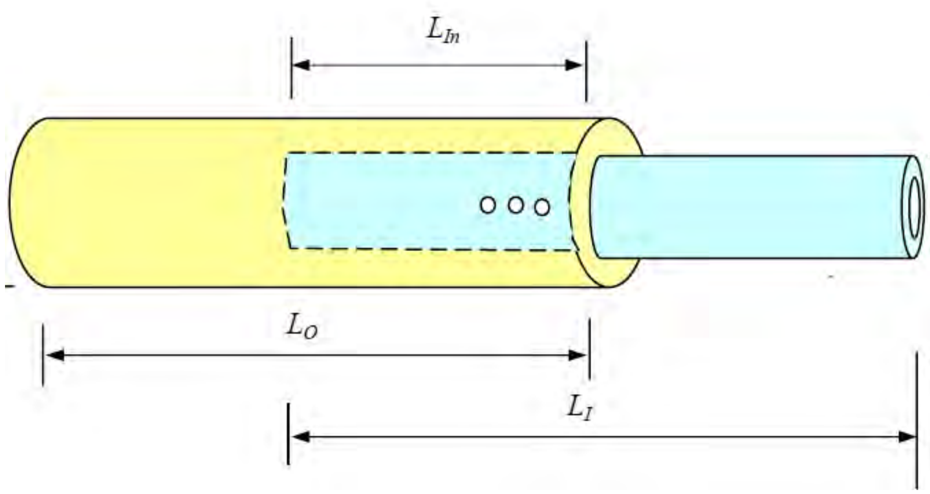

Figure 2.13 Geometric properties of the tested steel props [56]

Experimental study conducted on the stability and strength of scaffolds by Maheeb and Abdullah 2013 [54] observed that Cup lock and Wedge types of scaffolding systems' failure load-factor was found to be sensitive to the rotational stiffness of the "standard-to-ledger" connection and the story height.

The two common types of buckling in door type scaffolding systems are the out of plane mode perpendicular to the plane of scaffold unit and the in plane mode. The critical mode depends on the relative stiffness of the connecting members in each direction. The standards can buckle in single or double curvatures depending on the configuration of the scaffolds and support conditions. Figure 2.14 show common out of plain mode of single story door type scaffold [51].

From three dimensional; analysis of high clearance steel scaffolds, scaffolding system, Tayakorn & Kim JR [51]. observed that the deformation on modes the steel scaffolds were dependent on the relative strength between the steel scaffold units and the cross braces providing lateral support if the cross braces offered stiff lateral support, then the plain scaffold units would deform in plane; conversely the scaffold units would deform in the out of plane direction, in case of flexible cross braces.

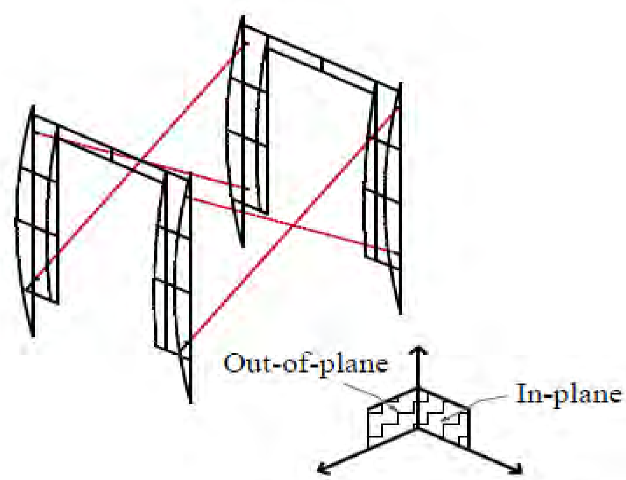

Figure 2.14 Typical mode of failure of single story door type scaffolding system [51]

4.3. Structural Failure

In a temporary structure, the material may be stressed well below the limiting value, and the compression components individually may be well braced against buckling. However, if the entire structure or a main segment of it has high slenderness ratio, that will fail by buckling. Likewise, if a rectangular panel has pinned ends or weak corner joints and no diagonals, the panel will collapse into a parallelogram under lateral or eccentric vertical loads, leading to structural failure. In a properly erected temporary structure, workmen may remove a diagonal member from a panel to allow a passage. This, if left uncorrected, would make the frame vulnerable to collapse [28].

Two distinct failure modes were observed from the advanced analysis of steel scaffolds in Tayakorn & Kim JR[51] research, as one exhibiting an S -shape member buckle (Figure 2.15 a) and the other a lateral frame buckle with large lateral displacements at the top story (Figure 2.15 b).

The failure modes are noticed to be sensitive to the jack extension length, where 600 mm jack extension produces lateral frame buckling with main failure in the jacks and 300 mm jack extension produces S-shape buckling of the standards with predominant failure deformations in the spigots.

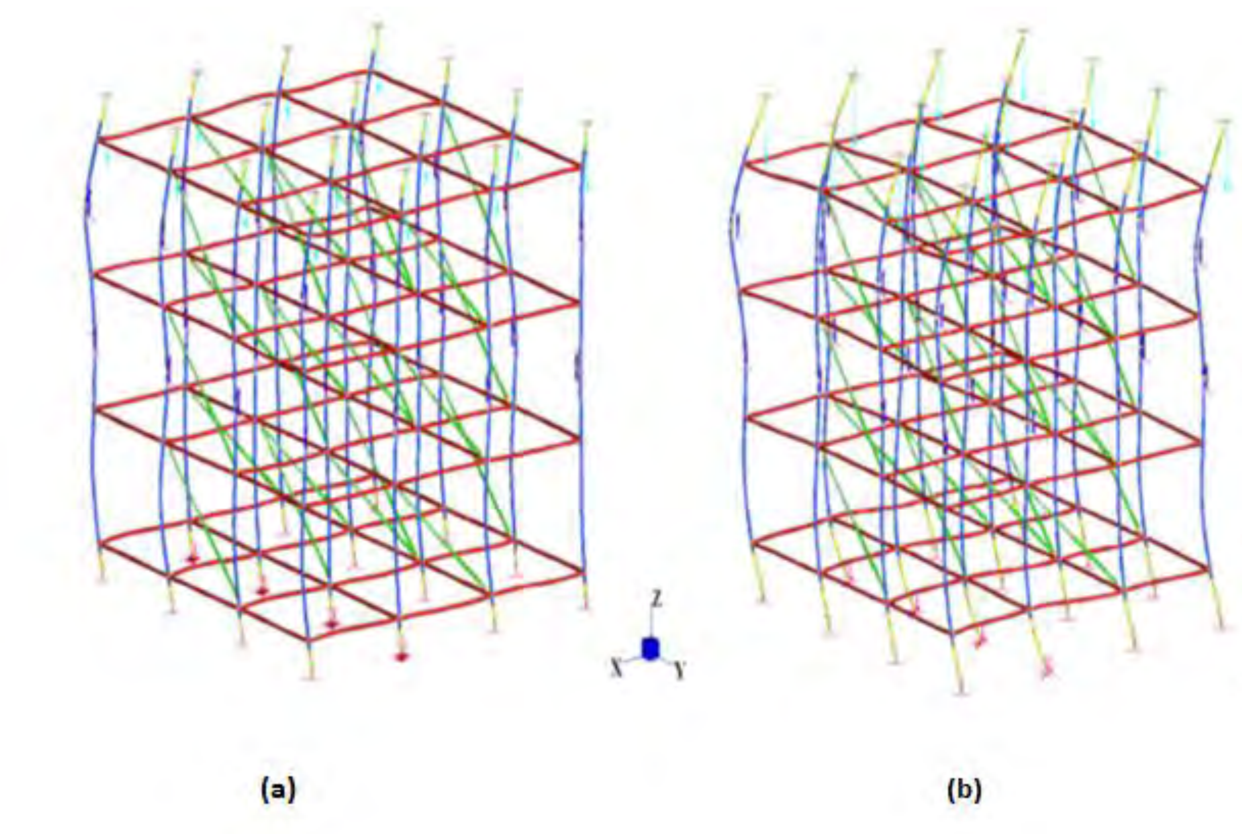

Figure 2.15 (a) S-shape member buckling and (b) Lateral frame buckling [51]

4.4. Connection Failure

The strength and stability of the temporary structure are highly dependent on the connections between its components Connections in temporary structures must be assumed at their most basic configuration. Spigot and socket joints attaching frames to one another, may be tight fitting to start with, but will become loose and shaky after a few uses. Rosettes which are expected to provide firm pinned connections will also allow some play for the connected members with use. [28]

Experimental and theoretical studies conducted by Tayakorn and Kim June [51] on Three-dimensional advanced analysis models to capture the behavior of shoring systems, the test results suggest that the failure modes are controlled by the jack extension length since when 600 mm top and bottom extensions are used the failure mode is North-South sway with final failure at the jacks. On the contrary, when 300 mm extensions are used, failure occurs mainly in the standards and spigots with only small sway displacements. Noticeably, the ultimate load decreases as the jack extension increases. Final failure occurred in spigots and jacks in most cases, as shown in Figure 2.16.

(a) (b)

Figure 2.16 Failure in (a) spigot and (b) jack [51]

Connections in temporary structures may be nails holding a wooden plank to another wooden piece, or by bolted clamps. During use, nails may pull off if the plank, instead of pressing down, tends to lift up from the wooden piece. Clamps may permit relative rotation and/or shifting of the connected members, and cause eccentric loading, swaying and collapse of the structure. All these problems with connections will compromise the load bearing capacity of the temporary structure. Because of the difficulty of providing fixity at the joints at site, and due to the loosening of tight fits with repeated use, connections in temporary structures can be expected to develop positional restraint only and not directional restraint. [28]

4.5. Support Failure

As temporary structures are made to rest on temporary supports, their bases must be wide enough and rigid enough to prevent settlement into the underlying soil or other medium. Otherwise, the structure will tilt, or sink locally, causing further problems.

The collapse of skyline plaza apartment tower in Virginia On March 2, 1973, is a perfect example. Concrete pouring was occurring on the 24th floor and shoring removal was occurring on the 22nd floor. The load and impact forces that resulted caused the progressive collapse of the entire parking garage under construction adjacent to the tower. The collapse resulted in the death of fourteen construction workers both in the tower and in the parking garage, with another 34 workers injured. [53]

Figure 2.17 Progressive collapse of Skyline Apartments whilst under construction [53]

The investigation by the National bureau of standards and other forensic engineers concluded that the premature removal of shoring on the 22nd floor caused a punching shear failure of the slab around one or more columns on the 23rd floor. The weight of the debris then resulted in the failures of the lower floors for the full height of the building [53]

The collapse of a cooling tower on April 27, 1978, at a power station being constructed at Willow Island, West Virginia, United States, caused the death of 51 construction workers. A team from both the National Bureau of Standards and the Occupational Safety and Health Administration (OSHA) board nominated the following as triggering events: [53]

- Scaffolding was attached to concrete that did not have time to sufficiently cure
- An elaborate concrete hoist system was modified without an engineer's review
- Contractors were rushing to speed construction [53].

Support conditions of temporary structures are difficult to control. If settlement occurs at isolated supports, it may result in the overloading of other members around the supported components and adverse consequences. Foundations of temporary structures are very susceptible to changing characteristics upon water-logging due to rain or run-off Softening of underlying soil due to rain, after false work has been checked and approved, is a very common cause of the base sinking under concrete placement or other heavy loading. [28]

4.6. Overall Instability of Structure

Even when every component of a temporary structure has been carefully designed and fabricated, occasionally the loads on a temporary structure may be placed in bad locations, or natural forces may occur in a very adverse combination, in such a way as to destabilize the structure as a whole.

If the resultant of all the applied loads falls outside of the "core" of the cross-section of the base of the structure, part of the support will separate from its base. If the resultant falls outside the base, the structure will topple, as the overturning moment becomes larger than the stabilizing moment. Examples are: Placement of a heavy load at one corner of a scaffold, or on a cantilever; very high wind on a crane or other tower; a worker climbing on the outside of a free-standing tower scaffold [28]

The failure of the scaffolding system of the Bojnourd Cement Factory in Iran In the construction of a bypass clinker silo resulted in the collapse of a newly poured concrete slab can be one of the example for overall instability of the scaffolding system. The collapse led to the death of three construction workers, the injury of seven others and a one-month delay in the project. The findings by Peurifoy, R.L cited by James (53, p. 14) determined that the main reasons for collapse where:

- Inadequate shoring or support elements
- Incorrect stripping and shore removal
- Insufficient bracing of members ¡V specifically, weak lateral bracings in two orthogonal directions
- Deficiency in control of the rate of concrete placement
- Improper or inadequate connections in vertical elements of scaffolding piers
- Improper or inadequate bearing detail [53]

2.7.2. Causes of Accidents

Apart from structural failure as such, other causes of accidents must be understood and evaluated. Accidents may be caused by (a) Unsafe acts, (b) unsafe conditions, or, (c) Combination of the two.

(a) Unsafe Acts:

- Use of defective equipment
- Failure to use personal protective equipment
- Unsafe material handling
- Failure to follow safety procedures
- Poor housekeeping

(b) Unsafe Conditions

- Improper guarding of equipment, platform
- Improper illumination, ventilation
- Hazardous chemicals, explosives, etc.
- Improper dress
- Poor site layout, housekeeping
- Defective tools and equipment
- Poor tag-out and lock-out practices
- Poor maintenance
- Unsanitary conditions
- Unsafe design and construction [28].

2.7.3. Economic Impact of Accidents

Many owners and contractors still believe the myth that safety concerns will lead to greater cost and reduced productivity. Research conducted in the USA indicates the total cost of accidents to constitute, 6.5% of the value of completed construction [30], and UK approximately 8.5% of tender price [31]. In Australia, the cost of work-related injury and illness of construction industry bears 11% of the total costs, in South Africa estimated the total 5% of the value of completed construction [32] .However the cost of implementing Health and safety systems within a company which it is estimated to cost between 0.5% and 3% of total project costs [30,32]. These international literatures confirm the total cost of accidents exceeds the cost of implementing Health and safety systems.

The costs associated with health and safety in construction companies are:

- The cost of goods and services utilized in implementing actions by the company to improve working conditions and to reduce accident rates in construction sites, and
- The negative value derived from the occurrence of incidents and/or accidents.

Cost of implementing health and safety systems

The costs associated with implementing health and safety systems can be distinguished between prevention costs and evaluation and monitoring cost.

- **Prevention costs** are those incurred in order to comply with legal requirements with respect to accident prevention, to implement measures to prevent accidents during construction work and to improve health and safety conditions in all areas of the work performed. Providing personal protective equipment, first-aid equipment, training new employees, periodic refresher training for each employee, etc.
- **Evaluation and monitoring costs**, these are derived from the actions taken by the company for appropriate testing and maintenance of the health and safety measures adopted, regarding every facet of the work in question, with the aim of reducing or minimizing the risk of accident or occupational disease.

The costs associated with accidents and fatalities are:

- **Direct Costs (Insured):** tend to be those associated with the treatment of the injury and any unique compensation offered to workers as a consequence of being injured and are covered by workmen's compensation insurance premiums[29].
- **Indirect Costs (Uninsured):** which are borne by contractors, include reduced productivity for both the returned worker(s) and the crew or workforce; clean-up costs; replacement costs; stand-by costs; cost of overtime; administrative costs; replacement worker orientation; costs resulting from delays; supervision costs; costs related to rescheduling; transportation, and wages paid while the injured is idle, the costs of impaired company image and loss of market [29].

2.7.4. Codes and Standards

The widespread use of scaffolding systems led to the definition of a series of standards covering a vast number of specific issues involving scaffolding. To address and counteract all the potential failures, most developed nations establish standards and codes of practice, based on extensive analyses, experimentation, research, and experience. Developing or less developed countries either specify these other codes for their construction, or adopt and modify them to suit their special needs. Table 2.1 shows a list of some of the international and regional codes that drive the scaffold design and construction process.

Table 2.1 International codes and standards for scaffolding and false work/shoring

British standards(BS)	Section
BS: 1139	Metal Scaffolding
BS: 2482	Specification for Timber Scaffold Boards
BS: 5507	Methods of Test for False work Equipment
BS: 5867	Specification for Fabric for Curtains and Drapes
BS: 5973	Code of Practice for Access and Working Scaffolds and Special Scaffold Structures in Steel
BS: 5975	Code of Practice for False work
German standards(DIN)	**Section**
DIN: 4420	working and protection scaffolds
DIN: 4421	False work calculation, Design and Construction
American standard	**Section**
ACI: 347	Guiding to Formwork for Concrete
Occupational Safety and Health	Safety and Health regulations for Construction

Administration (OSHA) 29CFR 1926	
Occupational Safety and Health Administration (OSHA) 29CFR 1910	occupational health and safety standards
Australian standards	**Section**
AS:1576	Scaffolding
AS:1577	Scaffolding planks
AS:1892	Portable ladders
AS:1163	Structural Steel Hollow section
Hong Kong standards(HKSAR)	**Section**
Occupational Safety and Health Branch, Labor Department	Code of Practice for Bamboo Scaffolding Safety
Occupational Safety and Health Branch, Labor Department	Code of Practice for Metal Scaffolding Safety
International Organizations, Associations and institutions	**Section**
International labor Organization (ILO)	Safety and Health in construction

Hong Kong recognized the use bamboo scaffolding by which had been successfully in use for hundreds of years could not be eliminated by a law forbidding it. Instead, it accepted bamboo as a feasible scaffolding material, and developed a code of practice for various aspects of its safe use [33].

The Ethiopian Labor Proclamation establishes general occupational safety and health standards and their means of enforcement. Part Seven of the proclamation on Occupational safety health and the Working Environment has three relatively brief chapters on preventative measures, injuries and benefits [61]. Although there are laws governing occupational health and safety issues in Ethiopia, such us The Ethiopian Labor Proclamation, there remains a gap in addressing those high risk sectors like the construction industry. Even if the Ministry of Urban Development and Construction has prepared a draft code (EBCS 14) regarding health and safety in building construction which includes code of practice for scaffolding works and false work [35], its adoption status remains unrealized.

2.7.5. Requirements for shoring and scaffolding construction and dismantling

Code of practices and regulations of different safety and health associations' around the world identified what workers and employers need to know to use all types of scaffolds safely. Usually the code of practices and regulations includes the followings as general requirements.

Shoring and Scaffolding capacities

The international Labor organization's code of practice on safety and health in construction states that Scaffolds should be designed for their maximum load and with a safety factor of at least 4. The intended load includes workers, equipment, and supplies. The ILO's also states, about the design of scaffolding that every scaffold and its part should be:

- Designed so as to prevent hazards for workers during erection and dismantling,
- Designed so that guard rails and other protective devices, platforms, putlogs, transoms, ladders, stairs or ramps can be easily put together, and
- Of suitable and sound material and of adequate size and strength for the purpose for which it is to be used and maintained in a proper condition [36].

ILO's code of practice also stated that formwork, false work and shoring should be so designed, constructed and maintained that it will safely support all loads that may be imposed on it. [36]

Access to scaffolds

The ILO's code of practice states that employers must provide all workers with safe access to scaffolds and scaffold platforms. Workers must use ladders or stairways to reach platforms that are more than 2 feet above or below the access point [36].

It also states formwork; false work and shoring should be so designed and erected that working platforms, means of access, bracing and means of handling and stabilizing are easily fixed to the formwork structure.[36]

Platform construction

As far as practicable, scaffold platforms, must be fully decked or planked between the front uprights and the guardrail supports. Guard-rails and toe-boards shall be installed at edges where persons are liable to fall from height [35].

Protecting workers from falling objects

Workers on scaffolds must wear hard hats and be protected by toe boards, screens, guardrail systems, debris nets, catch platforms, or canopies when falling objects are a hazard. Hard hats cannot be the only means of protecting workers from falling objects [37, 38].

Protecting workers from falling

OSHA1926 subpart M- fall protection specifies Workers on scaffolds more than 10 feet above a lower level must use fall protection. The employer has the option, in many cases, of protecting workers with guardrails or personal fall-arrest systems [37].

Safe work practices

All scaffolds and appliances used as supports for working platforms should be of sound construction, have a firm footing, and be adequately strutted and braced to maintain their stability. Every scaffold should be properly designed, constructed, erected and maintained so as to prevent collapse or accidental displacement when properly used [37].

Inspection and maintenance

On OSHA1926 subpart L stated that scaffolds and components must be inspected by a competent person before each workday and after any incident that could weaken them. Inspection by the competent person should more particularly ascertain that:

- The scaffold is of suitable type and adequate for the job;
- Materials used in its construction are sound and of sufficient strength;
- It is of sound construction and stable;
- That the required safeguards are in position.

Every scaffold should be maintained in good and proper condition, and every part should be kept fixed or secured so that no part can be displaced in consequence of normal use [37].

2.8. Performance measurement for shoring and scaffolding materials

2.8.1 Cost

Assessment of the whole life performance and cost of an asset over its lifetime takes into consideration of initial capital costs and future costs, including operational costs, maintenance costs and replacement/disposal costs at the end of its life [48]. Therefore cost of shoring and scaffolding system includes the initial cost of the shoring and scaffolding material, cost of accessories, labor cost, storage cost, wastage and disposal cost. The initial cost of metal shoring and scaffolding might be expensive but it's can be reused for more than ten years. Whereas eucalyptus wood shoring and scaffolding initial cost is cheap but it cannot be used for more than one project, hence, their cost analysis should also take into consideration of the impact of the material durability on the total cost.

Project analysis normally involves a series of cash flows occurring at different points in time. To make a just comparison between alternatives, the costs of each alternative should also have to be compared over the same reference period. A sum of money received some time in the future will always be of worth that is less than the same sum of money today and the difference will depend on the length of time involved, future risks and the probable interest rates. In doing these calculations it is a good idea to assume an interest rate that would reflect likely inflation and any special risks over the period concerned rather than a rate, which might actually be obtainable today [48].

2.8.2 Time

Time for shoring and scaffolding systems includes shipping or delivery time, preparation time, construction and dismantling. It's ideal to find a construction method to complete a specific construction activity with in short period of time with minimum cost and resource while maintaining the safety of work place. Each activity in construction project contributes to the success of the project, especially if the activity is a critical activity, it will directly affect the budget and completion time of the project. The most efficient way to speed up the construction work, especially in multi-story building, is by achieving a very short construction floor cycle duration. The floor cycle of a building mainly depend on the false work or the shoring type as it is the main time factor of a building project, because of that the total duration of the project will go down dramatically. Therefore in multi- story building projects, where cast-in-situ concrete is used for construction structural elements, careful consideration must be taken while selecting the type of the shoring material, as a false work. The required time to either construct or dismantle a shoring system mainly depends on choice of the shoring material.

2.8.3 Safety

Safety of scaffold depends on many factors as mentioned above, ensuring capacity of the shoring and scaffold is one way of keeping the safety of the work. The capacities of the shoring and scaffold systems are dependent on the performance of each scaffolding units on handling of the loads and weather impacts of the structure. Hence, designing of shoring and scaffolding units is dependent on the physical and mechanical properties of the scaffolding material. Different shoring and scaffolding materials have different physical and mechanical properties. Commonly natural materials show different behaviors hence that make them difficult to insure safely unlike fabricated materials such as metal shoring/scaffolding that have consistent physical and mechanical properties.

The problem with shoring and scaffoldings made of natural material such us eucalyptus and bamboo is they come from different species and mature in different period therefore they poses different mechanical and physical properties hence it's makes them difficult to make them standardized or configure their design. Consequently the safety and other parameters of these shoring and scaffolding materials mainly depend on judgments of the worker.

2.8.4 Operation and Application

The operation and application of shoring and scaffolding system includes their ability to be flexible and capable in different stages and conditions of the construction and use of the shoring and scaffolding systems such as in designing and preparation, for problems that could arise in high rise buildings, acute areas and irregularities, high wind pressure and humidity in the building that could compromise the stability, the efficiency and effectiveness of the shoring and scaffolding systems.

Design and preparation of the shoring and scaffolding material type also affects the design and availability of code of practice. Manufactured material like metal is easy to configure its property consequently their design will be easier. Whereas for natural materials, such us eucalyptus wood, it is difficult to configure their properties and therefore the design of such materials are difficult to obtain.

Application of scaffoldings in high rise buildings pose different problems such as the dead load of the scaffolding which will be constructed in the height of the building could impose to the stability of the scaffolding system hence it requires lighter material. But a problem may arise if the scaffolding material is too light and flexible since the wind load increases as the height of the building increases [22]. Restraining the scaffolding units with the building structural elements on the external wall could be one of the solutions for this problem. The other issue is height rise buildings have number of floors hence using nonrenewable shoring material could create a lot of wastes and the site will be congested could contribute to working space shortage or conflicts which could reduce the productivity of the labors .

In acute and irregular areas different scaffolding material could be difficult to construct where there are openings for windows or the height of the building might not perfectly fit with the scaffolding material especially if it only has standardized height and could be adjusted [22]. Cutting the standardize material would be one of the solutions .But since the cut materials could not be used on another projects it will increase the wastage of the material and incur additional cost of the scaffolding material

In humid areas could create main concern if the constructed scaffolding system has to stay for long period of time. If the selected scaffolding material have the property to absorb moisture and decompose it could create hazardous working place [22]. Natural scaffolding materials bamboo and eucalyptus wood are prone to this problem so care considerations have to be made when planning to use these materials for long period of time.

The other issue on the application and operation of scaffolding materials are their environmental effects and sustainability issues. Most of construction materials have their own contribution for Global warming weather in their production or in their application. When it comes to Scaffolding materials the production of metal scaffolding promotes Co2 emission whereas using natural material promotes deforestation.

2.9. Comparisons of shoring and supported scaffolding materials

Shoring and Scaffolding material used worldwide differs from projects to projects. Generally the most common shoring and scaffolding materials as mentioned above are eucalyptus wood , Bamboo, metal or a composite of these materials. Using each of them has their own advantages and disadvantages. Even though the use of eucalyptus wood is being outdated in most of the developed countries it is still practicable in most of developing countries like Ethiopia, Kenya, and India etc. Although it's difficult to find literatures that compare the performance of eucalyptus wood shoring or scaffoldings with metal or combination of the two materials, some literatures are available that compares bamboo scaffolding with metal scaffolding or a combination between them. The reason behind this could be wooden scaffoldings are not much popular or their use is being out of date in developed countries whereas in developing countries much more attention is given into improving direct works while ignoring indirect works such us shoring and scaffolding works, which have direct impact on project completion time by facilitating support, safe accesses and working platforms for workers. Since both eucalyptus and bamboo scaffoldings are natural material they share some similar pattern, these studies could lay some background information on why natural materials are preferable over fabricated material, metal shoring or scaffolding, in most developing countries.

2.9.1 Comparison of Cost

The cost of shoring and scaffolding includes the cost of materials, accessories and labor, and the hidden cost of constructing a piece of the system. A typical piece of bamboo is only about 6% the cost of a similar length of steel scaffolding. This vast difference in price is one of the key reasons why bamboo scaffolding is widely used in China [39].

Shing 22] made comparison of the labor and material costs of the three types of scaffolds, and revealed the traditional bamboo scaffold is the most economical in Hong Kong. The cost ratio for the three types of scaffolds is 1: 1.51: 1.977 for the bamboo, metal bamboo combination scaffolding and H-frame scaffold, respectively. If a full scaffold set including a work platform and toe-board were installed, then the ratio would be 1: 2.6: 3.06. Hence, in terms of costs, the main contractors and property developers have a strong motivation to use bamboo scaffolding for their projects [22].

Tong [40] revels; the cost ratio of bamboo scaffold, bamboo-steel scaffold, and steel scaffold is about 1:3:6 for one construction project [40]. But since the maintenance costs for these three types of scaffolds are just in the reverse ratio and the steel tubes can be reused for many times, the cost difference will be leveled out when more and more projects are taken into consideration [39].

Even though the cost varies from places to places and from time to time, one fact remains the same the initial cost of metal scaffolding is the most expensive one when compared to bamboo and bamboo-metal combination scaffolding.

2.9.2 Comparison of time

Bamboo is a light-weight material which can easily be manually handled, and the construction of bamboo scaffolding requires no machinery and no sophisticated hand tools. Bamboo scaffolding can thus be constructed much quicker than other types of scaffolding. It is estimated that the erecting of bamboo scaffolding is about six times faster, and the dismantling of bamboo scaffolding about twelve times faster than metal scaffoldings. This speediness of construction is quite often the overwhelming factor in bamboo’s continuing use in China and Southeast Asia [41]. Eucalyptus wood might not share these properties of bamboo scaffolding since their weight and method of construction are different.

2.9.3 Comparison of Safety

Timber is strong along the grain, and weak perpendicular to the grain. Problems with timber are knots, cracks and other natural interruptions to the grain that can make it unserviceable. If the grade of the timber is not marked, there is the risk that it may be of lower strength than assumed in the design, and hence liable to fail [42].

Bamboo is a natural material, and it expands and contracts as the moisture content changes. Proper workmanship, close supervision, and frequent inspection are required to ensure the structural integrity of the bamboo scaffolds after the scaffolding system is erected [39].

The structure of bamboo scaffold relies on the strength and quality of each piece due to the variation in size and its mature lifetime. Even though the checking of stability can be carried out from time to time, the maximum buckling strength may not be assured. In addition, the collapse of bamboo scaffold due to bamboo failure is mostly caused by the degradation of bamboo itself and by strong wind, such as a strong monsoon or typhoon. Moreover, sustained high moisture level in Southeast Asia, such as in Hong Kong, is the key factor that affects the quality of bamboo significantly, thus shortening the useful life of bamboo pieces [22].

When comparing the accident rate of different scaffolding material in Hong Kong over the 2003-2007 periods, statistics supplied by the Labor Department of the Hong Kong government shows that there were a total of 27 fatal cases related to bamboo or metal scaffolding. Among these cases, 10 were related to bamboo scaffolding, 13 to trussed-out scaffolding and 4 to metal scaffolding [22].

2.9.4 Comparison of Operation and Application

Design

Design and configuration eucalyptus wood shoring and scaffolding could be difficult since they are natural materials it's difficult to categorize their mechanical properties. Hence eucalyptus wood shoring and scaffolding works are mostly dependent on the experience and judgment of the worker.

Normally, bamboo scaffolding practitioners do not need to calculate the structural strength of the scaffold. They just have to follow the Code of Practice for Bamboo Scaffolding Safety which is available in most Asian counties which is developed through many researches and studies of bamboo scaffolding systems [33].

In contrast to Eucalyptus and Bamboo scaffolding, all of the design data for metal shoring and scaffolding can be provided by the manufacturer. All it needs to be done is to make some adjustments in accordance with the site conditions.

Preparation

Preparation before the commencement of work is not necessary for wooden and bamboo. All that needs to be done is to transport the material from the storage yard to the construction site and start the erection of the scaffold. They are erected on either solid concrete or steel brackets installed beforehand. These materials can be cut to exact measurements based on the site situation.

For metal and metal bamboo combination scaffolds, contractors have to pick up the required items from the scaffold check list. The scaffold can only be erected in accordance with the layout plan designed by the structural engineer, who has already obtained approval from his counterpart from the main contractor. No deviation from the materials or dimensions specified is allowed in the erection process. In this prospect, the construction of bamboo scaffolds has greater lead way than that of either metal bamboo combination scaffolds or metal scaffolds [22]. However, the latter systems have a high degree of reliability and safety because of the rigidity of procedures, and there is less chance of human error. Differences in the skills of each individual can also weaken the quality of work in eucalyptus wood or bamboo scaffolding.

Problems in high rise buildings

The use of a metal scaffolding system would create many problems, such as the dead load required to move the scaffold to a height of up to the height of a high rise building above ground level. If the scaffold were divided into separate zones, then there would be the problem of setting up a steel structural platform to support the scaffold, which would be very costly. Second, there would be problems with the anchorage system used to hold the scaffold at a high level in a firm position. The attached catch-fan system under strong winds at a high level in open areas could loosen, creating a hazardous situation. All of these problems have led main contractors to hesitate to use metal scaffolding at high levels [22].

Bamboo scaffolding for high-rise building projects has the advantage of being light, but bamboo cannot withstand the strong wind pressure at high levels. The bamboo scaffold deforms after its erection, and requires constant rectification. Hence, main contractors have to look for alternatives on high-rise building projects.

Acute areas and irregularities in the building

In addition, acute areas and irregularities such as internal light wells, bay windows and projecting features may cause difficulties in the erection of metal scaffolding. Some spaces are so narrow that moving in the basic materials is impossible [21].

Humid areas and low-rise structures with long construction periods

Humidity is one of the factors that cause bamboo scaffolding to collapse after a short period. Areas such as humid and dark light wells, mountain sides and peaks or seafronts are the most unfavorable. Humidity can cause bamboo pieces to rot very rapidly. Chang and Yu [22] have proven that under humid conditions, bamboo can rot easily and break at the rod area. The same principle applies to low-rise scaffolding in areas such as the podium levels of multi-block projects, where scaffolding is kept until the end of construction, 3 years after its erection, before being dismantled. [21] Metal scaffoldings have further advantages over the other systems, especially in humid areas and for low-rise structures with long construction periods.

Environmental effects

From the environmental point of view, bamboo is environmentally friendly as it is an organic material. Study conducted by P. van[60] have been able to recycle bamboo recovered from its use as scaffold material into useful intermediate raw material for the production of indoor furniture.[60] Some argue that metal components are not environmentally friendly because much carbon dioxide is generated during their manufacture. However, they are recyclable and can be used for over ten years.

The use of eucalyptus tree applied as scaffolding material and as support during the production of precast concrete beams, need to be minimized and alternatives must be developed. Averages of 800 eucalyptus tree logs were consumed while building of each block for the Grand housing project [40]. 144,460 condos have been built and transferred between the year 2005 and 2015 [46] and approximately 945,160 people are registered across the three housing schemes, 10/90, 20/80 and 40/60

[57].This implies that with an average of 30 units per block, 3.85 million eucalyptus trees have been consumed between the year 2005 and 2015, and 25.2 million eucalyptus tree logs will be consumed to complete the housing needs. Assuming these trend of the use of eucalyptus tree continues in the construction industry imagine how much of eucalyptus tree will be consumed in the future including all building projects that are being built around Addis Ababa. For a country like Ethiopia, who is struggling against poverty and unpredictable climatic change, it would be tragedy to lose the already endangered and undersized forests.

2.10. Planning shoring and scaffolding systems

Planning is a general term that sets a clear road map that should be followed to reach a destination. The term, therefore, has been used at different levels to mean different things. Planning involves the breakdown of the project into definable, measurable, and identifiable tasks/activities, and then establishes the logical interdependences among them [47].

In construction plans may exist at several levels: corporate strategic plans, pre-tender plans, pre-contract plans, short-term construction plans, and long-term construction plans. A detail construction planning is a pre-requisite element to ensure the project in completing on time, planning and meeting the budget, quality, safety and environmental requirements.

A considerable amount of resources are allocated to shoring and scaffolding works on building projects. Variability in geometrical features and space accessibility of structures on building projects, in addition to involvement of different trades that share the use of scaffolds, requires an extensive understanding of scaffolding requirements. Hence, it’s important to plan and estimate scaffolding man-hour requirements for the different construction areas [4].

All major works on a site are actually directly dependent on the effective planning of the construction and dismantling of scaffolds since they are associated with access point required by workers to perform the jobs. Hence, any delays in scaffolding directly affect the performance of the projects and so every work package model or planning mechanism developed for building construction should contain scaffolding as an integral component [45].

Planning before shoring and scaffolding work starts can help eliminate many problems associated with health and safety of the working environment. An effective plan will help to identify ways to protect persons who are: erecting, dismantling, maintaining and altering the shoring and scaffolding, using the scaffolding and near the scaffolding system.

A scaffold plan is one tool that can assist to safely plan and manage scaffold work and help to meet some of health and safety duties [44]. The scaffold plan should include a site layout plan and detail the elevations and sections of the scaffold. It is to be made available for inspection at the worksite. The scaffold plan should address the following issues:

- basis of design
- type of scaffold
- foundations (including ground)
- supporting structure
- access and edges
- tying and bracing
- edge protection

There are two other tools which can help to plan temporary works, such as scaffolding work. These tools are work health and safety management plans and safe work method statements for high risk construction activities. These tools can be used as part of a scaffold plan [44].

2.11. Selection of shoring and scaffolding material

In the past, decision making was thought of as a management function all by itself, but now almost everyone places it with planning. Decision making is a critical part of being an effective manager. Managers make dozens of decisions every day. Many are quite small but some are huge. The success of a manager depends on how well he makes decisions [47].

A decision is a process of choosing one alternative over the others. It is a process of identifying problems and resolving them, or of identifying opportunities and taking advantage of them. The process is made up of two components Judgment, a process of evaluating alternatives, and Choice, a process of selecting a specific alternative to implement. Judgment can occur without being followed by choice. However, some level of judgment will always precede choice [45]. Selecting the right type of shoring and scaffolding system for different projects involves some level of decision making process.

While selecting a shoring and scaffolding material different factors will influence the decision making since each material performance such us cost of the material, erection and dismantling time, safety of the work, application of the shoring or scaffold for unique project requirement are considered. Even though the purpose of these process could be to make either an investment decision or to meet the contract requiring for a specific projects it must insure the profit of the company.

2.11.1 Factors influencing selection of shoring and scaffolding systems

Different factors influence the choice of shoring and scaffolding types. In order to understand these factors critically they can be categorized based on their nature accordingly:

Geometry and Design related: these are factors that affects the dead load and wind loads transferred to the shoring and the scaffolding system which directly affects the type and volume of resources needed for construction of the systems. Some of these factors are height of the building, perimeter of the building, floor area of the building, no of floors, type of floor or formwork to be supported by the shoring system, shape, irregularity and acute areas of the building and available codes and standards that specify the type of shoring and scaffolding systems to be used in building projects [4, 49, 52].

Activity related: these are factors related to the execution of the shoring or the scaffolding system such us Degree of repetitiveness of the shore or the scaffolding work, expected duration for construction of the shore or the scaffold, expected duration of work on the constructed system, experience of the superintendent and skill of the Labor. [4, 49, 52, 55]

Project related: these are factors related to the performance of whole project such us project cost, location of the project, weather condition mainly humidity and wind pressure, manpower availability , type and complexity of the construction area such as site congestion, access and site condition etc. [4,49,52]

Market related: the market condition of the country also influence the choice of the shoring and the scaffolding materials these factors includes availability of the shoring or the scaffolding material in the market, the initial and life cost of the different scaffolding systems available in the market [23,55].

Company related: the financial capacity and priority of the contactor to invest in assets also influence the choice of the shoring or the scaffolding material since superintendents must make sure meeting the companies' requirement in parallel with technical efficiency of the shoring and the scaffolding systems. Financial status or grade of the contractor, priority of the company in owning or investing such assets & priority of the company for sustainably and health and safety of its workers are some of the influencing factors [23, 55].

Other related: these influencing factors are awareness of the advantages and disadvantage of the different shoring or scaffolding materials, government policies to support different shoring or scaffolding systems to be available in the market and regulations in the use of different shoring and scaffolding systems. Table 2.1 summarizes the mentioned influencing factors in selection of scaffolding systems.

Table 2.2 Factors influencing scaffolding selection

Category	Influencing factors
Geometry and Design related	Perimeter of the building
	Area per floor
	Height of the building
	Maximum floor height
	Type of the slab and Formwork to be supported
	Shape of the building
	Volume of Acute areas & Irregularity of the building
Activity Related	Degree of repetitiveness of the work
	Expected floor cycle construction duration
	Expected duration of work on the constructed temporary structure
	Skill of the crew
Project Related	Project cost
	Location
	weather condition
	Manpower Availability
	Terms and Specifications in the contract document
	Type and Complexity of the Construction Working Area
Company Related	Grade or financial capacity
	Availability of the shoring or scaffolding material in the company
	priority for purchasing shoring and scaffolding materials as an asset
	Priority for health and safety of workers

Market Related	Availability of scaffold material in the local market
	Initial cost
	Life cycle cost
Other	Awareness
	Countries policy for health and safety

2.11.2 Considerations in selection of shoring and scaffolding material

Considering the high cost of metal scaffolding material a decision to purchase shoring or scaffolding can be considered major equipment investment decision. Within any construction group, the main financial assets consist of plant and equipment. Therefore, site staff should be aware that the correct selection of these items not only affects the profitability of their own contract but is also fundamental to the longer-term success of the company. Hugh C.1989 [18] mentioned the effective selection of construction equipment for use on any construction project relies on the proper analysis of three principal considerations:

2.11.1.1. Technical efficiency

Technical efficiency is the requirement that the particular construction task be completed to the correct specification within the project timetable, by using the correct equipment. In short, this identifies the plant's ability to perform the job. [18]. Therefore ensuring the technical efficiency of shoring or scaffolding work have direct relation to geometry and design related, activity related and project related factors mentioned above.

2.11.1.2. Commercial and financial viability

Commercial and financial viability is the cost of the equipment falls within the estimates for the specific project. In addition, where purchase of equipment is involved, the selection must meet the overall financial criteria required by the construction company as a whole [18]. Market related and company related factors mentioned above have more influence on insuring the commercial and financial viability of the shoring and the scaffolding systems.

2.11.1.3. Availability

Availability of equipment can be supplied from a number of sources, i.e. existing internal holdings, the hire market or by additional purchase. Availability of shoring and scaffolding materials also have to be considered because selecting materials which is not available in the local market could incur additional cost and time until it's imported from another country.

These selection considerations should be analyzed by the appropriate level of management, as there may well be a need to resolve a conflict between what is technically desirable and what is financially viable [18].

A study made in Gujarat, region of India, revels that in the year 2001s and 2011s bamboo scaffolding has 100% and 95% of the market share of the construction work in the private section, respectively [23]. Hence Availability of the scaffolding material is represented the major reason for consideration to adopt bamboo scaffolding, followed by their low cost and safety. This shows that while choosing scaffolding material in developing countries technical efficiency such as safety might not be the first priority to consider, i.e., after addressing availability of the material and cost issues.

2.11.3 Selection methods and procedures

The need for investment of shoring or scaffolding material could be to complete a specific building project or it could be a company's managerial decision to improve it's the asset for future projects. In either cases the main objective is to find a suitable equipment that could insure the company's profitability while maintain its reputation.

Selection to meet contract requirements

Selecting shoring or scaffolding material for a specific building project can be broken down into six separate stages: (1) task identification; (2) preliminary selection; (3) output estimation; (4) equipment matching; (5) output costing; and (6) final selection. One of the dangers of any analytical process is that the work involved may not be justified by the end result. Therefore, an objective view must be taken at the outset to ensure that the project warrants detailed consideration of the alternative equipment and methods available [18].

Task identification: when selecting the most appropriate equipment to meet a contract requirement, consideration must firstly have to be given to the nature of the particular site task before the actual, alternative plant methods can be examined [18]. Therefore shoring and scaffolding work should be looked at from the following aspects geometry of the structure, height of the structure, safety codes and standards to follow, weather conditions, available skilled and unskilled labors, type and complexity of construction work area etc. The site engineer will generally be responsible for analyzing these factors, often taking into account any surveys done at tender stage.

Preliminary selection: the next step is for the site engineer to identify the various types of plant which would be suitable for carrying out the above task [18]. For shoring and scaffolding work, at this stage, all options would be considered in relation to factors such as the geometry of the structure such us height of the building, flexibility issues and availability of working area and then the type of shoring or scaffolding material that can meet these factors will be short listed .

Equipment output estimation: Calculations must then be made of the outputs which can be achieved using two or more alternative methods. Where operations lose money because of inefficiency, it is very often because over-optimistic assessments have been made of machine outputs, usually based on unrealistic figures provided by equipment manufacturers [18]. Estimation of shoring and scaffolding requirements can be a little difficult since most type of or shoring or scaffoldings works are hand crafted it depends on the performance of the labor force rather than expecting a machine output. Even though chosen type of shoring and scaffolding materials can have big impact on the performance of the labor other factor may also contribute. Careful prediction of man-hour for each of the short listed types of material is needed especially for shoring in slab and beam concrete construction, which have big contribution for fast completion of floor cycle in cast in-situ concrete construction. Hence it directly affects project completion time. These effects will be amplified for high rise building projects.

Equipment matching: Logical selection implies that the equipment finally selected will be matched to the task, i.e. the equipment capacity will match the job requirement and output costing [50]. Once the outputs of various alternatives have been established, these outputs must be converted into costs. For example for high rise building or for project with humid weather condition selecting scaffolding natural material, which can be easily decompose, won't match our ideal machine.

Final selection: the final selection is best achieved by tabulating the cost of the various alternatives, so that the most economical can be identified. This cost comparison may also reflect other commercial factors, i.e. the charges for transporting the various alternatives, if it is felt that these will influence the final decision. [18].

In the above analysis of the technical, commercial and availability factors, clearly the site management initiates the investigation and must take the final decision on machine selection.

If we only consider to meet one contract requirement it won't be a wise decision because the choice between wood and metal should be considered after one project have been completed because metal shoring and scaffolding is usable after one project for at least 10 years unlike wood scaffolding, which can't be used after one project have been completed.

Selection for purchase purposes

Within a construction organization, equipment will be purchased either as a replacement or as an addition to existing holdings. This investment must be preceded by a selection process to determine the most suitable make and model from a technical point of view for the applications to which the equipment will be put. In addition, the commercial implications of ownership must be calculated:

- In order to establish a hire (rental) rate for the equipment so that it can be charged to individual sites on the basis of usage. Most construction organizations now treat their plant and equipment holdings as a separate profit center with the result that plant is charged out internally on an equitable basis to each site.
- To enable the company to make a comparison between the cost of ownership and the cost of hiring-in the equivalent item. If an internal hire rate is calculated based on ownership costs, then this can be directly compared with the market-place to ascertain whether it would be more economical to hire [18].

2.12. Estimation of shoring and scaffolding systems

Estimating is an essential part of project management, since it becomes the baseline for subsequent cost and schedule control. If the estimate for a project is too low, a company may lose money in the execution of the work. If the estimate is too high, the company may well lose the contract due to overpricing [12]. No two construction projects are exactly the same and vary in many ways such as design, size, capacity, utilities, location, and orientation, and so on. When projects are planned and budgeted based on historical data, it is important to consider the differentiators and variables unique to the project and factor them accordingly. All projects are unique and have some variables [19].

The quality of construction management depends heavily on their accurate estimation. Construction cost and time prediction is a very difficult and sophisticated task especially when using manual calculation methods. Accuracy of estimation in building projects is directly related to the availability of information, time, available resources (people, equipment, and money), and proficiency of the estimator or estimating algorithm. These four trades-offs describe the classic estimating contradiction:

- The more accurate the estimate, the more information is required;
- The more information required, the more time is required to produce the estimate;
- The more resources are required to develop the estimate, the more money it will cost to produce the estimate;
- The more money spent the more pressure to reduce resources, time, information, and accuracy [50].

Therefore developing estimation tool which takes minimum amount of time, information and resources will have big impact on eliminating these controversies. Because the nature of temporary work is to provide temporary support for final product, it is very hard to allocate temporary work into a schedule or cost system to track data during the project. Thus, most often, temporary work is treated as indirect work, though the actual costs of temporary work consist of labor, materials, equipment and all the other physical costs. It is not considered economical to trace temporary work costs. However, temporary work is a crucial factor to the success of a project. Sometimes temporary work may take up to 60 percent of the total contract sum [49].

Shoring and Scaffolding are typical types of temporary work. Estimates for temporary work are usually considered as part of indirect work estimates. Although usually treated as indirect work estimates, temporary work estimates have their own characteristics, which are different from other indirect costs, for instance, overheads, and profits [49].

2.12.1 Shoring and Scaffolding cost estimation

In the practical world, different companies have their own methods to calculate scaffold costs. However, it is recognized that scaffold estimates heavily depend on the estimator’s judgments [49]. Since shoring and scaffolding works are considered as indirect work in most building projects it’s not included in bill of quantities hence it’s difficult to find unit rate or detailed cost estimation. Breaking down and estimating resources for scaffolding work is difficult and time taking hence It make it difficult to make cost analysis of different types of shoring and scaffolding materials and came up with the most efficient and effective type of material for each building construction projects. Therefore to make reliable choice between different materials easy and quick estimation tool that could easily be incorporated with the current building construction practice is necessary.

2.12.2 Shoring and Scaffolding man hour estimation

Construction of shoring for providing temporarily support for formwork in concrete construction of beam, slab and stair case takes tremendous amount of time hence it contribution to the length of the construction of floor cycle therefore it directly affects the total project duration. Precise estimation of man-hour of scaffolding system will have a great effect on estimation of project duration during planning of the building project.

Construction of scaffolding systems, treated as indirect work, is usually considered after the estimates of direct work. This also depends on time, type of contract, and scaffold estimate level divides. Sometimes, a bulk figure for the total scaffold man-hours is enough for the bidding process. Other times, estimates for scaffolding need to be detailed for each trade. Comparison between the coming project and the previous projects, examination of historical data, and coming up with a bulky ratio of scaffold man-hours over direct man-hours is the most commonly used strategy [48].

2.12.3 Parameters for estimation of shoring and scaffolding systems

All types of task managers and manufacturing companies are not only responsible to perform the current task but also to predict and manage a reliable plan for the future as well. Accurate estimation of cost and man-hour will support managers in decision making process. It allows managers to choose adequate alternatives and avoid misjudging of situations. Estimation of shoring and scaffolding work requires analyzing previous works and experiences and predicting for the current projects use. However due to unique nature of construction projects large number parameters affects the level of accuracy of the estimation. Therefore in order to increase the accuracy and reliability of the estimation would require analyzing large number of data. Learning and extracting the useful information lying behind large number of data for prediction of future projects is difficult to process in human brain therefore computer technologies must be involved.

Cost and Man-hour estimation of shoring and scaffolding works are affected by variety of factors. The cost estimation depends on different factors that influence Material cost, labor cost, equipment costs, and indirect costs and overhead costs of the shoring or the scaffolding works. Volume and complexity of the work, methodology adopted to execute the work are one of the reasons for variations of these costs. Therefore geometry of the building and type of the scaffolding are one of the affecting parameters for estimation of shoring and scaffolding works.

The parameters used for micro estimation of scaffolding man-hour in Chandan's [4] research which was mainly focused on estimating and planning methodology of scaffolding for industrial buildings were Type of Structure, Geometry of the Structure, Elevation of Construction, and Weight of the Equipment, Weather Conditions and Distance to Scaffold Yard [4].

In similar research conducted by Lingzi Wu [49] area of the construction, elevation of the scaffolding work and the scaffolding type was the input parameters for her initial data mining investigation. In her second data mining investigation she changed the parameters into area size, area complexity, area congesting degree and distance to material. Even though there were no significant improvements obtained in her second data mining phase the modified input table contains more useful information than the original input table. In the third experimental data mining Instead of making direct changes to the input table change of the output from ratio of scaffold man-hours over direct trade man-hour to predict scaffold man-hours generally improved performance of the models [49]. Some of the factors affecting the estimation of scaffolding work are listed below in table 2.3.

Since limited numbers of researches have been done in the area of shoring and scaffolding estimation the parameters for scaffolding estimation will not be limited only on the following factors they will be selected based on logical reasoning from the case study as well.

Table 2.3 Shoring and scaffolding estimation influencing factors

Category	Factors	Description
Geometry and design Factors	Geometry of the building	Height, shape, Area and perimeter of the building, number of floors
	Type of the structure	For temporarily supporting structural elements or providing access and platforms to elevated areas
Activity Factors	Height and Elevation of the construction	
	Type of shoring and scaffolding	Material type and method of construction, spacing between shoring and scaffolding units
	crew efficiency	Crew experience, crew skill and size
	Repetition	Degree of repetition, no of reuses
Project factors	Weather condition	Wind pressures, humidity
	Location	
	Distance to scaffold yard	Distance from storage to construction area
	Type and Complexity of the Construction Working Area	Degree of site congestion and site condition

2.13. Existing Planning, Estimation and selection tools for shoring and scaffolding works

Building construction has an ever-changing nature, and scenarios change on a day to day basis; hence, accurate prediction of shoring and scaffolding requirements before the start of a project is difficult. Despite the importance of temporary facilities to a construction project, there are currently several problems in planning and managing temporary facilities in the construction industry.

Architectural and bid drawings typically do not incorporate temporary facilities except for exceptionally complex temporary facilities such as cofferdams. Although some construction plans include important temporary facilities late in the construction planning process, they are often installed at construction sites when needed but without sufficient planning effort. Furthermore, due to the lack of time and understanding, calculations and drawings of scaffolding systems submitted by temporary facility vendors are most often reviewed only to assess their impact on the permanent part of the building [9].

Fedock [7] emphasizes the importance of involving Construction Engineers in the design process of temporary structures [7]. The early involvement of Construction Engineers in the design process would benefit the constructability scenarios of the equipment minimizing the requirement of temporary works during the actual installation processes [7].

Currently lack effective front-end planning and management, current industry practices suffer from heavy reliance on the knowledge and experiences of individual engineers. It is today's human decision makers that determine the proper types of temporary facilities requirement and they typically generate the corresponding detailed designs [14].

Due to the complex nature of construction projects and potentially imperfect human judgment, there are computer applications which create opportunities to reduce or eliminate potentially erroneous errors in temporary facility planning, especially for projects which are planned manually based on visual analysis of the construction site drawings and schedules.

Shoring and Scaffolding work differs from one project to another project hence it makes it difficult to estimate its man-hour and material requirements. Unlike metal natural shoring and scaffolding materials like bamboo and eucalyptus wood have no manufacture guide to follow and improve productivity. Even though code of practice for bamboo scaffoldings are available in different countries it's difficult to find eucalyptus wood shoring or scaffolding code of practice it's mainly depend on the judgment and experience of the work crew.

2.14. Need for planning Estimation and selection of shoring and scaffolding systems

In today's fast-paced industrialized age, where many of the products we see are increasingly being mass produced in factories by machines, a building still remains as one of the few handcrafted products put together piece by piece by craftsmen. In United States labor cost of a building project often ranges from 30 to 50%, and can be as high as 60% of the overall project cost [10]. Labor cost is the most influential in the total project cost and an increase in labor man-hours would increase the total cost of the project. Based on the case study conducted in one of leading contractors in North America, it was found that scaffolding can comprise of up to 30% of the total labor man-hours of a project with 15%-20% being an averaged out number [4]. However, Scaffoldings planning and management are deemed to be of less importance compared to other processes in construction operations.

A common problem in shoring and scaffolding planning and management is the absence of an easy to use estimating and planning tool that companies can use for a quick and reliable estimate. Also, it is to be noted here that most companies have their own ways of erecting and dismantling shoring and scaffolding works, hence, such a tool although useful to any company, would have to be customized for a particular company's use based on their historical data and working principles.

Superintendents are basically dependent on their experience for estimating the amount of man-hours or materials to assign for the construction of shores and scaffolds. This method is prone to common errors involved in building projects. Some examples of errors are: necessary temporary facilities can be omitted in a construction plan; improper types of temporary facilities can be selected; temporary facilities design may not reflect the design requirements; and, accordingly, the amount of materials and associated cost for temporary facilities cannot be estimated accurately. The system lacks a quick and reliable tool that would be able to help the Superintendent with the process, and thus, would help in better management of labor and material resources.

Taking into account the impact of temporary facilities on the entire construction project and the deficiencies of the current practices in planning and managing temporary facilities, the industry needs to overcome these drawbacks by enabling thorough front-end planning of temporary facilities and in this case shoring and scaffolding systems.

Deep assessment of the current practice and creating awareness of advantage and disadvantages of different shoring and scaffolding materials would help for developing effective planning, estimating and selection tool for scaffold construction in building projects. These could be one step for improving safety and productivity of workers hence the project will be completed with minimum amount of Budget and time. The output of this research will also help to estimate the required resources, costs and man-hours of different shoring and scaffolding materials available in Addis Ababa market.

2.15. Gaps in Existing Literature

Existing literature on construction of shoring and scaffolding systems are extremely scarce in Ethiopia. In fact, shoring and scaffolding works in general does not seem to be a well-researched area in Ethiopia. A number of reasons could attribute for the above conclusions, the first being it is categorized under indirect works and most indirect works have always been kept part as a factor or percentage of direct work involved in a project. Since the major portion of the cost relates to direct work, most researchers tend to investigate topics and processes in direct work. The second reason for sparse literature in this field is the diverse and complicated nature of construction scaffolding systems. Constructions of Scaffolds take place in both horizontal as well as vertical direction which makes planning and estimation difficult. Analysis of such scenarios would involve in-depth analysis and a considerable amount of time spent with the chance of success quite less compared to some other fields of study.

Chapter Three: Methods and Materials

3.1. Introduction

This chapter discusses the methodology used in this research. It provides information about the research strategy and design, process of data collection and data analysis.

3.2. Research limitation

This research is limited to shoring used as a temporary support in concrete construction of beam, slab and staircase and scaffoldings that provide temporary access in elevated areas. Focused only on supported scaffolding systems due to the time and resource shortages other types of shoring and scaffolding types are not included in this study.

3.3. Research strategy and design

The procedures used to achieve the study objectives can be summarized as shown in Figure 3.1 below. The findings from the literature review of previous researches served as key source in the identification of type and material of shoring and scaffolding systems, factors influencing selection of shoring scaffolding systems and performance measurements of shoring and scaffolding systems in building construction industry around the world. Hence, the studies shed a great deal of light for studying on the area of Scaffolding practice around Addis Ababa.

As a primary source a case study is conducted on construction site to assess the current practice of scaffolding systems around Addis Ababa**.** The general populations of this study are building projects that are currently under construction around Addis Ababa. The main principle behind selecting sample population is to come up with projects which are higher or equal to G+5 building projects that use either eucalyptus scaffolding system or metal scaffolding system.

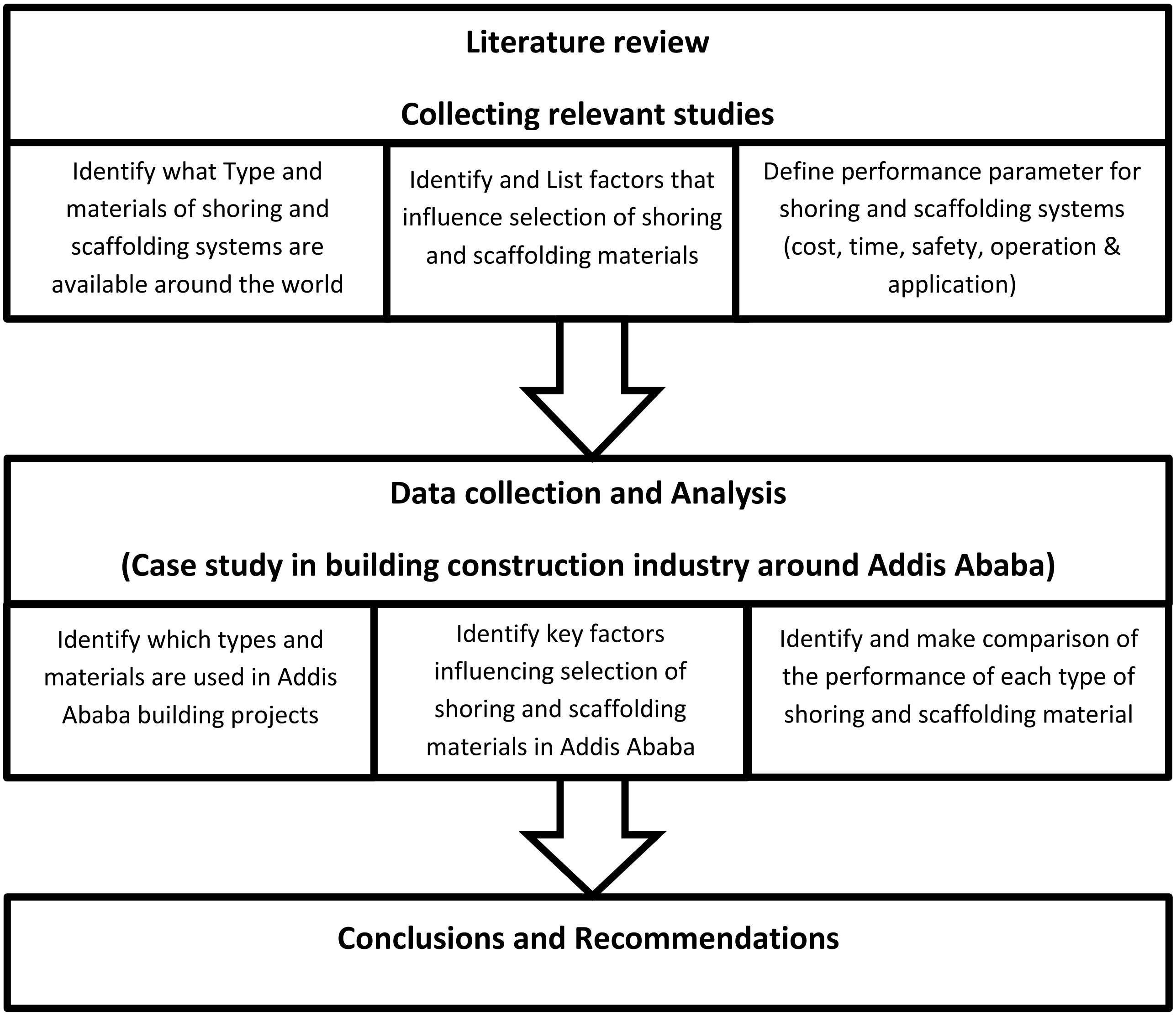

Figure 3.1. Research design and strategy

The case study was conducted by collecting data through site observation and questionnaire that represents the actual practices of shoring and scaffolding systems in the selected building construction Projects. The information gathered through this method was used for analyzing and discussing the current shoring and scaffolding practice in building construction industry around Addis Ababa.

Finally conclusions and recommendations are drawn out based on the data analysis results and discussions.

3.4. The Research Questionnaire Design

The questionnaire design was based on a combination of an extensive review of literature dealing with the methods and the practices of scaffolding systems and researcher's knowledge on the current shoring and scaffolding construction practice of national contractors.

The questionnaire, which was accompanied by a cover letter, consisted of four parts. The questionnaire was a mix of structured (closed) and unstructured (open) type of questions.

3.5. Rationale of the Research Questionnaire

A questionnaire consisted of four sections are prepared to investigate shoring and scaffolding practice on the selected building projects. The questionnaire is designed to extract information based on the actual practice in the selected projects rather than opinion based.

The first section contained four questions to evaluate the judgment of the acting superintendent on the selected projects based on his experience on building construction projects.

Section two contained 18 questions which are designed to extract information about the selected building projects, which includes the stakeholders of the project, the total project duration and cost, geometry of the building, etc.

Section three is designed to identify the critical factors that are accounting for selection of the current shoring and scaffolding system around Addis Ababa. 24 factors that could influence the selection of shoring and scaffolding system are selected from literature review and researcher's knowledge on the current shoring and scaffolding construction practice. From scale one to five the superintendent weighted these factors they considered while selecting the scaffolding system in their building project.

The fourth and the final section are designed to measure the performance of the shoring and scaffolding material used in the selected projects. It will provide detail information on the cost, time, safety application and operation of each shoring and scaffolding materials. This will help to make comparison of eucalyptus and metal shoring and scaffolding.

3.6. The Research Sample Selection

The selected building projects for this case study are equal or higher than G+ 5 building projects; in order to give more emphasis on the shoring and scaffolding works with the limited time. As the specific number of the general population is not known, purposive sample selection method is used for sample selection.

3.7. Data Collection methods

A sample of 61 building projects from several construction contractors that represent the governmental and private financed projects in Addis Ababa were selected for the data collection. Since shoring and scaffolding works were considered indirect works it was difficult to get the necessary data on time. Therefore the researcher managed to get 44 useable questioners from the respondents with response rate of 72%. The location of the selected projects and the response rates shown on table 3.1

Table 3.1 location of the projects and response rate

No	Location	Questionnaires issued	Responses	% Rate of response
1	Around Urael	1	1	100
2	Around Kasanchis	6	5	83
3	Around 22	6	4	67
4	Around Megeneagna	4	2	50
5	Around Lamberet	2	2	100
6	Around Wolo Sefer	3	1	33
7	Around Shewa Dabo	4	3	75
8	Around Dumbbell	2	1	50
9	Around Flamingo	4	4	100
10	Around Fluweha	1	1	100
11	Around Kality	1	1	100
12	Around Mexico and Beherawi	2	2	100
13	Around Lideta	4	3	75
14	Around Merkato	2	1	50
15	Around CMC Michael	3	3	100
16	Around Ayat	7	4	57
17	Around Semit	7	5	71
18	Around Arat kilo	2	1	50
	Total	**61**	**44**	**72**

3.8. Data Analysis and Discussions

The analysis was done using Microsoft Excel and the responses assigned to each question by the respondents the 44 selected projects were entered and consequently the responses were subjected to descriptive statistics using means, frequencies, percentages, and proportions to analyze the data collected. Frequency tables and charts were used to display results of the general information and the relation between the shoring and scaffolding materials and influencing factors.

The weight of each of the 24 listed factors considered having influence on selection of shoring and scaffolding systems on the selected building projects was examined and ranked the attributes in terms of their criticality as perceived by the respondents using of mean score. Where the respondents used from 1 to 5 scales, where 1 represent “not at all influential” and 5 represent “extremely influential”. Table 3.2 shows the frequency scales used to measure the weight of each factors.

The mean scores for each of influencing factors were computed using the following expression.

$$\text{Mean score} = \sum \frac{S}{N} \quad \text{[Eq. 3.1]}$$

Where: S = Scores given for each factor (1to 5)

N = Total number of responses for each factors

Table 3.2 frequency scale of the weight of the influential factors

Option	Mean
Not at all influential(1)	1< Mean score <1.8
Slightly influential (2)	1.80 < Mean score <2.6
Somewhat influential (3)	2.6< Mean score <3.4
Very influential(4)	3.4 < Mean score <4.2
Extremely influential(5)	4.2 < Mean score < 5

Chapter 4 Data Analysis and Discussion

4.1. Introduction

This chapter focuses on analyzing and discussing the results gathered through site observation and questionnaire. Based on the gathered data, methods used in construction of shoring and scaffolding systems, Influencing factors for selection of shoring and scaffolding material and also comparison of shoring and scaffolding materials with respect to cost, speed of construction, safety, their application and operation in building projects, are analyzed and discussed.

4.2. Respondents Profiles

4.2.1. Profiles of the selected building projects

The building projects are selected based on their height which is buildings which are G+5 and greater no of stories, these projects have different purpose. Table 4.2.1 shows the height and the purposes of the selected building projects.

Table 4.1 Height and purpose of the selected building projects

	Purpose of the building							Total Response distribution	
G+__	Commercial	Office	Apartment	Hospital	Hotel	Library	Multi-purpose	Frequency	%
5	0	1	0	0	0	0	3	4	9
6	0	0	0	1	0	0	1	2	5
7	0	0	3	0	0	0	0	3	7
8	1	0	1	0	0	1	1	4	9
9	0	0	0	0	0	0	0	0	0
10	1	1	1	0	0	0	1	4	9
11	0	0	1	0	0	0	2	3	7
12	0	2	1	0	0	0	2	5	11
13	0	0	2	0	0	0	2	4	9
14	0	0	2	0	0	0	1	3	7
15	0	0	0	1	1	0	0	2	5
16	0	0	0	0	0	0	1	1	2
17	0	1	0	0	1	0	1	3	7

	Purpose of the building							Total Response distribution	
G+__	**Commercial**	**Office**	**Apartment**	**Hospital**	**Hotel**	**Library**	**Multi-purpose**	**Frequency**	**%**
18	0	0	0	0	0	0	1	1	2
19	0	0	0	0	0	0	1	1	2
20	0	0	0	0	0	0	0	0	0
>20	0	1	1	0	1	0	1	4	9
Frequency	**2**	**6**	**12**	**2**	**3**	**1**	**18**	**44**	**100**
percentage	**5**	**14**	**27**	**5**	**7**	**2**	**41**		

4.2.2. Classification of Organization

Of the responding projects 28 (63.6%) of them are owned by private company and the remaining 16 (36.4%) of them by Government. Grade 1 contactors constitute 36 (81.8%) of the contracting companies Table 4.2 shows the grade of the contracting companies.

Table 4.2 Grade of contracting companies

Grade of contractors	Response Distribution		
	Frequency	**Cumulative Frequency**	**Percentage**
GC-1	14	36	81.8
BC-1	22		
BC-2	2	2	4.5
GC-3	1	2	4.5
BC-3	1		
BC-4	3	3	6.8
BC-5	1	1	2.3
Total	44	44	100

Of the contracting companies 4(9.1%) of them have been in construction industries more than 20 years and 2 (4.5%) of them have been less than 5 years in the construction industry. Table 4.3 illustrates year of establishment of the contracting companies.

Table 4.3 Year of establishment of the contracting companies

Year of Establishment	Response distribution	
	Frequency	Percentage
Before 1995 (more than 20 years)	4	9.1
1996- 2000 (16 - 20 years)	8	18.2
2001 - 2005 (11- 15 years)	10	22.7
2006 -2010 (6 - 10 years)	20	45.5
2011 -2013 (less than 5 years)	2	4.5
Total	44	100.0

4.2.3. Respondent's work position and Experience

Distribution of respondent's work position on the projects, years of experience in the construction industry and no building projects they have worked in the past are illustrated on table 4.4 below.

Table 4.4 Respondents work Position & Experience

Respondents work Position & Experience	Response distribution	
	Frequency	**Percentage**
Job title		
Company owner	1	2
Project manager	18	41
Site engineer	21	48
other	4	9
Total	**44**	**100**
Years of Experience in construction industry		
0-2	2	5
2-4	14	32
4-6	5	11
6-8	5	11
8-10	7	16
>10	11	25
Total	**44**	**100**
No of Building projects worked in the Past		
0-2	6	14
2-4	11	25
4-6	10	23
6-8	4	9

Respondents work Position & Experience	Response distribution	
	Frequency	Percentage
8-10	4	9
>10	9	20
Total	**44**	**100**

4.3. An Overview of the research data Analysis Process

This section is included for the purpose of creating continuity between the research objectives and data analysis and discussion. The major objectives of the research were

- To assess methods and materials used in erecting shoring and scaffolding systems in building construction projects around Addis Ababa.
- To identify critical factors for selection of shoring and scaffolding systems in building construction projects around Addis Ababa.
- To make comparison of cost, time, safety, operation and application of the eucalyptus wood with currently available shoring and scaffolding materials around Addis Ababa**.**

Analysis of the data collected through the research questionnaire and site observation is aim at addressing these research objectives. For the purpose of relating the research objectives with the analysis and also for the ease of presentation, the results and discussions are presented on three major sections.

Section 4.4 discusses the methods and materials used in erecting shoring and scaffolding systems in building construction projects around Ababa which is aimed for addressing the first objective.

Section 4.5 is linked with the second objective factors influencing selection of shoring and scaffolding systems are identified and discussed. Furthermore analysis of some of the influencing factor and choice of scaffolding material are presented

Section 4.6 address the third objectives by disusing and comparing shoring and scaffolding materials used in building construction projects around Addis Ababa.

4.4. Methods and materials used in construction of shoring and scaffolding systems

Metal, Eucalyptus or Eucalyptus wood metal combination are the most common materials used in construction of shoring and scaffolding systems around Addis Ababa. But the methods used for constructing these shoring and scaffolding systems vary from one construction site to another. Shoring is temporary structure built to provide support in concrete construction of slabs and beams. Scaffoldings are temporary structures built to provide access and working platforms on elevated areas.

4.4.1 Shoring

Of the 44 building projects 18(41%) of them used Eucalyptus wood metal combination, 13(29.5%) of them Eucalyptus wood and the remaining 13 (29.5%) of them Metal as shoring material. table 4.5 summarizes the frequency of the shoring material used for temporarily supporting structural elements.

Table 4.5 Distribution of shoring material

No	Shoring material	Frequency	Percentage
1	Eucalyptus Wood	13	29.5
2	Metal	13	29.5
3	Eucalyptus wood metal combination	18	41
	Total	44	100

The methods used to construct these shoring systems may vary depending on the material they used, the type of the structure to be supported, the floor height of the slab to be supported and the expected duration to complete the construction one floor cycle. Generally to describe the method of construction used on different building construction projects easily, it's better to categorize them based on the shoring material used as follows.

A. Eucalyptus wood shoring

As table 4.5 illustrates 13(29.5%) of the building projects are using Eucalyptus wood shoreing for temporarily supporting structural elements in building construction. However these 13 projects adopt variable methods to construct the shoring systems in their projects. The fact that eucalyptus wood is natural material and it is available in different Diameter and lengths makes it difficult to have consistent design and method of construction. The following are the sizes used in the construction sites.

- Eucalyptus dia. >= 12cm, length= 8m
- Eucalyptus dia. 10- 12cm, length= 4m & 8m
- Eucalyptus dia. 8cm, length= 4m & 8m
- Eucalyptus dia. 6cm, length= 4m

Based on common geometrical characteristics of the buildings the method of the construction can be classified based on the type of the slab and the method of slab concrete construction.

For different slab types, mainly slabs with exposed beams and flat slabs, different method of construction of eucalyptus wood shoring have been used in the selected building projects. The method of construction of the shoring elements will depend whether the slab to be supported have exposed beam or not. If it is flat slab the construction of the shoring will have consistent length of posts, ledgers and joists thorough out the floor however if it has exposed beams the method will be different on areas where there are drop down beam support is required due to the elevation difference created by the exposed beam. In these kinds of areas triangular shaped posts commonly known as “Crsti”, which are separated from slab support shores will be placed in every 60- 90 cm apart to maintain the floor height difference.

The second factors which influence the method of construction of eucalyptus wood shoring is method of slab concrete construction whether the temporary structure is used for supporting solid slab or prefabricated (ribbed slab). The methods of slab concrete construction define whether joists are necessary or not and at what interval they should be placed. In cast in situ (solid) slabs the joists are necessary and placed with the interval ranges from 10 to 60 cm depending on the size and strength of the eucalyptus wood they used. For prefabricated (ribbed) slabs in some cases it is not necessary to use the joists. Figure 4.1 and figure 4.2 shows method of eucalyptus wood shoring construction used for solid slabs and ribbed slabs respectively

Figure 4.1 Eucalyptus wood shoring for cast in situ slab support

Figure 4.2 Eucalyptus wood shoring for ribbed slab support

Elements of eucalyptus wood shores are Posts, ledgers, transoms, stringer and joists. For construction of posts Eucalyptus wood with diameter >=12cm and 10 -12 cm were used with interval of 60cm – 90 cm in both Longitudinal and transversal direction. The length of the eucalyptus wood may vary from 4meters to 8 meters depending on the floor height. The size and spacing of the posts is dependent on the dead load they support and the height of the shoring. Sometimes for higher clearance floors two posts will be braced together to ensure the strength of the shoring systems and prevent the buckling of the post.

Eucalyptus with Diameter 8 cm were being used for construction ledgers and transoms. They were placed in every 1.5 meter from the foot of the post to the top of the post. For construction of Stringers 10 -12 cm or 8 cm diameter eucalyptus wood spaced in every 60- 90 cm apart is commonly used. For joists depending on the method of construction of slabs eucalyptus wood with diameter 6cm or 8 cm with interval of 10cm to 60 cm were being used.

For connecting the elements of eucalyptus wood shoring Nail with size 8, 10 and 12 were being used. Nail no 10 and 12 are commonly used for connecting posts to legers and stringers. For connecting legers to transoms and stringers to joists nail no 8 and 10 were commonly used. Table 4.6 summarizes the material and methods used in construction of Eucalyptus wood shoring used on building projects around Addis Ababa.

Table 4.6 Materials and methods used in eucalyptus wood shoring construction

Elements		Method of slab construction	
		Solid slab	**Ribbed slab**
Posts			
Material	Eucalyptus wood	Size: dia. 12cm, length= 4m -8m	Size: dia. 10- 12cm, length= 4m -8m
		Size: dia. 10- 12cm, length= 4m -8m	
Spacing (cm)	X	60- 90	60- 90
	y	60-90	60-90
Ledgers and transoms			
Material	Eucalyptus wood	Size: dia. 8cm, length= 4m -8m	Size: dia. 8cm, length= 4m -8m
Spacing (cm)	z	150 -180	150 -180
Stringer			
Material	Eucalyptus wood	Size: dia. 10- 12cm, length= 4m -8m	Size: dia. 8cm, length= 4m -8m
		Size: dia. 8cm, length= 4m -8m	
Spacing (cm)	X or y	60 - 90	60 - 90
Joists			
Material	Eucalyptus wood	Size: dia. 8cm, length= 4m -8m	-
		Size: dia. 6cm, length= 4m	-
Spacing (cm)	x or y	10 - 60	-
Accessories			
Connectors	Post to ledgers	Nail no 8,10 & 12	Nail no 8,10 & 12
	Post to stringer	Nail no 10 & 12	Nail no 10 & 12
	Ledger to transoms	Nail no 8	Nail no 8
	Stringer to joists	Nail no 6 & 8	
Height Adjustors		Wooden pivots	Wooden pivots
Tools and equipment			
		Hammer	Hammer
		Saw	Saw
		Robs	Robs
		Leveler	Leveler

B. Metal shoring

Three types of metal shoring materials have been observed on building construction projects Around Addis Ababa. Those are H Frames, tube and coupler and adjustable steel props. The main differences between these materials are the configuration of their components.

The uses of H-frames are currently emerging in Addis Ababa building projects. They are easier to construct in short period of time. One set of H frame have two frames and four diagonal Braces and four adjustable jack heads and base plates. The size of H- frame available in Addis Ababa building projects are H-frame 1.20m (width) x 1.80m (length) and H-frame 1.20m (width) x 1.5m (length) with variety of height from 0.9 to 3.4 meters. In longitudinal direction the frames are placed with interval from 0.8 to 1.2 meter with no connecters whereas in transversal direction they are spaced 1.5 meter or 1.8 meter and connected one another using diagonal braces. Adjustable U head and Base plates were used on both top and toe of the frames to increase the height of the frame from 30 to 60 cm. In cases where the floor height is large and couldn't be adjusted using adjustable u head and base plates, mini frames or normal frames will be connected using pins (internal jointer) vertically to reach the required floor height.


Figure 4.3 Adjustable u-head, Base plates and mini frames

The Element of Tube and coupler types of shoring are posts ledgers, transoms and diagonal members, which are available in variety of length and diameter that suits the building construction works. Generally the lengths of the posts are in range from 2m to 3.5 m. The length of the leger is dependent on the spacing between the posts which varies from 0.6 meter to 2 meter. The spacing between the posts depends mainly on the available tube lengths of ledgers and transoms, dead load and height of the floor. Keeping in mind that these designs are adopted from the configuration of the materials or the experience of the contractor, there is no standard way to check the capacity and safety of the shoring work.

Figure 4.4 Tube and coupler metal shoring

The third type of metal shoring available in Addis Ababa building project are Adjustable steel props. These types of shoring do not require legers and transforms or other types of fittings. They have adjustable pins on them and only posts are used to construct the support shoring system. The spacing between these props may vary from 60 to 90 cm. figure 4.5 shows Adjustable steel prop.

Figure 4.5 Adjustable steel prop

For construction of joists and stringers four types of material with different shapes and sizes were being used in building projects which uses metal shoring system. They are RHS, I beam, Infiltrator Beam, and Purlin/ morale which are available in different thickness and length. The spacing between stringers and joists may vary from 0.6- 1.5 meter and 0.4 – 0.6 meter respectively depending on the type of the metal shoring, stringer and joists used.

(a) **(b)**

Figure 4.6 Metal shoring with (a) RHS and (b) wooden purlin joist

The strength and design of The metal shoring used in Addis Ababa building projects are also adopted form the crew experience and based on their standardize size. In most of the projects where there are acute and irregular areas it is difficult to fit and position standard sized metal shoring which is one of the main reasons for adopting eucalyptus wood metal combination shoring.

Table 4.7 Materials and methods used in metal shoring construction

Elements		Types of metal shoring					
		H- frame		Tube and coupler		Props (Adjustable tubes)	
Frame							
Material	Steel frame	Width x length = 1.2m x1.5m 1.2mx 1.8m	Height = 0.9m				
			1.7m				
			1.9m				
			2.25m				
			2.4m				
			3.4m				
Spacing	X	80cm -120cm					
	Y	150cm - 180cm					
Posts							
Material	steel Tube			Diameter = 48 mm	length = 1.5m	Diameter External tube = 54mm Internal tube = 48mm	Adjustable length = 1.7m - 3.4m
					2.5 m		1.7m - 3.9m
					3m		2.4m -2.8m
					3.4m		2.8m -3.4m
Spacing (cm)	X			60cm - 250cm		60cm- 80cm	
	Y			60cm - 250cm		60cm- 80cm	
Ledgers, transoms & diagonal braces							
Material	steel Tube			Diameter =48mm	Length = 0.6m		
					1m		
					1.1m		
					1.15m		
					1.2m		
					1.6 m		

Elements		Types of metal shoring					
		H- frame		Tube and coupler		Props (Adjustable tubes)	
					1.75m		
					1.8m		
					2.5m		
					3.10m		
Spacing	z			50cm - 150cm			
Stringers and Joists							
Material	RHS	Length x width = 40mmx40mm,	Height = 2m, 3m 6m	Length x width = 40mmx40mm,	Height = 2m, 3m & 6m	Length x width = 40mmx40mm,	Height = 2m, 3m & 6m
		40mmx40mm		40mmx40mm		40mmx40mm	
		40mmx60mm		40mmx60mm		40mmx60mm	
		50mmx50mm		50mmx50mm		50mmx50mm	
		50mmx70mm		50mmx70mm		50mmx70mm	
		50mmx80mm		50mmx80mm		50mmx80mm	
		60mmx60mm		60mmx60mm		60mmx60mm	
		80mmx80mm		80mmx80mm		80mmx80mm	
		100mmx40mm		100mmx40mm		100mmx40mm	
		100mmx60mm		100mmx60mm		100mmx60mm	
	Purlin/ morale	Length x width= 7cmx5cm,	Height = 5m	Length x width= 7cmx5cm,	Height= 5m	Length x width= 7cmx5cm,	Height= 5m
		10cmx5cm		10cmx5cm		10cmx5cm	
		12cmx5cm		12cmx5cm		12cmx5cm	
		7cmx5cm		7cmx5cm		7cmx5cm	
		7cmx7cm		7cmx7cm		7cmx7cm	
		15cm x7 cm		15cm x7 cm		15cm x7 cm	
	Infiltrator Beam	Length = 1.5m, 2m & 4m		Length = 1.5m, 2m & 4m		Length = 1.5m, 2m & 4m	
	I - Beam	Length = 2.9m, 3.9m & 4.9 m		Length = 2.9m, 3.9m & 4.9 m		Length = 2.9m, 3.9m & 4.9 m	
Spacing (cm)	stringer	80cm - 120 cm		60cm - 150 cm		60cm - 80cm	
	joist	15cm- 60cm		15cm- 60cm		15cm- 60cm	

Elements		Types of metal shoring		
		H- frame	Tube and coupler	Props (Adjustable tubes)
Accessories				
Connectors & Fittings (couplers)	Frames vertically	Pin or internal joiner	Pin or internal joiner	-
	Frames and Diagonal braces			-
	Posts vertically	-	Pin or internal joiner	-
	Post and legers	-	Right-angle couplers, Putlog couplers , Swivel couplers,	-
	Posts and diagonal braces	-	Right-angle couplers, Putlog couplers , Swivel couplers,	-
	Post and stringers	2.5 Black wire	2.5 Black wire	2.5 Black wire
	Ledgers and transoms	-	Right-angle couplers, Putlog couplers , Swivel couplers, Sleeve or external joiner, Pin or internal joiner	-
	Stringers and Joists	2.5 Black wire	2.5 Black wire	2.5 Black wire
Height Adjustors		Adjustable base plates	Adjustable base plates	-
		Adjustable U- head	Adjustable U-head	-
		End (mini) frames		-
Tools and equipment				
		Hammer	Hammer	Hammer
		Robs	Robs	Robs
		Leveler	Leveler	Leveler

C. Eucalyptus wood metal combination shoring

Of the 44 projects 18 (41%) of them were using a combination of eucalyptus wood and metal shoring which shows that it's the most common method of shoring construction used in Addis Ababa's building projects. The combinations of the two materials were different from one construction site to anther because the reasons for adopting this method vary from one project to another. The following were some of the main reasons for adopting eucalyptus wood metal combination shoring;

- If the strength of the shoring material is suspected to be insufficient to resist the coming load,
- Irregular and acute areas on the building that could make it difficult to construct the shoring using standard sized shoring materials,
- Limited amount of metal shoring material on the construction site etc.

Therefore depending on the reason for adopting eucalyptus wood metal combination the method of combination of these materials used for providing temporary support for slabs and beam formworks in Addis Ababa building construction projects can be classified as follows;

- Metal frames or tubes with eucalyptus ledgers, transoms, stringers and joists
- Metal tube for slabs & eucalyptus for exposed beam support
- Half metal frames or tubes with half eucalyptus and
- Random combination of Eucalyptus wood and metal shoring

Metal frames or tubes with eucalyptus ledgers transoms, stringers or joists; this method was adopted for a reasons that either the component of the metal shoring such as legers, transforms or fittings were incomplete or if the strength of the metal alone were considered to be insufficient to temporarily support the structural elements. Therefore for construction of posts metal shoring and for construction of ledgers, transforms and diagonal member's eucalyptus wood instead of metal were used to construct the shoring system. The two materials will be Braced using 2.5 black wire. Figure 4.7 shows shoring constructed using metal posts and eucalyptus ledgers, transoms and stringers.

Figure 4.7 Metal frames or tubes with eucalyptus ledgers, transoms and stringers

Metal tube for slabs & eucalyptus for exposed beam support; these methods were commonly adopted on projects which have slab types of one-way slab with exposed beams or two way slabs with exposed beams. There were two reasons for adopting this method in these kinds of building projects. The first reason was the minimum adjustable length of the metal shoring that were available in the company were longer than the required floor height in most cases these occurred in areas where exposed beams exist. Second it was difficult to attain the horizontal aliment of the shoring on both the slab and the exposed beams using constant spacing due to standard sized legers and transoms.

As a solution instead of cutting to fit required length or purchasing new metal shoring, eucalyptus wood shoring will be used for temporarily supporting formworks under the exposed beams. This method is similar to eucalyptus wood shoring used for supporting slabs with exposed beams as discussed in section 4.4.1(a) but for slab support instead of eucalyptus wood metal shoring will be used. Figure 4.8 shows eucalyptus wood metal combination shoring for slabs with exposed beams.

Figure 4.8 Metal shores for slabs and eucalyptus wood shores for exposed beams

Half metal frames or tubes with half eucalyptus; when there is shortage of metal shoring on the construction site some portion of the floor area will be supported using the available metal shoring on the site and the remaining floor areas will be supported using eucalyptus wood shoring. In this method of shoring construction there is no need to join the metal and eucalyptus wood using 2.5 black wire because both of the shoring materials will be constructed independent from each other Figure 4.9 shows the construction of shoring using metal and eucalyptus shoring

Figure 4.9 Half metal shoring with half eucalyptus wood shoring

Random combination of eucalyptus wood and metal shoring material; the reason for adopting this method is unknown because there is no similar pattern on the uses of the combination of eucalyptus wood and metal shoring material. It was observed that in some of the projects the shoring materials were extracted form waste of different construction activities which have unknown capacity and design. Even though it is good to optimize the use of construction materials to minimize wastage and ensure profitability of the company, safety of the construction site must be taken in to consideration.

4.4.2 Scaffolding

The methods used for providing access on elevated areas vary from project to projects. From the selected 44 building projects 38(86.4%) of them were using supported scaffolding system either alone or in combination with other types of scaffolding systems and only the remaining 6(13.6%) projects were using other types scaffolding system. These shows supported scaffolding systems are the most frequently used scaffolding system around Addis Ababa. Table 4.8 illustrates the types of scaffolding systems used to provide access on elevated areas. Of the 38 of the projects which were using supported scaffolding system, 30(68 %) of them were using only supported scaffolding system, whereas 5(11%) of them used a combination of supported and suspended scaffolding systems and 3(6.8%) supported and mobile scaffolding systems.

Table 4.8 Type of scaffolding system used in elevated areas

No	**Type of scaffolding system**	**Frequency**	**Percentage**
1	Supported	30	68.2
2	Supported & suspended	5	11.4
3	Supported & Mobile	3	6.8
4	suspended	3	6.8
5	Suspended & Mobile	3	6.8
6	Mobile	0	0
	Total	44	100

The method of construction of the supported scaffoldings for providing external access and working platforms could be single layered and double layered scaffolding systems. The difference between them is the first one uses single post and the second one uses double layered posts alone the perimeter of the external wall to provide access and working platforms for working on the elevated wall. They could be constructed from the ground up or from some floor elevation resting on temporary board suspended on air where the ground is not accessible for construction because of limited working space or irregularity of the shape of building.

The material choice for supported scaffolding systems may depend on the shape of the building, the total height of the building or the expected duration to work on the scaffolding system. Eucalyptus wood, metal or combination of eucalyptus wood and metal were being used for the construction of the supported scaffolding systems in the 38 projects. Eucalyptus wood were the most popular or frequently used scaffolding material, which were being used in 22(57.9%) of the projects. Table 4.9 shows scaffolding material used for construction of supported scaffolding systems for providing access and working platforms on elevated areas.

Table 4.9 Types of supported scaffolding material used in building projects in Addis Ababa

No	Scaffolding material	Frequency	Percentage
1	Eucalyptus Wood	22	57.9
2	Metal	12	31.6
3	Eucalyptus wood metal combination	4	10.5
	Total	38	100

A. Eucalyptus wood scaffoldings

Eucalyptus is the most common material used in construction of scaffoldings in building construction industry around Addis Ababa as shown in table 4.10 of the 38 building projects 22(57.9%) of them were using Eucalyptus wood. Even though size and the spacing of the eucalyptus vary from place to place most of these projects follow similar method of construction. For construction of posts eucalyptus wood with diameter from 10cm and 12 cm diameter which were placed in every 60cm to 100 cm in transversal direction and 60 cm to 180 cm in the longitudinal direction along the perimeter of the building were being used. The spacing and the size the eucalyptus wood used in construction of posts were dependent on height of the scaffolding system to be constructed. If the height is considered to be significant enough for raising the question of stability of the system stronger eucalyptus wood which have greater or equal to 12m diameter will be used throughout the height of the building or on the base (foot) of the scaffolding system, if not 10 cm diameter eucalyptus wood is used. The problem with their approach is there is no standard or code of practice which could verify the maximum height limit of a building which will raise such kind of question which makes it subjected to the experience and judgment of the carpenter who construct the scaffolding system.

10cm or 8cm thick eucalyptus which were spaced form 180 cm to 190 cm along the height of the building for construction of ledgers and transoms 8cm diameter eucalyptus wood or 4cm- 6cm diameter Eucalyptus wood also called "Chefeka" in Amharic word for very thin eucalyptus wood, were being used commonly. To ensure the stability of the structure diagonal cross bracing using 8cm diameter eucalyptus wood were constructed in some of the projects. Typical type of eucalyptus scaffolding system used around Addis Ababa are shown in the figure 4.10 below.

For connecting and bracing each scaffolding elements with each other # 8 to #12 size nails were being used. The choice of the nails depends on the thickness of eucalyptus wood used. Posts will be restrained to the slab or beam in each floor using 2.5 black wires to make it stable form wind loads or movement of the whole scaffolding system.

For stair cases, ladders and working platform commonly wasted eucalyptus wood or "Chefeka", an Amharic word for very thin eucalyptus wood, were being used. In most of the projects Guardrail and toe boards were missing it seems their significance in providing safe working environment is overlooked.

Figure 4.10 Eucalyptus wood scaffolding systems

B. Metal scaffoldings

Metal is the second commonly used scaffolding material. Two types of metal scaffoldings were being used in building projects around Addis Ababa. They are H- frames and tube and copular their size and method of construction is similar with metal shoring systems mentioned in section 4.4.1 which were used to provide temporary support for construction of slab and beam concrete, except there are no joists and stringers in metal scaffolding construction.

For connecting and bracing each scaffolding elements horizontally and diagonally pins, diagonal braces and different couplers were being used. For connecting the scaffolding elements internal jointers (pins) or external jointer were being used. For maintaining the stability of the scaffolding system 2.5 black wires were used to brace the scaffolding elements with the building in similar with eucalyptus wood scaffolds.

Scaffolding pedal which could be assembled with the scaffolding systems, Steel panels or wood panels were used for construction of stair cases, working platforms and toe boards. Figure 4.11 shows metal scaffolding system used in building projects in Addis Ababa.

Figure 4.11 Metal scaffolding system around Beherawi theater

C. Eucalyptus wood metal combination scaffoldings

It was observed that eucalyptus wood metal combination scaffolds were being used commonly on Buildings which have irregular shape. Therefore the method of construction for these types of scaffolding system may vary from projects to projects depending on the shape of the building or other reasons for adopting them. Figure 4.12 shows Eucalyptus wood metal combination scaffolding system constructed on building projects around Kasanchis Addis Ababa.

Figure 4.12 Eucalyptus wood metal combination scaffolding system around Kasanchis

Finally the type of shoring and scaffolding systems used on the selected 44 building projects are summarized on table 4.10 below.

Table 4.10 Types of shoring and scaffoldings systems

Shoring	Scaffolding	No of Projects	
		Frequency	%
Eucalyptus wood	Eucalyptus Wood	11	25
	Metal	0	0
	Eucalyptus wood metal combination	0	0
	Suspended scaffolding	2	5
Metal	Eucalyptus Wood	0	0
	Metal	8	18
	Eucalyptus wood metal combination	3	7
	Suspended scaffolding	2	5
Eucalyptus wood metal combination	Eucalyptus Wood	11	25
	Metal	4	9
	Eucalyptus wood metal combination	1	2
	Suspended scaffolding	2	5
Total		44	100

4.5. Influencing Factors for selection of shoring and scaffolding material

For different reasons the choice of the shoring and the scaffolding system vary from projects to projects therefore many factors have influence on the decision which type of shoring and scaffolding are suitable for a specific projects. To understand these factors clearly in literature review part in section 2.11.1 they were categorized into 5 parts. Those were Geometry and design related, Activity related, Project related, Market related and company related. A total of 24 factors were taken out from them and the contractors were asked to identify the weight of each factor while selecting the shoring and scaffolding system in their projects.

4.5.1 Shoring

The top three influencing factors for selection of the shoring material in the selected projects were fall under company and market related factors, which are financial capacity of the company, Availability of shoring material in the company and initial cost of the material respectively, which fall into "extremely influential" factors while selecting the shoring materials. even if 36(81.8%) of the selected projects were being constructed by grade one contractors and 50 % of them have been in the construction industry for more than 10 years the result indicated shoring works have not been given enough consideration in building construction industry around Addis Ababa. Table 4.11 illustrates the rank and mean of the influencing factors for selection of shoring material.

Table 4.11 Rank of influential factors for selection of shoring material

Rank	Influential Factors	Mean	Frequency category
1	Financial capacity of the company	4.32	Extremely influential
2	Availability of the material in the company	4.25	Extremely influential
3	Initial cost of the material	4.20	Extremely influential
4	Type of the slab and Formwork to be supported	3.86	Very influential
5	Life cycle cost of the material	3.82	Very influential
6	Maximum floor height	3.77	Very influential
7	Availability of material in the market	3.66	Very influential
8	Expected floor cycle duration	3.61	Very influential
9	Degree of repetitiveness of work (no of floors)	3.55	Very influential
10	Type and complexity of the construction working Area	3.55	Very influential
11	Height of the building	3.52	Very influential
12	Health and safety of workers	3.36	Somewhat influential
13	Terms and specifications in the contract document	3.36	Somewhat influential
14	Skill of the crew	3.25	Somewhat influential
15	Expected duration of work on the constructed system	3.23	Somewhat influential
16	Area per floor	3.14	Somewhat influential
17	Weather condition	3.00	Somewhat influential
18	Shape of the building	2.98	Somewhat influential
19	Volume of acute areas and irregularity of the building	2.98	Somewhat influential
20	Available codes and standards	2.93	Somewhat influential
21	Environmental effects of the materials	2.86	Somewhat influential
22	Perimeter of the building	2.84	Somewhat influential
23	Location of the project	2.84	Somewhat influential
24	Manpower availability	2.82	Somewhat influential

From the above result it can be understand that Geometry and design related, activity related and project related factors were given second priority, which falls under “very influential” factors, while selecting the shoring system. To understand the relation between these factors and the choice of the shoring material furthermore the characteristics of each Building projects were analyzed in terms of the shoring material used in each projects as follows.

Company and market related factors vs. choice of the shoring material

Of the 44 building projects 36(81.8%) of them were constructed by grade one contactors which means most of the contractors in the selected projects have the capacity to own heavy machinery and equipment however the result reviles that financial capacity of a contractor, availability of shoring material in the company and initial cost of the shoring material being extremely influential factors for selection of the shoring material shows that investing on shoring materials as an asset of a company have less priority to the national contractors.

Geometry or design related and activity related factors vs. choice shoring material

A. Type of slab to be supported

When trying to see the effect of the types slab and form work to be supported on the shoring systems two major characteristics the slab should be critically evaluated. They are type of the slab and method of construction of the slab.

The type of slab to be supported determines the variation of the required length (height) of the post of the shoring system to be constructed. Flat slabs require single height of posts or frames whereas slabs with exposed beams require more than one height of posts and frames depending on the depth of the beams a floor.

Of the 44 projects 31 of them slab types were two way slabs with exposed beams and the remaining 13 were flat slabs. For buildings with exposed beams the most common shoring material were eucalyptus wood metal combination which were being used on 14(45.2%) of the projects the remaining 11(35.5%) and 6(19.4%) used Eucalyptus wood and metal shoring respectively. The choice or the use of the shoring material were different on flat slab buildings, 7(53.8%) of them were using metal shoring which makes it the most frequently used material followed by eucalyptus wood metal combination and eucalyptus wood taking a share of 4 (30.8%)and 2 (15.4%) respectively.

The result revels that as the requirement for posts height varies the choice of the shoring were dependent on the ability of the shoring material to be available on different height or length. For companies which have metal shoring with limited variation of post or frame lengths and construct slabs with exposed beams using only metal shoring might not be feasible. As it was illustrated on table 4.12 since availability of the shoring material and initial cost of the shoring material are extremely influential factors to address the height variation issue the solution taken were using eucalyptus wood metal combination because eucalyptus wood can provide an option be cut and fixed on areas the height variation occurred with minimum initial cost. The Figure 4.13 shows the variation of the choice or use of shoring material between slabs with exposed beams and flat slabs.

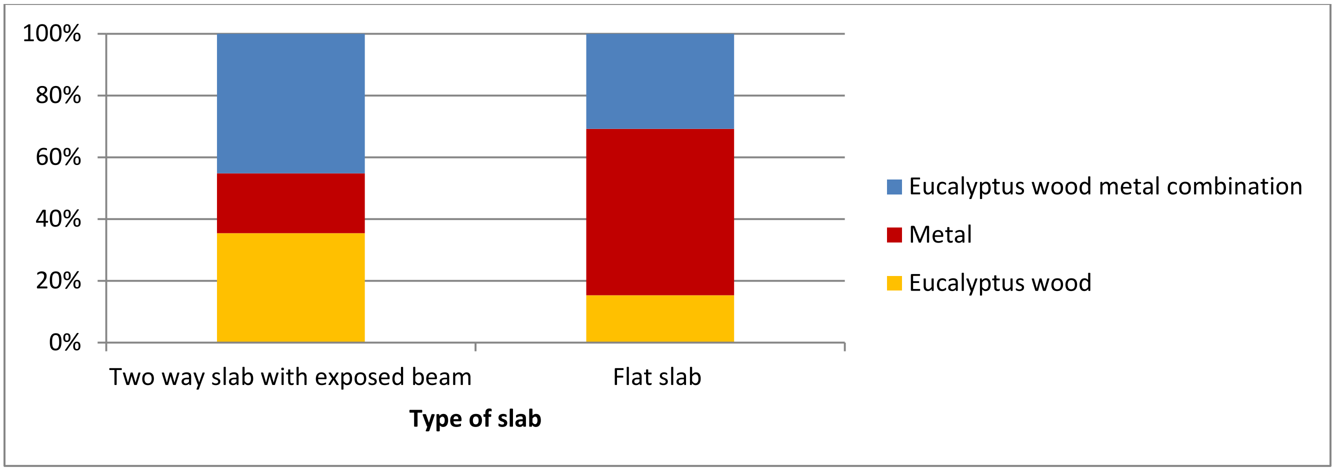

Figure 4.13 Type of slab vs. choice of shoring material

The methods of slab concrete construction also have effect on the choice of the shoring material because it determines the unit weight of the dead load to be supported by the shoring system. Therefore it affects the method of construction of the shoring, the size and volume of the shoring material requirements. Of the 44 projects 30 (68.2%) of them uses solid slab and 14(31.8%) of them uses ribbed slabs. from 30 of the projects which were constructing solid slabs, 13(43.3%) of them used metal shoring, 12(40%) of them used eucalyptus wood metal combination and only 5(16.7%) of them uses eucalyptus wood. From 13 projects which were constructing ribbed slabs 8(57.1%) of them use Eucalyptus wood and 6(42.9%) of them use eucalyptus wood metal combination. Figure 4.14 shows the relation between the method of slab concrete construction and choice of shoring material around Addis Ababa building projects.

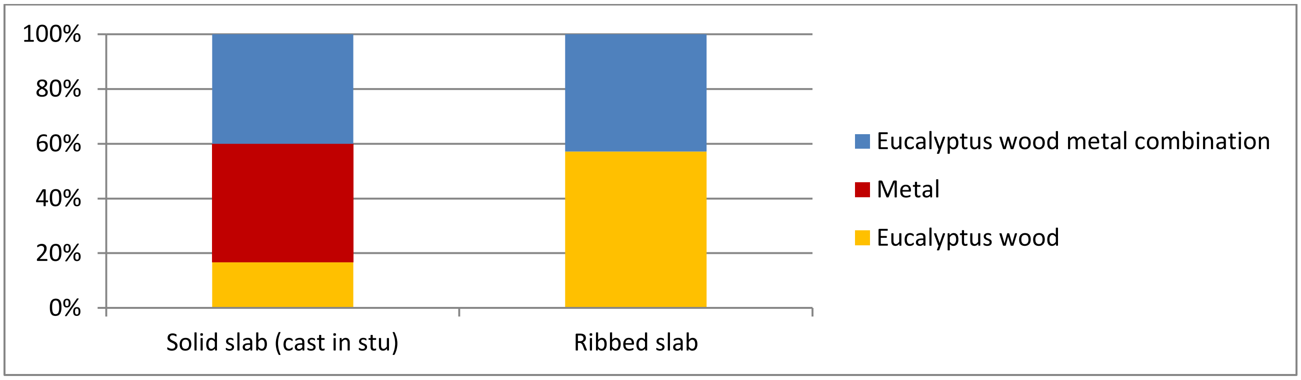

Figure 4.14 Method of slab concrete construction vs. choice of shoring material

When comparing solid slab with ribbed slab for deciding the type of shoring to be used the main difference between them are the unit weight of the dead load of the slab to be transferred to the shoring and method of casting the concrete. Since Unit weight of the dead load of solid slabs is larger than ribbed slab hence the volume of shoring units required and the factor of safety one has to consider would be much greater. Because of the material strength of eucalyptus wood vary and there are no available designs or code of practices for Eucalyptus wood shoring systems that for construction of solid slabs metal shoring and eucalyptus wood metal combination shoring are preferred over eucalyptus wood shoring.

B. Maximum Floor height

Maximum floor height of a building were one of Geometry and design related factors which were considered very influential factor by projects representatives while selecting the shoring system ranking in sixth place. The relation between the maximum floor height and the shoring material chosen in each of the project is summarized in table 4.12.

Table 4.12 Maximum floor height vs. choice of the shoring material

Maximum Floor height	Frequency	Eucalyptus wood		Metal		Eucalyptus wood metal combination	
		Frequency	%	Frequency	%	Frequency	%
<= 4 meter	25	11	44	4	16	10	40
4 - 8 meter	14	2	14	8	57	4	29
>8 meter	5	0	0	1	20	4	80
Total	44	13	29.5	13	29.5	18	40.9

The result shows that when the maximum floor height is less than 4 meter eucalyptus wood is commonly used however when the maximum floor height is between 4meter and 8 meter the preference shifts to metal shoring and it shifts to eucalyptus wood metal combination shoring for buildings with maximum floor height exceeds 8 meters. As the floor height increases the required strength of the shoring material which temporarily supports the slab will increase therefore using Eucalyptus wood alone for floor height greater than 4 meters were not preferred in most of the projects because the eucalyptus shoring posts have the tendency to buckle and forming deformed slab or further collapse of the systems. Figure 4.15 summarizes the maximum floor height and the choice of shoring material in building projects around Addis Ababa.

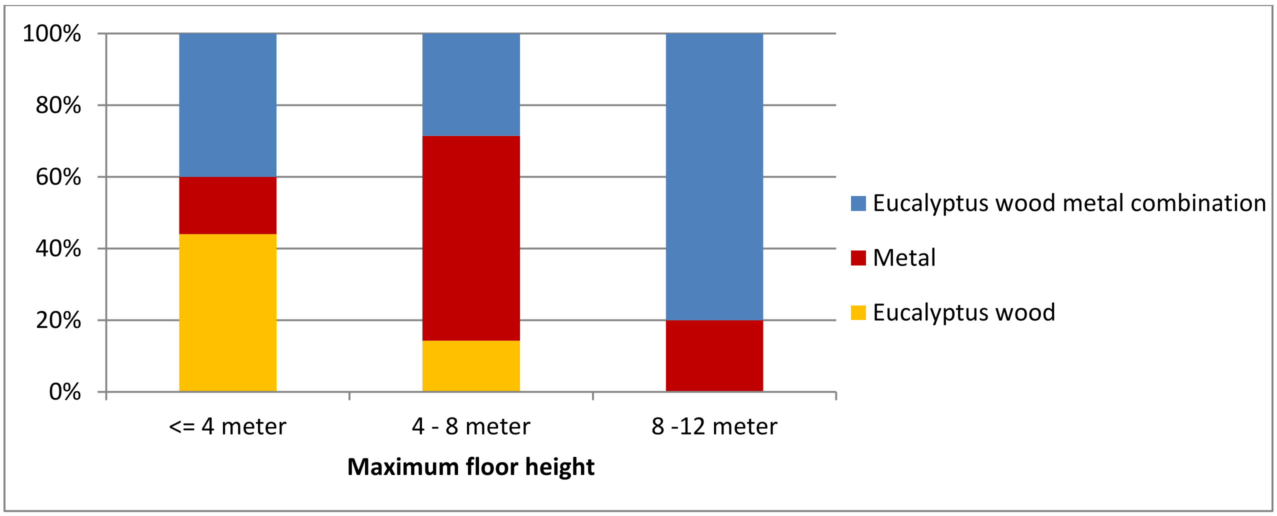

Figure 4.15 Maximum floor heights vs. choice of shoring material

The result for slabs with maximum floor height greater than 8 meter shows that eucalyptus wood metal combination is commonly adopted which is inconvenient since the metal shoring is considered to have reliable and consistent strength compared to eucalyptus wood. Considering only 5 building projects have greater than 8 meter floor height to identify the result large no projects have to be compared to reach to any kind of conclusion. However from the conducted site observation in buildings where the maximum floor height greater than 8 meters requires more than 3 posts or frames needs to be connected vertically to reach the required height which increases the no of connections hence the buckling effect of the structure. Therefore additional joist like structures were provided after one or two frame or steel shoring elevation level is reached to create firm resting support, minimizing the number of connection, the buckling effect of posts and make the structure more stable. In most of the projects for construction of these joists structures eucalyptus wood, RHS, I beams or other types of material were being used, which could explain the reasons for commonly adopting eucalyptus wood metal combination in these kinds of projects. Figure 4.16 shows typical method of shoring construction used in floor height greater than 8 meter.

Figure 4.16 Shoring for floor height greater than 8 meters

C. Expected Floor cycle duration

The expected floor cycle duration of a building depends on activities such as construction of formworks and shores, laying bars and casting the concrete etc. For faster construction all these activities must be completed within short period of time. Since construction of shoring is one of the major activities to complete the construction of each structural element, choice of the method of construction of the shoring system may depend on the required speed of construction of one floor cycle duration. As it was ranked in the 8th place out of the 24 listed factors and considered "very influential" factor while selecting the shoring system in their project identifying which type of shoring material were commonly preferred based on the required speed of construction each building project is important. on the selected 44 projects their plan to complete the construction of one floor structural elements were varying from 7 days to 60 days and the average floor area from 329m^2 to 3152 m^2. Since expected speed of construction of the structural element is expressed in reference with the expected floor cycle duration and to the volume of the work the analysis were made based on the ratio of the average floor area to the expected duration the result is shown on Table 4.13.

Table 4.13 Expected speed of construction vs. choice of shoring material

Average floor Area per Expected floor cycle duration	Frequency	Eucalyptus wood		Metal		Eucalyptus wood metal combination	
		Frequency	%	Frequency	%	Frequency	%
<=25 m^2/day	11	5	45.5	2	18.2	4	36.4
25-50 m^2/day	19	6	31.6	5	26.3	8	42.1
50-100 m^2/day	10	2	20	5	50.0	3	30
>100 m^2/day	4	0	0	1	25.0	3	75
Total	44	13	29.5	13	29.5	18	41

The result shows that when the speed of construction were in the range between 0 - 25 m^2/day eucalyptus wood were frequently utilized but when the speed of construction were in the range from 50- 100m^2/day the preference shifts to metal shoring and to eucalyptus wood metal combination for building projects which plans to accomplish speed of construction 25 – 50m^2/day greater than 100m^2/day. Figure 4.17 illustrates the preference of the shoring material for different speed of construction requirement.

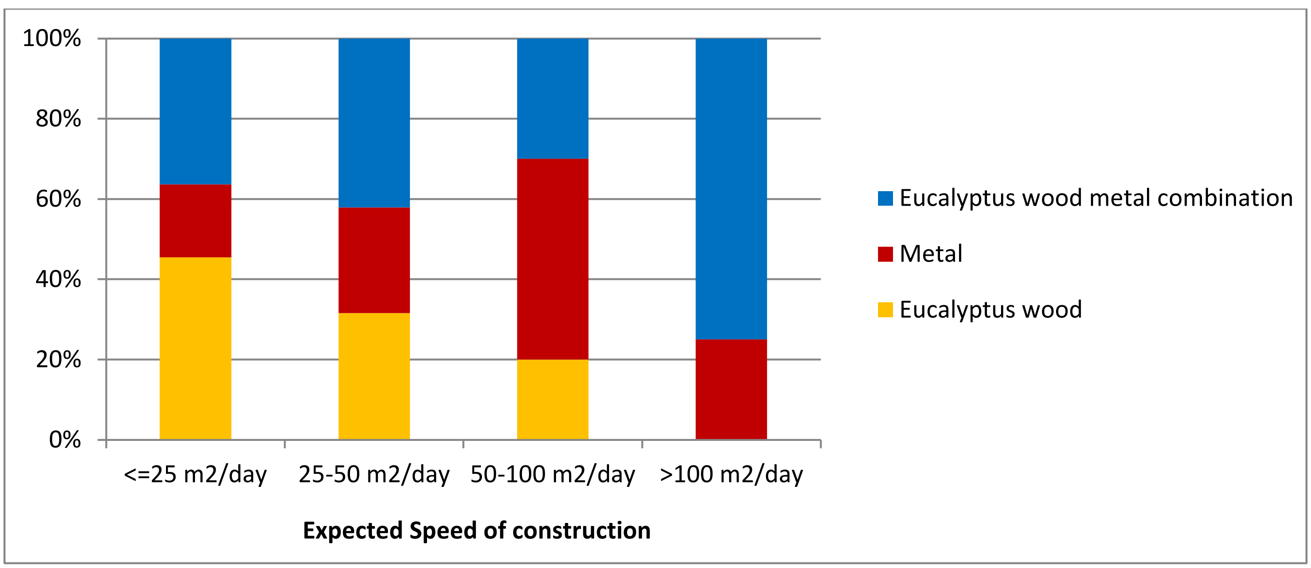

Figure 4.17 Expected speed of construction vs. choice of shoring material

It can be understood that eucalyptus wood is not the most preferable shoring material if the required speed of construction is greater than 25m^2/day. However adopting eucalyptus wood metal combination for projects which have planned to accomplish more than 100m2/day seems unreasonable. Justifiable reason for this could not be identified with only four projects which have planned to accomplish more than 100m2/day. Therefore large no of data are required to explain the reason behind adopting eucalyptus wood metal combination instead of metal shoring in these projects

D. Degree of Repetitiveness of the shoring work or No of floors

Degree of repetitiveness of the shoring work or no floor were considered very influential factor for choosing shoring system around Addis Ababa building projects. To understand which type of shoring material chosen under what degree of repetition of the work analysis of the 44 projects were made as shown on table 4.14.

Table 4.14 Degree of repetition of the work vs. choice of shoring material

Degree of repetitiveness of the work (no of Floors)	Frequency	Eucalyptus wood		Metal		Eucalyptus wood metal combination	
		Frequency	%	Frequency	%	Frequency	%
5-10	17	8	47.1	4	23.5	5	29.4
11-15	17	4	23.5	3	17.6	10	58.8
16-20	6	1	16.7	3	50	2	33.3
>20	4	0	0	3	75	1	25
Total	44	13	29.5	13	29.5	18	41.5

The result shows eucalyptus wood is frequently were being used on buildings which have less than 10 floors, the preference shifts to eucalyptus wood metal combination for buildings which have 11 -15 floors and metal shoring were frequently utilized on buildings which have greater than 15 floors in building projects around Addis Ababa figure 4.18 illustrates the result. It can be concluded that the degree of repetition of the shoring work and the life use of the shoring materials affected the choice of shoring material in Addis Ababa building projects.

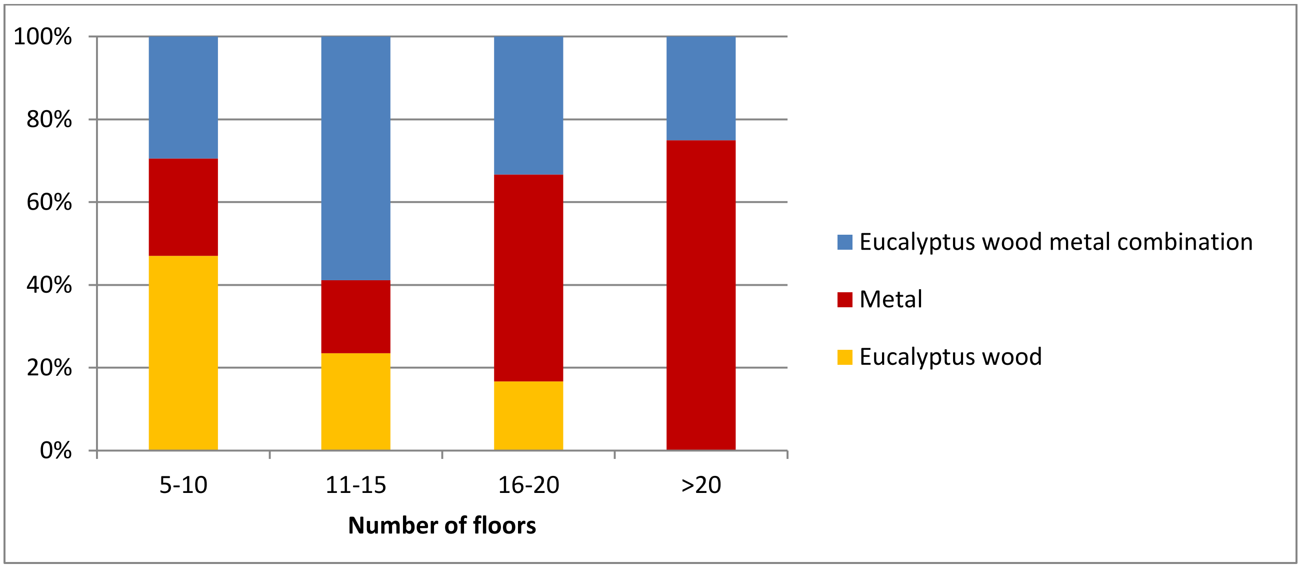

Figure 4.18 Degree of repetition of the shoring work vs. choice of shoring material

4.5.2 Scaffolding

For access scaffolds the top three influencing factors remains the same as the support scaffolds but only financial capacity of the company remain under "Extremely influential" category while availability of scaffold material in the company and initial cost of the scaffold material were considered very influential factors for selecting the scaffolding system. Table 4.15 illustrates the ranks, mean scores and categories of the influencing factors.

Table 4.15 Rank of influential factors for selection of the scaffolding system

Rank	Influential factors	Mean	Frequency category
1	Financial capacity of the company	4.27	Extremely influential
2	Availability of the material in the company	4.09	Very influential
3	Initial cost of the material	4.05	Very influential
4	Height of the building	3.95	Very influential
5	Life cycle cost of the material	3.66	Very influential
6	Type and complexity of the construction working Area	3.59	Very influential
7	Health and safety of workers	3.57	Very influential
8	Availability of material in the market	3.57	Very influential
9	Expected duration of work on the constructed system	3.41	Very influential

Rank	Influential factors	Mean	Frequency category
10	Shape of the building	3.25	Somewhat influential
11	Terms and specifications in the contract document	3.23	Somewhat influential
12	Perimeter of the building	3.20	Somewhat influential
13	Maximum floor height	3.14	Somewhat influential
14	Skill of the crew	3.11	Somewhat influential
15	Degree of repetitiveness of work (no of floors)	3.09	Somewhat influential
16	Weather condition	2.95	Somewhat influential
17	Volume of acute areas and irregularity of the building	2.84	Somewhat influential
18	Expected floor cycle duration	2.84	Somewhat influential
19	Location of the project	2.84	Somewhat influential
20	Manpower availability	2.82	Somewhat influential
21	Available codes and standards	2.82	Somewhat influential
22	Type of the slab and Formwork to be supported	2.80	Somewhat influential
23	Area per floor	2.73	Somewhat influential
24	Environmental effects of the materials	2.73	Somewhat influential

The choice of the scaffolding material could depend on different characteristics of the buildings. Therefore the researcher tries to find out the relation between some of the characteristics of the projects and the choice of the scaffolding material.

A. Height of the building

Since scaffolding's purpose is to provide safe access and working plat forms on elevated areas height of the building is one of the important factors to be considered in fulfilling the objectives of scaffolding. As the height increases it affects some aspects of the scaffolding system such us the stability of the scaffolding structure, the required strength of the scaffolding material, etc. Therefore identifying the relation between the selected building project's height with the scaffolding material used or planning to use is important. Table 4.16 shows the relation between height of the buildings and the chosen scaffolding material on the selected projects.

Table 4.16 Height of the building vs. choice of the scaffolding material

Height of the building	Frequency	Eucalyptus wood		Metal		Eucalyptus wood metal combination	
		Frequency	%	Frequency	%	Frequency	%
<=30 meter	10	6	60	4	40	0	0
30 - 45meter	10	9	90	1	10	0	0
45 - 60 meter	8	5	62.5	1	12.5	2	25
>60meter	10	2	20	6	60	2	20
Total	38	22	57.9	12	31.6	4	10.5

The result shows that Eucalyptus wood scaffolding were frequently being used on building projects which have height equal or less than 60m, as the height increases from 45 - 60 meters the frequency start to decrease then the preference of changed to metal scaffoldings for height of the buildings greater than 60 meter figure 4.19 illustrates the relation between height of the buildings and the choice of scaffolding material used or planning to use on the selected projects.

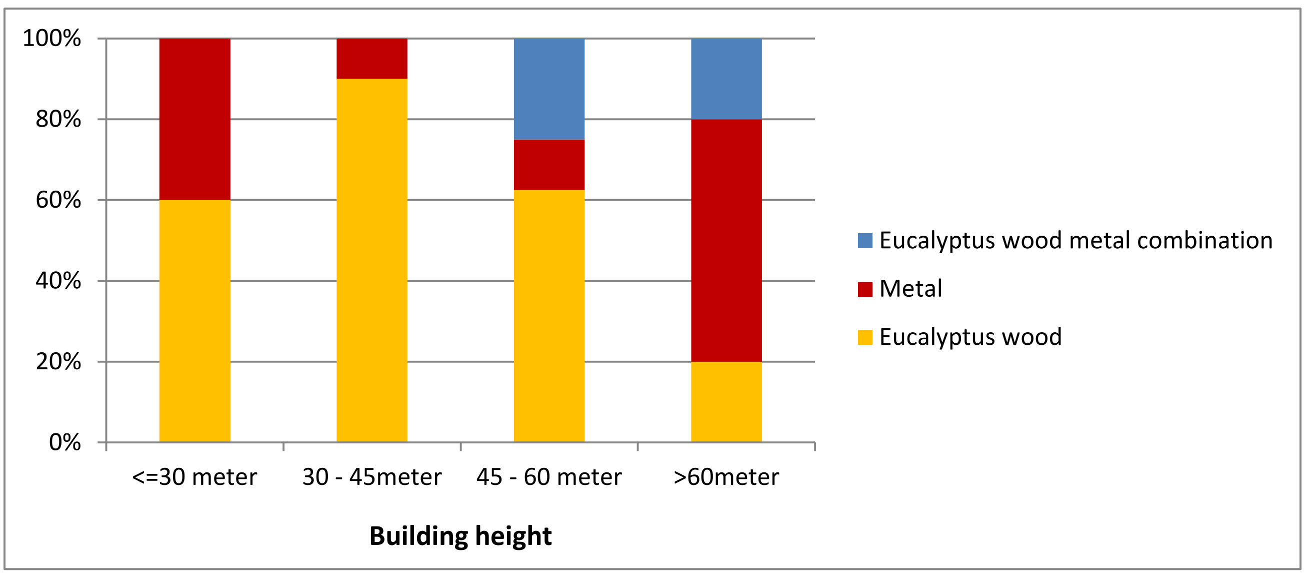

Figure 4.19 Building height vs. choice of scaffolding material

The reason behind the above result could be related to problems that could arise from the stability issues of the constructed scaffolding systems. Since there are no code of practice available for use of eucalyptus wood scaffolding systems on the maximum height limit of building to be used the above pattern indicate that the maximum height limit of a building for using eucalyptus wood scaffolding could be 60meter or above. But this judgment is only made from the current practice scaffolding systems around Addis Ababa Building projects which were gained or adopted from the experience of the project managers or carpenters therefore more experimental analysis should be made for confirming whether these kind of practice should continue or not in order to maintain the health and safety of the construction industry.

B. Expected duration of work on the constructed scaffolding system

Expected duration of work on the constructed scaffolding have impact on the safety of the scaffolding system due to its exposed to different season of weather condition, the scaffolding material strength and durability could be compromised especially Eucalyptus wood since it is natural material and have the ability to absorb moisture and decompose easily.

The other issue raised in considering expected duration of work on the constructed scaffolding system is ensuring the cost effectively of assigning the available scaffolding material projects on hand which requires. the priority for assigning expensive scaffolding material such us metal scaffolding for longer period where it does not have direct impact on the project duration over other projects at hand which require to use them for short period and have direct impact on the floor cycle duration and project duration such us slab and beam support shoring.

Therefore finding the relation between the scaffolding material and expected duration could give information on which of the two factors are given the highest priorities. Since scaffolding is indirect work it was difficult to get the expected duration of work on the scaffolding systems therefore from 38 of the projects which were planning to use supported scaffolding system only 28 of them had complete information and provided the data on how long they were planning to use the constructed scaffolding system. Table 4.17 summarizes the results as follows

Table 4.17 Expected duration of work on the constructed scaffolding system vs. choice of scaffolding material.

Expected duration	Frequency	Eucalyptus		Metal		Eucalyptus wood metal combination	
		Frequency	%	Frequency	%	Frequency	%
=< 6months	12	5	41.7	7	58.3	0	0
6 -12months	4	3	75	1	25	0	0
12 -24 months	12	11	91.7	1	8.3	0	0
Total	28	19	67.9	9	32.1	0	0

The result shows that for projects with expected duration of work on the scaffolding system less than 6 months metal scaffolding were preferred over eucalyptus scaffoldings but as the expected duration to work on the scaffolding system increases the choose of the scaffolding material shifts from metal scaffolding to eucalyptus wood scaffolding systems figure 4.19 illustrates the relation between the expected duration to work on the constructed scaffolding system and choice of the scaffolding material on building projects in Addis Ababa.

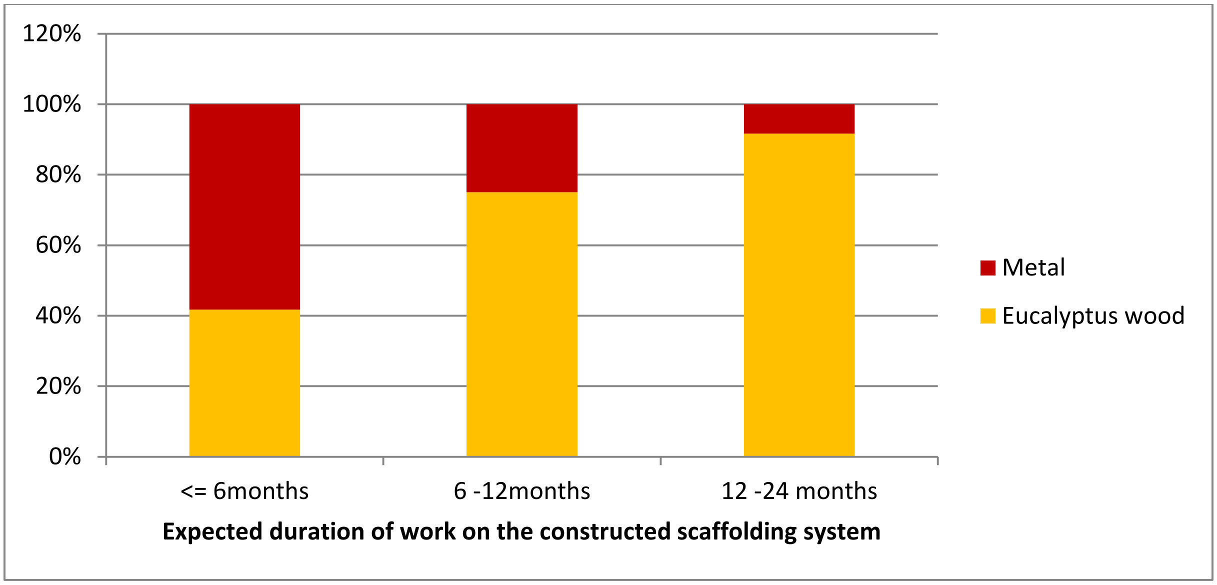

Figure 4.20 Expected duration of work on the constructed scaffolding system vs. choice of the scaffolding material

Hence the result reveals that even though eucalyptus wood poses more traits and safety issues when used for longer period exposed to different weather and rainy season it were being used most commonly than metal scaffolding. It can be concluded that the current practice of scaffolding systems are giving priority to companies profitably over the safety of the workers table 4.15 also support these conclusion as health and safety ranked on the 7th place whereas Initial cost and lifecycle cost of the scaffolding raked on the 3rd and 5th place respectively.

4.6. Comparisons of shoring and scaffolding materials

Shoring and Scaffolding materials frequently used on building projects around Addis Ababa were Eucalyptus wood, Metal or Eucalyptus wood metal combination. However each of these materials has their own merits and demerits. Comparing them based on different performance measurement could give new insight for selecting the appropriate shoring and scaffolding material for a specific building project. Therefore this section will make comparison of eucalyptus wood and metal shoring and scaffoldings based on their cost, speed of construction, safety, application and operation.

4.6.1 Comparison of speed of construction

Speed of construction of shoring affects the floor cycle duration of hence affect the project duration. Therefore identifying the share of duration of shoring work in completing one floor cycle is important for planning and managing project duration. In order to make comparison of speed of construction of eucalyptus wood, metal and eucalyptus wood metal combination shoring some of the affecting parameters must be constant therefore the following assumption were taken when analyzing the speed of construction of the shoring work in the selected 44 projects.

- Average floor area were taken
- Average duration taken to construct one floor shoring work is used
- The spacing between the shore elements were not considered
- Duration to dismantle the shoring systems were not included
- The method of combination of eucalyptus wood and metal shoring were not considered
- The crew performance were taken into account
- The average crew formation includes 1 carpenter and 1 daily labor
- The average no of crew employed were 12, 13 and 15 for eucalyptus wood, metal and eucalyptus wood metal combination shoring systems respectively.
- The productivity for each scaffolding material was identified by interpolating the crew performance and the number of crew employed into 12.

Based on the above assumptions the speed of construction of the shoring materials using 12 crew members were identified and compared. Table 4.19 illustrates the performance of each scaffolding material with respect to the expected speed of the construction and the actual speed of construction of the shore.

Table 4.19 Comparisons of speed of construction of shoring material

Performance measurement	Speed of construction (using 12 crew)		
	Eucalyptus wood	Metal	Eucalyptus wood metal combination
% of expected floor cycle duration	39	32	31
Productivity (m^2/day.)	121	208	169

Construction of Eucalyptus wood shoring was taking 39% of the expected floor cycle duration in projects which were using eucalyptus wood shoring. Metal shoring 32% and eucalyptus wood metal combination 31% of the expected floor cycle duration were taking to construct the shoring system.

When interpreting these figures it should not be confused with the productivity of the crew because the percentage of expected floor cycle of duration to construct shoring systems is subjected not only to the speed of construction of the shoring but also the contractors' plan to complete one floor cycle it's simply there to show how much percentage of the expected floor cycle duration was spent in construction of the shoring systems ,which were identified to be from 31- 39 % of the expected floor cycle duration using 12 crew.

Further analysis is done to measure the actual performance by taking the ratio of the average floor area and the duration taken to construct one floor slab support shoring. Using the 12 crew their productivity were 121m^2/day, 208m^2/day and 169m^2/day for eucalyptus wood, metal and eucalyptus wood metal combination shoring construction respectively. The result shows that using metal and eucalyptus wood metal combination is 72% and 40% faster than Eucalyptus wood shoring respectively.

Unlike shoring getting data for making comparisons of the speed of construction of scaffolding was unsuccessful. However from the observed method of construction metal scaffolding construction is faster than eucalyptus wood scaffolding since their elements are prefabricated they are assembled easily unlike eucalyptus wood which requires to cut and fixed on site.

4.6.2 Comparison of cost

As the analysis from section 4.5 implies initial cost of the shoring and scaffolding materials are extremely influential factor in selecting the shoring and the scaffolding systems in building construction projects around Addis Ababa. One of the main reasons for adopting eucalyptus wood due it's the initial cost is very much less than metal in Addis Ababa. Currently the initial cost of the eucalyptus wood varies from 105 to 55 birr/ pieces depending on the type and size of eucalyptus wood. Whereas for metal shoring or scaffoldings depending on their sizes the H- frames the costs from 2800 to 3100 birr per full set and adjustable Steel props costs 600 to 1100 birr /Pieces.

However the life cycle cost or the reusability of the scaffolding material and the speed of construction should be taken into account when considering the cost of the shoring and scaffolding material as selection criteria of shoring and scaffolding systems.

From the selected 44 building construction projects it was identified eucalyptus woods were being reused from 4 to 8 times for shoring construction. For metal it was difficult to identify how many times it can be reused since it emerge in building construction projects around Addis Ababa recently, there weren't previous data available therefore the cost estimations were done by forecasting It's reusability from 20 to 100 times.

The result from the analysis on comparison of speed of construction is taken to identify the hourly output of the crew when constructing eucalyptus wood, metal and eucalyptus wood metal shoring.

$$\text{Output per crew} = \frac{\text{Productivity}}{\text{No crew x 8hr/day}}$$

$$\text{Eucalyptus wood shoring output} = \frac{121m^2/day}{12 \text{ crew x 8hr/day}} = \mathbf{1.26m^2/hr.}$$

$$\text{Metal shoring output} = \frac{208\ m^2/day}{12 \text{ crew x 8hr/day}} = \mathbf{2.16m^2/hr.}$$

$$\text{Eucalyptus wood metal combination output} = \frac{169\ m^2/day}{12 \text{ crew x 8hr/day}} = \mathbf{1.76m^2/hr}.$$

Based on the above assumptions and out findings the direct costs of eucalyptus wood, metal and eucalyptus wood metal combination shoring are estimated. Figure 4.20 shows a sample cost breakdown done for cost estimations of different types shoring used for temporarily supporting floor slabs and beams.

Table 4.20 Sample cost break down for shoring work

Eucalyptus wood shoring for Solid slabs spacing between posts 60cm x60 cm 1.44

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Eucalyptus wood dia. 10-12	ml	14.1	3.28	46.1	Carp.	1	1	35.3	1.26	28.0	Tools	2	1	1	1.26	1.59	
Eucalyptus wood dia. 8cm	ml	7.33	1.56	11.5	DL	1	1	10	1.26	7.9							
Nail 12	Kg	0.02	35	0.8													
Nail 10	Kg	0.06	35	2.1													
Nail 8	Kg	0.01	35	0.4													
				60.8						**35.9**						**1.59**	**98.3**
Remark				Use of eucalyptus wood 4 times and wastage 10% Nail wastage 5%													

H-frame 1.20m (width) x 1.80m (length)x2.4m Height spacing 80cmx 180cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-fame 1.20m (width) x 1.80m (length) x 2.4m (Height)	full set	0.14	155	21.53	Carp	1	1	35.3	2.16	16.3	Tools	2	1	1	2.16	0.9	
RHS 60cm X 60cm X 1.5mmx 6m	Pcs	0.18	22	2.18	DL	1	1	10	2.16	4.62							
RHS 40cm X 40cm X 1.5mmx 6m	Pcs	0.49	12.5	10.69													
Black wire 2.5	Kg	0.02	35	0.77													
				32.23						**20.9**						**0.9**	**54.1**
Remark				Use of H- frame 20 times and wastage 0% Use of RHS 20 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%, the price includes top jacks													

Adjustable steel props 60cm dia., 2mm thick, 3.9 m length spacing 60cm x60cm 1.44

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Adjustable props 6cm dia. x 2mmthick x 3.9 height	pcs	2.78	55	152.8	Carp.	1	1	35.3	2.16	16.30	Tools	2	1	1	2.16	0.9	
RHS 60cm X 60cm X 1.5mm x 6m	Pcs	0.29	22	3.646	DL	1	1	10	2.16	4.62							
RHS 40cm X 40cm X 1.5mm x 6m	Pcs	0.58	12.5	12.83													
Black wire 2.5	Kg	0.02	35	0.773													
				167						**20.9**						**0.9**	**189**
Remark			Use of steel props 20 times and wastage 0% Use of RHS 20 times Spacing :- RHS 60x60 - c/c 60cm, RHS 40x40 - c/c 40cm wastage 5%														

Eucalyptus wood metal combination: H-frame 1.20m (width) x 1.80m (length)x2.4m Height & Eucalyptus wood for joists and stringer Spacing 80cm x 180cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length) x 2.4m (Height)	full set	0.14	155	21.53	Carp.	1	1	35.3	1.76	19.97	Tools	2	1	1	1.76	1.13	
Eucalyptus wood dia. 10- 12	ml	1.1	2.18	2.41	DL	1	1	10	1.76	5.67							
Eucalyptus wood dia. 8cm	ml	3.97	1.04	4.14													
Nail 10	Kg	0.03	35	0.90													
Black wire 2.5	Kg	0.02	35	0.77													
				29.74						**25.6**						**1.13**	**5**
Remark				Use of H- frame 20 times and wastage 0% Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%													

In similar pattern with the above sample work break down the average cost of shoring for each materials are estimated. It is estimated by taking the average estimated cost of different method of construction and reusability of each scaffolding material. The estimated cost break down for shoring works are attached in the appendix B. The average cost of shoring for 1m^2 floor slab support is identified and summarized in the table 4.20 below.

Table 4.20 Average cost comparison of shoring materials

Life use	Eucalyptus wood (Birr/m2)	Metal		Eucalyptus wood metal combination	
		H-frame (Birr/m2)	Adjustable steel props (Birr/m2)	Eucalyptus wood & H-frame combination (Birr/m2)	Eucalyptus wood & adjustable steel prop combination (Birr/m2)
4 times	73.03				
8 times	56.02				
20 times		39.0	154.66	53.26	157.80
40 times		37.9	88.64	42.79	98.12
60 times		32.8	66.63	40.14	75.54
80 times		30.3	55.63	37.56	68.28
100 times		28.7	49.03	36.51	62.31

From the above result Eucalyptus wood shoring which is used four times during its life will cost an average of 73.03birr/m^2 and if it's used eight times during its life the cost will decrease up to 56 birr/m^2 having 17birr/m^2 (23.3%) price difference. To get the benefit of the 17birr/m^2 price difference constructors use eucalyptus wood as many times as they can without considering the material quality degradation from overusing it, which creates hazardous working environment and contribute to health and safety problems in the construction industry. Table 4.21 shows the cost difference and cost ratios between eucalyptus wood shoring used 4 times and metal shoring considering from 20 – 100 life use.

Table 4.21 Cost difference and cost ratios of eucalyptus wood shoring and metal shoring

Life use of metal storing	Cost difference (eucalyptus wood - metal) Birr /m^2		Cost ratio (metal/eucalyptus wood)	
	H- frame	Steel props	H- frame	Steel props
20 times	34.41	-81.23	0.53	2.11
40 times	35.50	-15.21	0.52	1.21
60 times	40.60	6.80	0.45	0.91
80 times	43.15	17.80	0.41	0.76
100 times	44.69	24.40	0.39	0.67

The cost analysis result shows contractors have advantage if they use H-frames shoring instead of using Eucalyptus wood. H frames costs less than eucalyptus wood shores with cost difference from 34.4 birr/m2 up to 44.69 birr/m^2 , if the life use of the H frame is considered from 20 to 100 times. In other word using h frame shore costs only 39% to 53% of eucalyptus wood shores. Due to H- frame's life use in addition to the direct cost the effort of buying and disposing the materials and inflation costs will be eliminated or minimized compared to Eucalyptus wood shores. Therefore in contrast to the tread way thinking using H- frame instead of Eucalyptus wood is more profitable or economical.

Using adjustable steel props shoring material costs more than eucalyptus wood scaffolding systems if the life use is less than 60 times. If the life use of adjustable steel prop is 20 times and using them instead of eucalyptus wood will cost an addition of 81.23 birr/m^2 or 2.11 times the cost eucalyptus wood. But if the life use is 60 times it will cost less than eucalyptus wood shoring with cost difference of 6.28 birr/m^2 and the cost difference would be as much as less than 24.40 birr/m^2 for 100 times life use.

When comparing H-frames with adjustable steel prop their cost difference varies from 115.64birr/m^2 to 20.29 birr/m^2 when their life is 20 times to 100 times respectively. Therefore from economical point of view using H- frames shores is better than steel props and eucalyptus wood shoring.

4.6.3 Comparison of safety

Safety is always the most important issue in shoring and scaffolding works in the construction industry. Safety has a close relationship with shoring and scaffolding system, the workers, their operation and their management. If any link in this chain fails, accidents will happen. In relation to the shoring and the scaffolding system, safety is determined by their design, application and material strength. This section will discuss shoring and scaffolding related accidents in the selected building projects around Addis Ababa and also tries to identify the relation between the accidents and the shoring and scaffolding materials.

According to the respondents out of the 44 projects 13 (30%) of them experienced incidents related to scaffoldings. From these 13 projects a total of 24 incidents occurred. Further investigations were made to identify which type of scaffolding material frequently these incidents occurred. Table 4.19 illustrates what types of material were being used for both shoring and scaffolding system and frequency of the incident occurred in the selected 44 building projects.

Building projects which uses Eucalyptus wood for both shoring and scaffolding systems are in the first place for frequently experiencing incidents related to shoring and scaffolding. A total of 10(42%) of the incidents out of the 24 incidents occurred from these building project.

Table 4.22 Incidents occurred vs. types of shoring and scaffolding system.

Types of scaffolding systems		No of Incidents Occurred	
Shoring material	**scaffolding system**	**Frequency**	**%**
Eucalyptus wood	Eucalyptus Wood	10	42
	Metal	0	0
	Eucalyptus wood metal combination	0	0
	Suspended scaffolding	2	8
Metal	Eucalyptus Wood	0	0
	Metal	2	8
	Eucalyptus wood metal combination	1	4
	Suspended scaffolding	0	0
Eucalyptus wood metal combination	Eucalyptus Wood	6	25
	Metal	3	13
	Eucalyptus wood metal combination	0	0
	Suspended scaffolding	0	0
Total		**24**	**100**

In the second and third place in projects which were using Eucalyptus wood metal combination for shoring and Eucalyptus wood for scaffolding and in projects which uses eucalyptus wood metal combination for shoring and metal scaffolding with a total of 6(25%) and 3(13%) from the24 incident occurred respectively.

Only 8% of the incidents occurred on projects which uses metal both shoring and scaffolding systems. The remaining 92% of the incidents were occurred on projects which were having the involvement of eucalyptus wood use either alone or in combination with metal for both shoring and scaffolding systems. From the above result it can be conclude that using eucalyptus wood as shoring and scaffolding material is prone to many accidents. Of course one could argue that the result doesn't related to the quality of the material itself but also the workers and the operation and management that might be true but one fact remains constant the method of construction, the trends and practices of shoring and scaffolding systems always will be traced back to the type of material used.

Furthermore the above incidents could be evaluated in terms of the impact of the injuries they coursed on the human life. A total of 6 fatal, 13 medical attention needing, 22 first aid needing and 6 nearly missed works were injured caused by the 24 incidents. Table 4.23 illustrates the types of injuries occurred with the type of scaffolding used when the incidents occurred.

Table 4.23 Injures occurred vs. type of the shoring and scaffolding system

Types of scaffolding systems		**Type of the injuries**							
Type of Shoring	**Type of scaffolding**	**Near miss**		**First aid needing**		**Medical attention needing**		**Fatality**	
		Frequency	**%**	**Frequency**	**%**	**Frequency**	**%**	**Frequency**	**%**
Eucalyptus wood	Eucalyptus Wood	2	33	12	55	8	62	2	33
	Suspended scaffolding	0	0	0	0	2	15	0	0
Metal	Metal	0	0	0	0	1	8	1	17
	Eucalyptus wood metal combination	2	33	2	9	1	8	1	17
Eucalyptus wood metal combination	Eucalyptus Wood	2	33	7	32	0	0	1	17
	Metal	0	0	1	5	1	8	1	17
	Total	6	100	22	100	13	100	6	100

Buildings which were using eucalyptus wood for both shoring and scaffolding system have contributed most of the shares for all kinds of injuries occurred. The result implies that the use eucalyptus wood shoring and scaffolding need improvement and workers health and safety should be given more attention.

4.6.4 Comparison of Application and operation

A. Problems occurred when the building height increases

As the height of the building increases the major issues encountered in the selected projects are transporting the shoring and scaffolding material and stability of the constructed scaffolding systems. to solve the for transportation problem for scaffolding most of them mention using cranes and for shoring managing and storing the dismantled scaffolding material on the same floor and transporting these materials when they needed in the next level of floor construction were used as a solution. These solution works perfectly only for metal shoring which are to be used until the project completion. whereas for eucalyptus wood shoring materials which require replacement after using them from three to five floors by new material which again needs to be transported from ground to upper floor construction.

For scaffolding the other problem encountered as the height of the building increases was the stability of the constructed scaffolding systems the solution for these problem was to restrain the scaffolding system on the structure of the building using 2.5 black wire.

B. Problems occurred in irregular and acute areas

In acute or irregular areas fitting standardized material such us metal is difficult therefore in most cases metal shoring and scaffolding were used in combination with Eucalyptus wood. to mention some of the areas this problems occurred

- Exposed beams and the height of the bottom beam is less than the minimum adjustable height of the available shoring units on site.
- The position of the beam shoring and the slab shoring do not fit where they were using for tube and coupler shoring. In these cases they used tube and coupler for slab support and eucalyptus wood shoring for beam support.
- Circular shaped or irregular shaped buildings such us the floor areas vary form one floor to the other it’s difficult to construct the scaffolding system with only metal which are manufactured to from only straight line vertically and horizontally.

- For floor elevation greater than 8 meters using a single unit of shoring material won't reach to the required height in this case combining three or more shoring units vertically is required. After two shoring unit elevation level is reached a bed like structures will be built to make a firm resting support of the additional elevation. Using only Eucalyptus wood is reported to have a buckling problem when concrete were casted and vibrated and it resulted on forming deformed slabs.

4.7. Issues related to current practice of scaffolding construction in the selected site

The last portion of the questionnaire raised the issue related to shoring and scaffolding construction practices in Addis Ababa. Respondents were asked to give their comments that should be raised for further investigation and study. From 44 collected questionnaires only 16 (36.4 %) responded on this part. These further comments help the researcher and scholars to study other attribute aspect of shoring and scaffolding construction around Addis Ababa. The following are the comments given by the respondents:-

- ✓ There should be strong regulation against using eucalyptus scaffolding for high rise buildings.
- ✓ Excess amount of resources are being employed for construction of shoring and scaffolding systems because of measure of the required amount of resources needed for both shoring and scaffolding works are unknown.
- ✓ Scaffolding works should be included on the bill of quantities specifying the design and method of construction in the contract document.
- ✓ There is a need for design of shoring and scaffolding systems
- ✓ There is a shortage of professionals who practice on shoring and scaffolding systems.

4.8. Summery

4.8.1. Methods and materials of shoring and scaffolding system

- ✓ Eucalyptus wood, metal and eucalyptus wood metal combinations are common shoring and scaffolding materials in building construction around Addis Ababa.
- ✓ Of the 44 building projects 18(41%) of them used Eucalyptus wood metal combination, 13(29.5%) of them Eucalyptus wood and the remaining 13 (29.5%) of them Metal for construction of shoring for providing temporary support during floor slab and beam construction.
- ✓ Eucalyptus wood were the most popular scaffolding material for construction of scaffoldings which were being used in 22(57.9%) of the 38 projects which used supported scaffolding systems for providing access and working platforms on elevated areas.
- ✓ For construction of eucalyptus wood shoring and scaffoldings posts Eucalyptus wood of diameter 10-12 were being used and for joists, stringers, legers and transoms eucalyptus wood with diameter 8cm and 6cm were being used for construction of shoring and scaffolding in building construction project around Addis Ababa. Nail of size vary from 8 to 12 were used for connection of each element of the shoring and scaffolding system.
- ✓ For construction of metal shoring H frames, tube and coupler and adjustable steel props were used and for construction of joists and stringer RHS, I beams, infiltrator beam and morale/purine of different sizes with different spacing were used. Different fittings, couplers and 2.5 black wires were used for connection and adjusting height of each element of the shoring systems.
- ✓ Method of combination of eucalyptus wood and metal as shoring material vary depending upon the reasons for adopting eucalyptus wood metal combination shoring system.
- ✓ the main reasons for adopting eucalyptus wood metal combination shoring are ;
  - ➢ If the strength of the shoring material is suspected to be insufficient to resist the coming load,
  - ➢ Irregular and acute areas on the building that could make it difficult to construct the shoring using standard sized shoring materials,
  - ➢ Limited amount of metal shoring material on the construction site etc.
- ✓ Generally the methods of combinations of eucalyptus wood and metal are:
  - ➢ Metal frames or tubes with eucalyptus ledgers, transoms stringers or joists,
  - ➢ Metal tube for slabs & eucalyptus wood for exposed beam support
  - ➢ Half metal frames or tubes with half eucalyptus and

- Random combination of Eucalyptus wood and metal shoring.

- ✓ For construction of scaffolding stair cases, ladders and working platform commonly wasted eucalyptus wood or “Chefeka”, an Amharic word for very thin eucalyptus wood, were being used in eucalyptus wood scaffolding systems. In most of the projects construction of Guardrail and toe boards were omitted from the constructed scaffolding systems showing their significance in providing safe working environment is overlooked

4.8.2. Influencing factors for selection of shoring and scaffolding systems

- ✓ The top three influencing factors identified by the respondents in the selected building projects were company and market related factors for both shoring and scaffolding systems. Those are financial capacity of the company, Availability of the shoring or scaffolding material in the company and initial cost of the shoring or scaffolding material. However there were also relations between some of Geometry and activity related factors in the top ten influencing factors and the choice of the shoring and scaffolding material.
- ✓ For buildings with exposed beams the most common shoring material were eucalyptus wood metal combination which were being used on 14(45.2%) of buildings which have exposed Beams whereas on flat slab buildings, the most frequently used material were metal shoring 7(53.8%) of flat slab building Projects.
- ✓ The methods of slab concrete construction also have effect on the choice of the shoring material for ribbed slabs Eucalyptus wood is chosen and for sold slabs metal shoring was the most frequently used.
- ✓ For buildings of maximum floor height less than 4 meter eucalyptus wood is commonly used, for the maximum floor height is between 4meter and 8 meter the preference shifts to metal shoring. Despite metal shoring strength is considered to be reliable eucalyptus wood metal combination was used frequently for floor height which exceeds 8 meters. Even though the available data was limited to identify the reason behind this from the conducted site observation it was observed that in addition to metal posts eucalyptus wood was used to construct joists at some elevation levels of the shoring system to make the structure more stable and firm in high clearance buildings.
- ✓ For slow speed of construction eucalyptus wood was preferred over the available types of shoring material but as the expected speed of construction increases metal shoring and then Eucalyptus wood metal combination shoring were preferred. The choice of eucalyptus wood metal combination

for fast expected speed of construction over metal shoring was unreasonable and identifying the reason behind it was unsuccessful with the limited data available.

- ✓ Degrees of repetitiveness of the shoring work also have effect on the choice of the shoring material. Metal scaffoldings are preferred over eucalyptus wood scaffoldings when the numbers of floors are greater than 15 floors.
- ✓ Heights of the building have effect on the choice of the scaffolding material. Metal scaffoldings were chosen over eucalyptus wood as the height of the building exceeds 60m.
- ✓ Expected duration of work on the constructed scaffolding have impact on the choice of the scaffolding systems. The analysis reveals eucalyptus wood was used most frequently than metal scaffoldings in buildings which have plan to use the constructed scaffolding system for more than 6 months. The problem with this approach is since eucalyptus wood is a natural material it will absorb moisture and decompose easily when used for longer period of time exposed to different weather conditions and rainy seasons leading to degradation the material strength creating hazardous working environment.

4.8.3. Comparison of shoring and scaffolding materials

- ✓ Using metal shoring and eucalyptus wood metal combination shoring is faster than Eucalyptus wood shoring by 72% and 40% respectively. The average productivity of one crew using 1 carpenter and 1 daily labor were identified to be 1.26m2/hr. for eucalyptus wood shoring, 2.16 m2/hr. and 1.76 m2/hr. for metal and eucalyptus wood metal combination shoring respectively.
- ✓ Construction of Eucalyptus wood shoring were taking 39%, metal shoring 32% and eucalyptus wood metal combination 31% of the expected floor cycle duration using 12 number of crews. When interpreting these figures it should not be confused with the productivity because the % of expected floor cycle of duration to construct the shoring systems is subjected to not only the speed of construction of the shoring but also on the contractors' plan to complete one floor cycle.
- ✓ Initial cost of the shoring and scaffolding material is one of the three influencing factors for selection of scaffolding material keeping in mind that cost of eucalyptus wood is cheaper than metal scaffoldings. But the cost analysis reviles that using H-frames instead of using Eucalyptus wood have comparative advantage if the life use and speed of construction are considered.
- ✓ Eucalyptus wood which have a life use of 4 times costs more than H- frames with average direct cost difference of 34.41 birr/m2 (47%) & 44.69 birr/m2 (61%) when the life use of the h frame is

20 times & 100 times respectively. Which means H frames costs only 39% to 53 % of eucalyptus wood shoring

- ✓ The average direct cost of adjustable steel props is greater than eucalyptus wood if the life uses of the steel props are less than 60 times. If the life use of the steel prop is 20 times it costs 81.23 birr/m^2 more than eucalyptus wood or 2.11 times cost of eucalyptus wood.
- ✓ Buildings which were using eucalyptus wood for both shoring and scaffolding systems have contributed most of the shares for all kinds of injuries occurred in the selected projects. A total of 10(42%) of the incidents out of the 24 incidents and 2 (33%) of the fatality out of 6 were occurred from these building project.
- ✓ In acute or irregular areas fitting standard sized material such us metal scaffolding was difficult therefore in most cases a combination of metal and eucalyptus wood shoring and scaffolding systems were used.

Chapter 5 Conclusions and Recommendations

This chapter presents the conclusions and recommendations of the research which are based on the results of the data analysis and discussions made on the previous chapters

5.1. Conclusions

As it is to be recalled, the major objectives of the research were to investigate methods and materials of shoring and scaffolding systems, to identify critical factors for selection of shoring and scaffolding systems and finally to make comparison of cost, time, safety, operation and application of the eucalyptus wood with currently available shoring and scaffolding materials around Addis Ababa. The research conclusions made with respect to the mentioned objectives and other related issues are summarized below.

5.1.1. **Methods and materials of scaffolding materials**

- ✓ Eucalyptus wood metal combination is commonly adopted material for construction of shoring. The method of combination varies depending on the reason for adopting this method. Having limited or incomplete metal shoring components on the construction site and unidentified material strength were some of the reasons for adopting this method. As a result the method of combination of eucalyptus wood and metal was variable from projects to projects, the strength and design capacity of the shoring systems are unknown leading to uneconomical and unsafe practice. The industry is demanding for guidelines and code of practices to be used during shoring construction.

- ✓ Eucalyptus wood was the most commonly used scaffolding material for construction of scaffolding systems. Despite the traits and safety issues raised when using eucalyptus wood for longer period time it was preferred over metal scaffolds in projects where their expected duration of work is greater than 6 months. Since eucalyptus wood is a natural material it will absorb moisture and decompose easily when used for longer period of time exposed to different weather conditions and rainy seasons leading to degradation the material strength and creating hazardous working environment. The current practice of scaffolding systems are giving priority to companies profitably over the health and safety of the workers

- ✓ Generally the methods of scaffolding construction were dependent on the experience of the crew. As a result there were no designs, plan or estimation of the shoring and scaffolding works which makes it difficult to monitor and control the shoring and scaffolding works against its cost, speed of construction or safety of the working environment. Hence contributing to health and safety problems raised in the construction industry and wastage of resources employed for construction of shoring and scaffolding works.

5.1.2. Influencing factors for selection of shoring and scaffolding systems

- ✓ The top three influencing factors identified by the respondents were company and market related factors for both shoring and scaffolding systems. Those are
    - ➢ Financial capacity of the company,
    - ➢ Availability of the shoring and scaffolding material in the company and
    - ➢ Initial cost of the shoring and scaffolding material.
- ✓ Considering these top three influencing factors, the commonly used shoring and scaffolding materials and profiles of the contractors on the selected building projects, which was 36(81.8%) of them were grade one contractors and 50 % of them have been in the construction industry for more than 10 years, it can be concluded that investing on shoring and scaffolding materials as an asset of a company have been given less priority and shoring and scaffolding works have not been given enough consideration as direct works in building construction industry around Addis Ababa.
- ✓ From the pattern of the selected scaffolding material and some characteristics of the selected building projects, type of the slab, method of slab concrete construction, maximum floor height, degree of repetition the shoring work and expected floor cycle duration were also found to be the other critically influencing factors for selection of the shoring materials and for selection of scaffolding material height of the building and expected duration of work on the constructed scaffolding systems were the other critically influencing factors.

5.1.3. Comparison of shoring and scaffolding materials

- ✓ Construction of shoring works was taking 31% - 39% of the expected floor cycle duration of the selected projects. Using metal shoring and scaffolding is faster than eucalyptus wood and eucalyptus wood metal combination. Construction of metal shoring was faster than Eucalyptus wood shoring by

72%. Selecting the appropriate shoring material in building multi story buildings have immense role in completing the projects with short period of time.

- ✓ The initial material cost of eucalyptus wood is cheaper than metal shoring and scaffolding. However the cost analysis reviles that using H-frames instead of using eucalyptus wood have comparative advantage if the life use and speed of construction are considered. Eucalyptus wood shoring costs more than H- frames with average direct cost difference of 34.41 birr/m2 (47%) when the life use of the eucalyptus wood and H- frame is 4 times & 20 times respectively. Despite the tread way thinking metal shoring and scaffoldings are cheaper than eucalyptus wood.
- ✓ Buildings which were using eucalyptus wood for both shoring and scaffolding system have contributed most of the shares for all kinds of injuries occurred in the selected projects. This makes eucalyptus wood shoring and scaffolding systems construction prone to many accidents calling for modernization of the method of construction of shoring and scaffolding in Addis Ababa building projects
- ✓ From the comparative advantages of metal shoring and scaffolding systems and the observed current practice of shoring and scaffolding systems in building construction projects around Addis Ababa it can be concluded that constructors underestimate the importance of shoring and scaffolding works since they do not give enough attention to the scaffolding works, making their judgment based on the trend experience rather than making detailed analysis, design and planning for successful project implementation. Lack of rules, regulations and code of practices related to shoring and scaffolding systems also attributes to the mentioned problems

5.2 Recommendations

Based on the above findings the researcher forwarded the following recommendations for improving the current practice of scaffolding systems in building construction industry around.

- ✓ The use of eucalyptus wood scaffolding should be gradually outdated from the building construction industry at least for high rise buildings due to the comparative advantage of metal shoring and scaffolding systems on the cost, speed of construction and improving the safety of the working environment.
- ✓ Policy which prohibits contractors from using eucalyptus wood should be enacted. The policy should consider contractors grade and height of the building projects. Grade one contractors should be

prohibited first and applying the policy gradually to other grade contractors too. Approval for high rise building construction should not be given unless the client or contractors agree to use metal shoring and scaffolding materials instead of eucalyptus wood.

- ✓ Contractors should give enough consideration for shoring and scaffolding works as it takes 31%-38 % of the floor cycle duration, it affects directly the total project duration. They should develop the habit of designing, estimating and planning the shoring and scaffolding requirements in early stages of the construction to eliminate the problems related to shoring and scaffolding works and improve the project cost, completion time and the safety of the working environment.
- ✓ There should be strict inspection and regulation by providing Design and code of practice for shoring and scaffolding systems and Ministry of Urban Development and Construction should consider shoring and scaffolding, type and amount, as main criteria for grading of the contractors.
- ✓ Metal shoring and scaffolding suppliers should make the market more attractive by providing incentives and credit facilities with fair interest rates for contractors to increase the demand of metal shoring and scaffoldings since they can play a big role in eliminating the initial cost difference as the major reason for selecting eucalyptus wood scaffolding over metal scaffoldings.
- ✓ The government of Ethiopia should support local contractors by providing long term loans with fair interest rate so that they can purchase metal shoring and scaffolding easily, which will eliminate the initial cost and financial capacity of a contractor as selection criteria of shoring and scaffolding materials.

Recommendations for Further Works

This research has identified major shortcomings of the national contractors' practice, with regard to shoring and scaffolding works. Therefore the following issues are identified and suggested for future studies.

- ✓ Development of a shoring and scaffolding estimation tool that could help for selection of shoring and scaffolding material for different building projects.
- ✓ Design of shoring and scaffoldings systems related to the current practice of the building construction industry In Addis Ababa.

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APPENDIX

Appendix - A Questionnaire

Assessment on Current Practice of shoring and Scaffolding Systems in Building Construction Industry

Questionnaire listed below are statements, which describe some aspects of Scaffolding practice in your project. Please rate the stated propositions by marking the appropriate boxes or fill in the blanks. The questionnaire will be used for a thesis that is being conducted to assess the current scaffolding practice in building construction around Addis Ababa. All the information you submit will be treated confidentially. I am sincerely thankful for your earnest cooperation in advance.

Section one: Personal information

1. Job title:
   Company owner ☐ Project manager ☐ Site engineer ☐ other ☐
2. Experience in construction industry:

______________ Years

3. Number of building projects worked in the past years:

______________ Projects

Section Two: Project information

1. Grade of the contractor in this building project ____
2. Year of establishment of the contractor____
3. Grade of the consultant in this building project ____
4. Year of establishment of the consultant____
5. Client of this building project: Government ☐ Private company ☐
6. Purpose of the building project:
   Commercial ☐ Office ☐ Apartment ☐ Hospital ☐ Multipurpose ☐
7. Estimated Total Cost of the project ____
8. Estimated project Duration ____
9. Perimeter of the Building ____
10. Height of the building ____
11. No of stories ____
12. Maximum Floor height ____
13. Ground floor Area ____

14. Average floor Area ____

15. Total Area of the construction Site ____

16. Shape of the building: Rectangular ☐ Circular ☐ Irregular ☐

17. Method of slab concrete construction: Cast in situ ☐ Prefabricated ☐

18. Type of slab:

One way slab (with beam) ☐ Two way slab (with beam) ☐ Flat slab ☐ Flat plate ☐ Joist slab ☐ Waffled slab ☐

19. Expected duration to complete construction of one floor structural elements ________________

20. Type of scaffolding system used or planning to use in this building project

Supported scaffolding ☐ suspended scaffolding ☐ Mobile scaffolding ☐ other ☐

21. shoring material used or planning to use for supporting structural elements:

Eucalyptus Wood ☐ Metal ☐ Eucalyptus wood metal combination ☐

22. Scaffolding material used or planning to use for providing temporary access on elevated area:

Eucalyptus Wood ☐ Metal ☐ Eucalyptus wood metal combination ☐

Section Three: Influencing factors for selection of shoring and scaffolding systems

Please choose the weight of the following influencing factors you considered while selecting the shoring and scaffolding material in this building project. Shoring is structures built to provide support in construction of slabs, beams, and staircase. Scaffoldings are structures built to provide access and working platforms on elevated areas. The influence of the factors will be measured based on 5 scaled rating, where each scale represents:

1. Not at all influential
2. Slightly influential
3. Somewhat influential
4. Very influential
5. Extremely influential

Please feel free to add the factors you consider are important and are not listed below.

No	Influencing Factors	Purpose of the system									
		Shoring					Scaffolding				
		Scale					Scale				
		1	2	3	4	5	1	2	3	4	5
1	Perimeter of the building										
2	Area per floor										
3	Height of the building										
4	Maximum floor height										
5	Type of the slab and Formwork to be supported										
6	Shape of the building										
7	Volume of acute areas and irregularity of the building										
8	Degree of repetitiveness of work (no of floors)										
9	Expected floor cycle duration										
10	Expected duration of work on the constructed system										
11	Skill of the crew										
12	Health and safety of workers										
13	Location of the project										
14	Weather condition										
15	Manpower availability										
16	Type and complexity of the construction working Area										
17	Terms and specifications in the contract document										
18	Available codes and standards										
19	Environmental effects of the materials										
20	Financial capacity of the company										
21	Availability of the material in the company										
22	Availability of the material in the market										
23	Initial cost of the material										
24	Life cycle cost of the material										

Section Four: Shoring and Scaffolding performance

1. Please provide the amount of the following parameters you used or plan to use per **ONE FLOOR** construction of scaffolding system in your building project. Please note that shoring is structure built to provide support in construction of slabs, beams, and staircase. External scaffolding are structures built to provide access and working platforms on elevated height around the external wall of the building. Internal scaffolding represents structures built to support temporary ladders, guardrails, and staircases. Please feel free to add any cost element you consider important.

No	Parameters	Unit	Unit Cost	Quantity Per One Floor		
				Purpose of the system		
				Shoring	External Scaffolding	Internal Scaffolding
1	Type of material (Eucalyptus, Metal or Eucalyptus wood metal combination)	Type	NA			
2	Spacing between Posts in both longitudinal and transversal direction	Meter	NA			
3	H-frame(1.70m (height) x 1.20m (width) x 1.80m (length)	Pcs				
4	Galvanized H-frame(1.70m (height) x 1.20m (width) x 1.80m (length)	Pcs				
5	Steel Tubes (dia. = 48mm)	Pcs				
6	Galvanized steel Tubes (dia. 48mm)	Pcs				
7	Right-angle couplers	Pcs				
8	Putlog couplers	Pcs				
9	Swivel couplers	Pcs				
10	Sleeve or external joiner	Pcs				
11	Pin or internal joiner	Pcs				
12	Adjustable base plates	Pcs				
13	Eucalyptus dia. 10- 12cm, length= 8m	Pcs				
14	Eucalyptus dia. 10-12 cm, length= 4m	pcs				
15	Eucalyptus dia. 8cm, length= 4m	pcs				
16	Eucalyptus dia. 6cm, length= 4m	Bundle				
17	#4 nail	Packet				
18	#6 nail	Packet				
19	#8 nail	Packet				
20	#9 nail	Packet				
21	#10 nail	Packet				
22	#12 nail	Packet				
23	Bolt ties	Pcs				
24	Ropes	m				
25	Sheeting	m^2				

No	Parameters	Unit	Unit Cost	Quantity Per One Floor		
				Purpose of the system		
				Shoring	External Scaffolding	Internal Scaffolding
26	Wasted material in %	%				
27	How many times do you reuse the materials	No				
28	Waste disposal cost	Birr				
29	No. of crew	No				
30	No. of carpenter in one crew	No				
31	No. of daily labor in one crew	No				
32	Duration to prepare materials	Days				
33	Duration to construct the system:					
	Elevation level from Ground- G+4	Days				
	G+5 – G+8	Days				
	G+9 – G+12	Days				
	G+ 13 - G+ 16	Days				
	G+17 – G+20	Days				
	> G20	Days				
34	Duration to dismantle the system	Days				
35	Expected duration to work on the constructed system	Days				
36	Hiring rate of carpenter	Birr/day				
37	Hiring rate of daily labor	Birr/day				
38	Hiring rate of subcontractor	Birr/m^2 (Birr/m)				

2. On scale of 1 to 5 describe the skill of the shoring and scaffolding crew performance, where ‘1” refers to Poor and ‘5’ refers to excellent performance: ____

3. What was the proportion of acute and irregular areas to the total floor areas (%) that could make it difficult for the construction of the shoring and scaffolding system? ______________________________

4. Describe the safety incidents and accidents that occurred while constructing or using the shoring and scaffolding systems and what were the major causes of these accidents?

Incident/ Accident Case	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**
A. Year of case					
B. Type and number of incident:					
Near miss incident					
First aid needing incident					
Medical attention needing incident					
Fatality					
C. Major cause					

5. Please describe major problems that occurred in construction and use of the shoring material as the height of the building increases? What measures did you take to solve this problem?

____

____

____

____

6. Please describe major problems that occurred in construction and use of the scaffolding material as the height of the building increases? What measures did you take to solve this problem?

____

____

____

____

7. Please describe major problems that occurred in construction of shoring and scaffolding where there are window openings, acute areas and irregularities on the buildings? What measures did you take to solve this problem?

____

____

____

____

Other comment related to shoring and scaffolding practices in Addis Ababa

If you feel there is any other issue related to shoring and scaffolding practices in Addis Ababa that should be raised please do not hesitate to mention?

____

____

____

____

Appendix- B Cost Break Down For Shoring

A. Cost Break down for eucalyptus wood shoring

Life use of 4 times

Eucalyptus wood shoring for Solid slabs spacing between posts 60cm x60 cm 1.44

A. material cost					B. Labor cost						C. Tools and Equipment						
Type of material	**unit**	**Qty.**	**unit rate**	**Cost per unit**	**Labor tread**	**No**	**UF**	**Indexed cost**	**out put**	**Cost per unit**	**Tools**	**No**	**UF**	**Hourly rental cost**	**out put**	**Cost per unit**	**Direct cost= A+B+C**
Eucalyptus wood dia.10- 12	ml	14.06	3.28	46.1	Carp.	1	1	35.25	1.26	28	Tools	2	1	1	1.26	1.59	
Eucalyptus wood dia.8cm	ml	7.33	1.56	11.46	DL	1	1	10	1.26	7.9							
Nail 12	Kg	0.02	35	0.80													
Nail 10	Kg	0.06	35	2.07													
Nail 8	Kg	0.01	35	0.36													
				60.8						**35.9**						**1.59**	**98.3**
Remark				Use of eucalyptus wood 4 times and wastage 10%													
				Nail wastage 5%													

Eucalyptus wood shoring for Solid slabs spacing between posts 90cm x90 cm 3.24

A. material cost					B. Labor cost						C. Tools and Equipment						
Type of material	**unit**	**Qty.**	**unit rate**	**Cost per unit**	**Labor tread**	**No**	**UF**	**Indexed cost**	**out put**	**Cost per unit**	**Tools**	**No**	**UF**	**Hourly rental cost**	**out put**	**Cost per unit**	**Direct cost= A+B+C**
Eucalyptus wood dia.10- 12	ml	6.65	3.28	21.8	Carp.	1	1	35.25	1.26	28	Tools	2	1	1	1.26	1.59	
Eucalyptus wood dia.8cm	ml	6.11	1.56	9.55	DL	1	1	10	1.26	7.9							
Nail 12	Kg	0.01	35.00	0.36													
Nail 10	Kg	0.04	35.00	1.23													
Nail 8	Kg	0.00	35.00	0.16													
				33.1						**35.9**						**1.59**	**70.6**
Remark				Use of eucalyptus wood 4 times and wastage 10%													
				Nail wastage 5%													

Eucalyptus wood shoring for ribbed slabs spacing between posts 60cm x60 cm 1.44

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Eucalyptus wood dia.10- 12	ml	5.43	3.28	17.8	Carp.	1	1	35.25	1.26	28	Tools	2	1	1	1.26	0	
Eucalyptus wood dia.8cm	ml	3.67	1.56	5.73	DL	1	1	10	1.26	7.9							
Nail 12	Kg	0.02	35	0.80													
Nail 10	Kg	0.02	35	0.69													
Nail 8	Kg	0.01	35	0.36													
				25.4						**35.9**						**1.59**	**61.3**
Remark				Use of eucalyptus wood 4 times and wastage 10%													
				Nail wastage 5%													

Eucalyptus wood shoring for ribbed slabs spacing between posts 90cm x90 cm

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost = A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Eucalyptus wood dia.10- 12	ml	5.43	3.28	17.8	Carp.	1	1	35.25	1.26	27.9	Tools	2	1	1	1.26	1.59	
Eucalyptus wood dia.8cm	ml	3.67	1.56	5.73	DL	1	1	10	1.26	7.9							
Nail 12	Kg	0.01	35	0.36													
Nail 10	Kg	0.01	35	0.31													
Nail 8	Kg	0.00	35	0.16													
				24.4						**35.9**						**1.59**	**61.9**
Remark				Use of eucalyptus wood 4 times and wastage 10%													
				Nail wastage 5%													

Life use 8 times

Eucalyptus wood shoring for Solid slabs spacing between posts 60cm x60 cm 1.44

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Eucalyptus wood dia.10- 12	ml	14.06	1.64	23.06	Carp.	1	1	35.25	1.26	28	Tools	2	1	1	1.26	1.59	
Eucalyptus wood dia.8cm	ml	7.33	0.78	5.73	DL	1	1	10	1.26	7.94							
Nail 12	Kg	0.02	35	0.80													
Nail 10	Kg	0.06	35	2.07													
Nail 8	Kg	0.01	35	0.36													
				32.03						**35.9**						**1.59**	**69.5**
Remark				Use of eucalyptus wood 8 times and wastage 10%													
				Nail wastage 5%													

Eucalyptus wood shoring for Solid slabs spacing between posts 90cm x90 cm 3.24

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost = A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Eucalyptus wood dia.10- 12	ml	6.65	1.64	10.92	Carp.	1	1	35.25	1.26	28	Tools	2	1	1	1.26	1.59	
Eucalyptus wood dia.8cm	ml	6.11	0.78	4.77	DL	1	1	10	1.26	7.94							
Nail 12	Kg	0.01	35	0.36													
Nail 10	Kg	0.04	35	1.23													
Nail 8	Kg	0.005	35	0.16													
				17.44						**35.91**						**1.59**	**54.9**
Remark				Use of eucalyptus wood 8 times and wastage 10%													
				Nail wastage 5%													

Eucalyptus wood shoring for ribbed slabs spacing between posts 60cm x60 cm 1.44

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost = A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Eucalyptus wood dia.10- 12	ml	5.43	1.64	8.91	Carp.	1	1	35.25	1.26	28	Tools	2	1	1	1.26	1.59	
Eucalyptus wood dia.8cm	ml	3.67	0.78	2.86	DL	1	1	10	1.26	7.94							
Nail 12	Kg	0.02	35	0.80													
Nail 10	Kg	0.02	35	0.69													
Nail 8	Kg	0.01	35	0.36													
				13.63						**35.9**						**1.59**	**51.1**
Remark				Use of eucalyptus wood 8 times and wastage 10% Nail wastage 5%													

Eucalyptus wood shoring for ribbed slabs spacing between posts 90cm x90 cm 3.24

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Eucalyptus wood dia. 10- 12	ml	5.43	1.64	8.91	Carp.	1	1	35.25	1.26	28	Tools	2	1	1	1.26	1.59	
Eucalyptus wood dia.8cm	ml	3.67	0.78	2.86	DL	1	1	10	1.26	7.94							
Nail 12	Kg	0.01	35	0.36													
Nail 10	Kg	0.01	35	0.31													
Nail 8	Kg	0.005	35	0.16													
				12.60						**35.9**						**1.59**	**50.1**
Remark				Use of eucalyptus wood 8 times and wastage 10% Nail wastage 5%													

B. Cost Break Down For H- Frame shoring

Life use 20 times

H-frame 1.20m (width) x 1.80m (length)x2.4m Height spacing 80cmx 180cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost = A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.80m (length)x 2.4m(Height)	full set	0.14	155	21.53	Carp.	1	1	35.3	2.16	16.3	Tools	2	1	1	2.16	0.9	
RHS 60cm X 60cm X 1.5mmx 6m	Pcs	0.18	22	3.96	DL	1	1	10	2.16	4.62							
RHS 40cm X 40cm X 1.5mmx 6m	Pcs	0.49	12.5	6.13													
Black wire 2.5	Kg	0.02	35	0.77													
				32.3						**20.9**						**0.9**	**54.1**
Remark				Use of H- frame 20 times and wastage 0% Use of RHS 20 times Spacing :- RHS 60x60 - c/c 120cm & 80cm RHS 40x40 - c/c 40cm wastage 5%, the price includes top jacks													

H-frame 1.20m (width) x 1.80m (length)x2.4m Height spacing 120cmx 180cm 8.64

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost = A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.80m (length)x 2.4m (Height)	full set	0.12	155	17.94	Carp.	1	1	35.3	2.16	16.3	Tools	2	1	1	2.16	0.9	
RHS 60cm X 60cm X 1.5mm x 6m	Pcs	0.15	22	3.3	DL	1	1	10	2.16	4.62							
RHS 40cm X 40cm X 1.5mm x 6m	Pcs	0.49	12.5	6.13													
Black wire 2.5	Kg	0.02	35	0.77													
				28.14						**20.9**						**0.9**	**53**
Remark	Use of H- frame 20 times and wastage 0% Use of RHS 20 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%, the price includes top jacks																

H-frame 1.20m (width) x 1.50m (length)x2.4m(length) spacing 80cm x 150cm 6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.17	145	24.17	Carp.	1	1	35.3	2.16	16.3	Tools	2	1	1	2.16	0.93	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.18	22	3.96	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.50	12.5	6.25													
Black wire 2.5	Kg	0.02	35	0.77													
				35.15						**20.9**						**0.93**	**57.0**
Remark				Use of H- frame 20 times and wastage 0%													
				Use of RHS 20 times Spacing :- RHS 60x60 - 120cm & 80cm , RHS 40x40 - c/c 40cm wastage 5%													

H-frame 1.20m (width) x 1.50m (length)x2.4m(length) spacing 120cm x 150cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost=A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.14	145	20.14	Carp.	1	1	35.3	2.16	16.3	Tools	2	1	1	2.16	0.93	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.15	22	3.3	DL	1	1	10	2.16	4.6							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.50	12.5	6.25													
Black wire 2.5	Kg	0.02	35	0.77													
				30.46						**20.9**						**0.93**	**52.32**
Remark				Use of H- frame 20 times and wastage 0%													
				Use of RHS 20 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%													

Life use 40 times

H-frame 1.20m (width) x 1.80m (length)x2.4m Height spacing 80cmx 180cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.80m (length)x2.4m Height full set	full set	0.14	77.5	10.8	Carp.	1	1	35.25	2.16	16.3	Tools	2	1	1	2.16	0.93	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.18	11	1.98	Dl	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.48	6.25	3													
Black wire 2.5	Kg	0.02	35	0.78													
				16.55						**20.9**						**0.93**	**38.4**
Remark	Use of H- frame 40 times and wastage 0% Use of RHS 40 times Spacing :- RHS 60x60 - c/c 120cm & 80cm, RHS 40x40 - c/c 40cm wastage 5%, the price includes top jacks																

H-frame 1.20m (width) x 1.80m (length)x2.4m Height spacing 120cmx 180cm 8.64

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.80m (length)x2.4m Height full set	full set	0.12	77.5	8.97	Carp.	1	1	35.25	2.16	16.3	Tools	2	1	1	2.16	0.9	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.15	11	1.65	Dl	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.49	6.25	3.06													
Black wire 2.5	Kg	0.02	35	0.77													
				14.45						**20.9**						**0.93**	**36.3**
Remark				Use of H- frame 40 times and wastage 0% Use of RHS 40 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%, the price includes top jacks													

H-frame 1.20m (width) x 1.50m (length)x2.4m(length) spacing 80cm x 150cm 6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x1.50m (length) x2.4m Height full set	full set	0.17	72.5	12.08	Carp.	1	1	35.25	2.16	16.3	Tools	2	1	1	2.16	0.93	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.18	11	1.98	Dl	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.5	6.25	3.13													
Black wire 2.5	Kg	0.02	35	0.77													
				16						**20.9**						**0.93**	**37.9**
Remark				Use of H- frame 40 times and wastage 0%													
				Use of RHS 40 times Spacing :- RHS 60x60 - c/c 120 & 80cm,RHS 40x40 - c/c 40cm wastage 5%													

H-frame 1.20m (width) x 1.50m (length)x2.4m(length) spacing 120cm x 150cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.14	72.5	10.07	Carp.	1	1	35.25	2.16	16.3	Tools	2	1	1	2.16	0.93	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.15	11	1.65	Dl	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.45	6.25	2.8													
Black wire 2.5	Kg	0.02	35	0.77													
				15.3						**20.9**						**0.93**	**37.2**
Remark				Use of H- frame 40 times and wastage 0%													
				Use of RHS 40 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%													

Life use 60 times

H-frame 1.20m (width) x 1.80m (length)x2.4m Height spacing 80cmx 180cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.80m (length)x2.4m Height full set	full set	0.14	51.7	7.18	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	0.92	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.18	7.33	1.32	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.49	4.17	2.08													
Black wire 2.5	Kg	0.02	35	0.77													
				11.4						**21**						**0.92**	**33.5**
Remark				Use of H- frame 60 times and wastage 0% Use of RHS 60 times Spacing :- RHS 60x60 - c/c 120cm & 80cm, RHS 40x40 - c/c 40cm wastage 5%, the price includes top jacks													

H-frame 1.20m (width) x 1.80m (length)x2.4m Height spacing 120cmx 180cm 8.64

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.80m (length)x2.4m Height full set	full set	0.12	51.7	5.98	Carp.	1	1	35.3	2.16	16.3	Tools	2	1	1	2.16	0.92	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.15	7.33	1.1	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.49	4.17	2.04													
Black wire 2.5	Kg	0.02	35	0.77													
				9.89						**21**						**0.92**	**31.8**
Remark				Use of H- frame 60 times and wastage 0% Use of RHS 60 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%, the price includes top jacks													

H-frame 1.20m (width) x 1.50m (length)x2.4m(length) spacing 80cm x 150cm 6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.17	48.3	8.06	Carp.	1	1	35.3	2.16	16.3	Tools	2	1	1	2.16	0.92	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.18	7.33	1.32	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.5	4.17	2.08													
Black wire 2.5	Kg	0.02	35	0.77													
				12.2						**21**						**0.92**	**34**
Remark			Use of H- frame 60 times and wastage 0%														
			Use of RHS 60 times Spacing :- RHS 60x60 - c/c 120 & 80cm, RHS 40x40 - c/c 40cm wastage 5%														

H-frame 1.20m (width) x 1.50m (length)x2.4m(length) spacing 120cm x 150cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.14	48.3	6.71	Carp.	1	1	35.3	2.16	16.3	Tools	2	1	1	2.16	0.92	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.15	7.33	1.1	Dl	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.50	4.17	2.08													
Black wire 2.5	Kg	0.02	35	0.77													
				10.7						**21**						**0.92**	**32**
Remark			Use of H- frame 60 times and wastage 0%														
			Use of RHS 60 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%														

Life use 80 times

H-frame 1.20m (width) x 1.80m (length)x2.4m Height spacing 80cmx 180cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.80m (length)x2.4m Height full set	full set	0.139	38.75	5.38	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	0.9	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.175	5.5	0.96	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.486	3.13	1.52													
Black wire 2.5	Kg	0.022	35	0.77													
				8.64						**21**						**0.9**	**30.5**
Remark	Use of H- frame 80 times and wastage 0%																
	Use of RHS 50 times Spacing :- RHS 60x60 - c/c 120cm & 80cm, RHS 40x40 - c/c 40cm wastage 5%, the price includes top jacks																

H-frame 1.20m (width) x 1.80m (length)x2.4m Height spacing 120cmx 180cm 8.6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.80m (length)x2.4m Height full set	full set	0.116	38.75	4.49	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	0.9	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.146	5.5	0.8	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.486	3.13	1.52													
Black wire 2.5	Kg	0.022	35	0.77													
				7.58						**21**						**0.9**	**29.5**
Remark	Use of H- frame 80 times and wastage 0%																
	Use of RHS 80 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%, the price includes top jacks																

H-frame 1.20m (width) x 1.50m (length)x2.4m(length) 6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	**unit**	**Qty.**	**unit rate**	**Cost per unit**	**Labor tread**	**No**	**UF**	**Indexed cost**	**out put**	**Cost per unit**	**Tools**	**No**	**UF**	**Hourly rental cost**	**out put**	**Cost per unit**	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.18	36.25	6.04	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	0.9	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.18	5.5	0.96	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.5	3.13	1.52													
Black wire 2.5	Kg	0.02	35	0.77													
				9.36						**21**						**0.9**	**31.3**
Remark				Use of H- frame 80 times and wastage 0%													
				Use of RHS 80 times Spacing :- RHS 60x60 - c/c 120 & 80cm, RHS 40x40 - c/c 40cm wastage 5%													

H-frame 1.20m (width) x 1.50m (length)x2.4m(length) spacing 120cm x 150cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	**unit**	**Qty.**	**unit rate**	**Cost per unit**	**Labor tread**	**No**	**UF**	**Indexed cost**	**out put**	**Cost per unit**	**Tools**	**No**	**UF**	**Hourly rental cost**	**out put**	**Cost per unit**	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.139	36.25	5.04	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	0.9	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.146	5.5	0.8	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.496	3.13	1.52													
Black wire 2.5	Kg	0.022	35	0.77													
				8.2						**21**						**0.9**	**30.1**
Remark				Use of H- frame 80 times and wastage 0%													
				Use of RHS 80 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%													

Life use 100 times

H-frame 1.20m (width) x 1.80m (length)x2.4m Height spacing 80cmx 180cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.80m (length)x2.4m Height full set	full set	0.14	31	4.31	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	0.92	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.18	4.4	0.77	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.49	2.5	1.22													
Black wire 2.5	Kg	0.02	35	0.77													
				7.06						**21**						**0.92**	**29.0**
Remark				Use of H- frame 100 times and wastage 0%													
				Use of RHS 100 times Spacing :- RHS 60x60 - c/c 120cm & 80 cm, RHS 40x40 - c/c 40cm wastage 5%, the price includes top jacks													

H-frame 1.20m (width) x 1.80m (length)x2.4m Height spacing 120cmx 180cm 8.64

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.80m (length)x2.4m Height full set	full set	0.12	31	3.59	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	0.92	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.15	4.4	0.64	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.49	2.5	1.22													
Black wire 2.5	Kg	0.02	35	0.77													
				6.22						**21**						**0.92**	**28.14**
Remark				Use of H- frame 100 times and wastage 0%													
				Use of RHS 100 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%, the price includes top jacks													

H-frame 1.20m (width) x 1.50m (length)x2.4m(length) spacing 80cm x 150cm 6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.17	29	4.83	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	0.92	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.18	4.4	0.77	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.5	2.5	1.22													
Black wire 2.5	Kg	0.02	35	0.77													
				7.02						**21**						**0.92**	**28.9**
Remark	Use of H- frame 100 times and wastage 0%																
	Use of RHS 100 times Spacing :- RHS 60x60 - c/c 120 & 80cm, RHS 40x40 - c/c 40cm wastage 5%																

H-frame 1.20m (width) x 1.50m (length)x2.4m(length) spacing 120cm x 150cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.14	29	4.03	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	0.92	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.15	4.4	0.64	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.50	2.5	1.22													
Black wire 2.5	Kg	0.02	35	0.77													
				6.71						**21**						**0.92**	**28.6**
Remark	Use of H- frame 100 times and wastage 0%																
	Use of RHS 100 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%																

C. Cost Break Down for adjustable Steel props

Life use 20 times

Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 60cm x60cm 1.4

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	**unit**	**Qty.**	**unit rate**	**Cost per unit**	**Labor tread**	**No**	**UF**	**Indexed cost**	**out put**	**Cost per unit**	**Tools**	**No**	**UF**	**Hourly rental cost**	**out put**	**Cost per unit**	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	pcs	2.78	55	153	Carp.	1	1	35	2.16	16	Tools	2	1	1	2.16	1	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.29	22	6.4	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.58	13	7.3													
Black wire 2.5	Kg	0.02	35	0.77													
				167.3						**21**						**0.925**	**189**
Remark				Use of steel props 20 times and wastage 0%													
				Use of RHS 20 times Spacing :- RHS 60x60 - c/c 60cm, RHS 40x40 - c/c 40cm wastage 5%													

Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 80cm x80cm 2.6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	**unit**	**Qty.**	**unit rate**	**Cost per unit**	**Labor tread**	**No**	**UF**	**Indexed cost**	**out put**	**Cost per unit**	**Tools**	**No**	**UF**	**Hourly rental cost**	**out put**	**Cost per unit**	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	Pcs	1.56	55	85.9	Carp.	1	1	35	2.16	16	Tools	2	1	1	2.16	0.925	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.22	22	4.8	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.55	13	6.8													
Black wire 2.5	Kg	0.02	35	0.77													
				97.9						**21**						**0.925**	**119**
Remark				Use of steel props 20 times and wastage 0%													
				Use of RHS 20 times Spacing :- RHS 60x60 - c/c 80cm, RHS 40x40 - c/c 40cm wastage 5%													

Life use 40 times

Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 60cm x60cm 1.4

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	pcs	2.778	27.5	76.4	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	0.9	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.292	11	3.21	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.583	6.25	3.65													
Black wire 2.5	Kg	0.022	35	0.77													
				84.0						**21**						**0.9**	**106**
				Use of steel props 40 times and wastage 0%													
Remark				Use of RHS 40 times Spacing :- RHS 60x60 - c/c 60cm, RHS 40x40 - c/c 40cm wastage 5%													

Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 80cm x80cm 3

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	Pcs	1.563	27.5	43	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	1	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.219	11	2.41	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.547	6.25	3.42													
Black wire 2.5	Kg	0.022	35	0.77													
				49.5						**21**						**0.9**	**71.5**
				Use of steel props 40 times and wastage 0%													
Remark				Use of RHS 40 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%													

Life use 60 times

Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 60cm x60cm 1.4

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	pcs	2.78	18	50.9	Carp.	1	1	35	2.16	16.30	Tools	2	1	1	2.16	0.93	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.29	7.3	2.1	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.58	4.2	2.4													
Black wire 2.5	Kg	0.02	35	0.77													
				56.2						**20.92**						**0.93**	**78.04**
Remark				Use of steel props 60 times and wastage 0%													
				Use of RHS 60 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%													

Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 80cm x80cm 2.6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	pcs	1.56	18	28.6	Carp.	1	1	35	2.16	16	Tools	2	1	1	2.16	0.93	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.22	7.3	1.6	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.55	4.2	2.3													
Black wire 2.5	Kg	0.02	35	0.77													
				33						**21**						**0.93**	**55**
Remark				Use of steel props 60 times and wastage 0%													
				Use of RHS 60 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%													

Life use 80 times

Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 60cm x60cm 1.44

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	**unit**	**Qty.**	**unit rate**	**Cost per unit**	**Labor tread**	**No**	**UF**	**Indexed cost**	**out put**	**Cost per unit**	**Tools**	**No**	**UF**	**Hourly rental cost**	**out put**	**Cost per unit**	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	pcs	2.77	13.8	38.2	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	0.92	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.29	5.5	1.6	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.58	3.13	1.82													
Black wire 2.5	Kg	0.02	35	0.77													
				42.3						**21**						**0.92**	**64.2**
Remark				Use of steel props 80 times and wastage 0%													
				Use of RHS 80 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%													

Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 80cm x80cm 3

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	**unit**	**Qty.**	**unit rate**	**Cost per unit**	**Labor tread**	**No**	**UF**	**Indexed cost**	**out put**	**Cost per unit**	**Tools**	**No**	**UF**	**Hourly rental cost**	**out put**	**Cost per unit**	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	Pcs	1.56	13.8	21.5	Carp.	1	1	35.3	2.16	16	Tools	2	1	1	2.16	1	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.22	5.5	1.2	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.55	3.13	1.71													
Black wire 2.5	Kg	0.02	35	0.77													
				25.2						**21**						**0.9**	**47.1**
Remark				Use of steel props 80 times and wastage 0%													
				Use of RHS 40 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%													

Life use 100 times

Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 60cm x60cm 1.44

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	pcs	2.78	11	30.6	Carp	1	1	35	2.16	16.30	Tools	2	1	1	2.16	0.925	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.29	4.4	1.3	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.58	2.5	1.5													
Black wire 2.5	Kg	0.02	35	0.77													
				34.1						**20.92**						**0.925**	**56.0**
Remark				Use of steel props 100 times and wastage 0% Use of RHS 100 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%													

Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 80cm x80cm 2.6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	pcs	1.56	11	17.2	Carp.	1	1	35	2.16	16	Tools	2	1	1	2.16	0.925	
RHS 60cm X60cm X 1.5mmx 6m	Pcs	0.22	4.4	0.55	DL	1	1	10	2.16	4.62							
RHS 40cm X40cm X 1.5mmx 6m	Pcs	0.55	2.5	2.41													
Black wire 2.5	Kg	0.02	35	0.77													
				20.3						**21**						**0.925**	**42.4**
Remark				Use of steel props 100 times and wastage 0% Use of RHS 100 times Spacing :- RHS 60x60 - c/c 120cm, RHS 40x40 - c/c 40cm wastage 5%													

D. Cost Break Down For Eucalyptus wood Metal Combination

Life use of H- frame 20 times
Eucalyptus wood 6 times

Eucalyptus wood metal combination:- H-frame 1.20m (width) x 1.80m (length)x2.4m Height & eucalyptus wood for joists Spacing 80cm x 180cm

7.2

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m	full set	0.14	155	22	Carp.	1	1	35	1.76	20.0	Tools	2	1	1	1.76	1.1	
Eucalyptus wood dia. 10- 12	ml	1.10	2.2	2.4	DL	1	1	10	1.76	5.6							
Eucalyptus wood dia. 8cm	ml	3.97	1	4.1													
Nail 10	Kg	0.03	35	0.9													
Black wire 2.5	Kg	0.02	35	0.8													
				30						**25.6**						**1.1**	**56**
Remark	Use of H- frame 20 times and wastage 0%																
	use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%																

Eucalyptus wood metal combination:- H-frame 1.20m (width) x 1.80m (length)x2.4m Height & eucalyptus wood for joists Spacing 120cm x 180cm

8.6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height	full set	0.12	155	18	Carp.	1	1	35	1.76	20	Tools	2	1	1	1.76	1.1	
Eucalyptus wood dia. 10- 12	ml	0.92	2.2	2	DL	1	1	10	1.76	5.7							
Eucalyptus wood dia. 8cm	ml	3.97	1	4.1													
Nail 10	Kg	0.02	35	0.7													
Black wire 2.5	Kg	0.02	35	0.8													
				26						**25.6**						**1.1**	**52**
Remark	Use of H- frame 20 times and wastage 0%																
	Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%																

Eucalyptus wood metal combination:- H-frame 1.20m (width) x 1.50m (length)x2.4m(length) & eucalyptus wood for joists Spacing 80cm x 150cm 6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.17	145	24	Carp.	1	1	35	1.76	20	Tools	2	1	1	2.16	1	
Eucalyptus wood dia. 10- 12	ml	1.10	2.2	2.4	DL	1	1	10	1.76	5.7							
Eucalyptus wood dia. 8cm	ml	4.84	1	5													
Nail 10	Kg	0.03	35	0.9													
Black wire 2.5	Kg	0.02	35	0.8													
				33						**25.6**						**1**	**60**
Remark				Use of H- frame 20 times and wastage 0% Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%													

Eucalyptus wood metal combination:- H-frame 1.20m (width) x 1.50m (length)x2.4m(length) & eucalyptus wood for joists spacing 120cm x 150cm 7

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
alvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height	full set	0.14	145	20	Carp.	1	1	35	1.76	20	Tools	2	1	1	1.76	1	
Eucalyptus wood dia. 10- 12	ml	0.92	2.2	2	DL	1	1	10	1.76	5.7							
Eucalyptus wood dia. 8cm	ml	3.36	1	3.5													
Nail 10	Kg	0.02	35	0.8													
Black wire 2.5	Kg	0.02	35	0.8													
				27						**25.6**						**1**	**54**
Remark				Use of H- frame 20 times and wastage 0% Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%													

Life use For Adjustable steel prop 20 times
Eucalyptus wood 6 times

eucalyptus wood metal combination:- Adjustable props 60cm dia., 2mm thick, 3.9 m length &, eucalyptus wood Joists: spacing 60cm x60cm

1.4

A. material cost					**B. Labor cost**						**C. Tools and Equipment**						
Type of material	**unit**	**Qty.**	**unit rate**	**Cost per unit**	**Labor tread**	**No**	**UF**	**Indexed cost**	**out put**	**Cost per unit**	**Tools**	**No**	**UF**	**cost**	**out put**	**Cost per unit**	**Direct cost= A+B+C**
Adjustable props 6cm dia. x 2mmthickx 3.9 height	pcs	2.78	55	153	Carp.	1	1	35	1.76	19.97	Tools	2	1	1	1.76	1.1	
Eucalyptus wood dia. 10-12	ml	1.83	2.2	4	DL	1	1	10	1.76	5.67							
Eucalyptus wood dia. 8cm	ml	4.58	1	4.8													
Nail 10	Kg	0.05	35	1.7													
Black wire 2.5	Kg	0.02	35	0.8													
				164						**25.64**						**1.1**	**190**

Remark	Use of steel props 20 times and wastage 0%
	Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%
	Nail wastage 5%

Life use For H- frame 40 times

Eucalyptus wood 6 times

Eucalyptus wood metal combination :-H-frame 1.20m (width) x 1.80m (length)x2.4m Height & Eucalyptus wood for joists Spacing 120cm x 180cm 8.6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.1	78	9	Carp.	1	1	35	1.76	19.97	Tools	2	1	1	1.76	1.1	
Eucalyptus wood dia. 10- 12	ml	0.9	2.2	2		1	1	10	1.76	5.67							
Eucalyptus wood dia. 8cm	ml	4	1	4.1													
Nail 10	Kg	0.02	35	0.7													
Black wire 2.5	Kg	0.02	35	0.8													
				17						**25.6**						**1.1**	**43**
Remark				Use of H- frame 40 times and wastage 0%													
				Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%													

Eucalyptus wood metal combination;- H-frame 1.20m (width) x 1.50m (length)x2.4m(length) & Eucalyptus wood for joists Spacing 120cm x 180cm 6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.17	73	12	Carp.	1	1	35	1.76	20	Tools	2	1	1	1.76	1	
Eucalyptus wood dia. 10- 12	ml	1.10	2.2	2.4	DL	1	1	10	1.76	5.7							
Eucalyptus wood dia. 8cm	ml	4.84	1	5													
Nail 10	Kg	0.03	35	0.9													
Black wire 2.5	Kg	0.02	35	0.8													
				21						**25.6**						**1**	**48**
Remark				Use of H- frame 40 times and wastage 0%													
				Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%													

Eucalyptus wood metal combination:- H-frame 1.20m (width) x 1.50m (length)x2.4m(length) spacing 120cm x 150cm & Eucalyptus wood for joists Spacing 120cm x 180cm 7

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height	full set	0.1	73	10	Carp.	1	1	35	1.76	20	Tools	2	1	1	1.76	1	
Eucalyptus wood dia. 10- 12	ml	0.92	2.2	2	DL	1	1	10	1.76	5.7							
Eucalyptus wood dia. 8cm	ml	3.36	1	3.5													
Nail 10	Kg	0.02	35	0.8													
Black wire 2.5	Kg	0.02	35	0.8													
				17						**25.6**						**1**	**34**
Remark				Use of H- frame 40 times and wastage 0%													
				Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%													

Life use For Adjustable steel prop 40 times
Eucalyptus wood 6 times

Eucalyptus wood metal combination:- Adjustable props 60cm dia., 2mm thick, 3.9 m length & eucalyptus wood joists: spacing 60cm x60cm 1.4

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	pcs	2.8	28	76	Carp.	1	1	35	1.76	19.97	Tools	2	1	1	1.76	1.1	
Eucalyptus wood dia. 10- 12	ml	1.8	2.2	4	DL	1	1	10	1.76	5.67							
Eucalyptus wood dia. 8cm	ml	4.6	1	4.8													
Nail 10	Kg	0.05	35	1.7													
Black wire 2.5	Kg	0.02	35	0.8													
				88						**25.64**						**1.1**	**114**
Remark				Use of steel props 40 times and wastage 0%													
				Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%													
				Nail wastage 5%													

Life use For H- frame 60 times

Eucalyptus wood 6 times

Eucalyptus wood metal combination: H-frame 1.20m (width) x 1.80m (length)x2.4m Height & Eucalyptus wood for joists Spacing 120cm x 180cm

8.6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.12	52	6	Carp	1	1	35	1.76	20	Tools	2	1	1	1.76	1	
Eucalyptus wood dia. 10-12	ml	0.92	2.2	2	DL	1	1	10	1.76	5.67							
Eucalyptus wood dia. 8cm	ml	3.97	1	4.1													
Nail 10	Kg	0.02	35	0.7													
Black wire 2.5	Kg	0.02	35	0.8													
				14						**25.6**						**1**	**40.4**
Remark	Use of H- frame 60 times and wastage 0% Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%																

Eucalyptus wood metal combination ;_H-frame 1.20m (width) x 1.50m (length)x2.4m(length),eucalyptus wood joist spacing 80cm x 150cm

6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.17	48	8.1	Carp.	1	1	35	2.16	20	Tools	2	1	1	1.76	1	
Eucalyptus wood dia. 10-12	ml	1.10	2.2	2.4	DL	1	1	10	2.16	5.76							
Eucalyptus wood dia. 8cm	ml	4.84	1	5													
Nail 10	Kg	0.03	35	0.9													
Black wire 2.5	Kg	0.02	35	0.8													
				17						**25.6**						**1**	**44**
Remark	Use of H- frame 60 times and wastage 0% Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%																

Eucalyptus wood metal combination:- H-frame 1.20m (width) x 1.50m (length)x2.4m(length) spacing 120cm x 150cm& Eucalyptus wood for joists Spacing 120cm x 180cm 7

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	**unit**	**Qty.**	**unit rate**	**Cost per unit**	**Labor tread**	**No**	**UF**	**Indexed cost**	**out put**	**Cost per unit**	**Tools**	**No**	**UF**	**Hourly rental cost**	**out put**	**Cost per unit**	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.14	48	6.7	Carp.	1	1	35	1.76	20	Tools	2	1	1	1.76	1	
Eucalyptus wood dia. 10-12	ml	0.92	2.2	2		1	1	10	1.76	5.76							
Eucalyptus wood dia. 8cm	ml	3.36	1	3.5													
Nail 10	Kg	0.02	35	0.8													
Black wire 2.5	Kg	0.02	35	0.8													
				14						**25.6**						**1**	**40.3**

Remark	Use of H- frame 60 times and wastage 0%
	Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%

Eucalyptus wood metal combination:- Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 60cm x60cm, Eucalyptus wood Joists 1.4

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	**unit**	**Qty.**	**unit rate**	**Cost per unit**	**Labor tread**	**No**	**UF**	**Indexed cost**	**out put**	**Cost per unit**	**Tools**	**No**	**UF**	**Hourly rental cost**	**out put**	**Cost per unit**	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	pcs	2.78	18	51	Carp.	1	1	35	1.76	20	Tools	2	1	1	1.76	1	
Eucalyptus wood dia. 10-12	ml	1.83	2.2	4	DL	1	1	10	1.76	5.67							
Eucalyptus wood dia. 8cm	ml	4.58	1	4.8													
Nail 10	Kg	0.05	35	1.7													
Black wire 2.5	Kg	0.02	35	0.8													
				62						**25.6**						**1**	**88.9**

Remark	Use of steel props 60 times and wastage 0%
	Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%
	Nail wastage 5%

Eucalyptus wood metal combination:- Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 80cm x80cm, Eucalyptus wood Joists 2.6

<table>
<tr><th colspan="5">A. material cost</th><th colspan="6">B. Labor cost</th><th colspan="6">C. Tools and Equipment</th><th rowspan="2">Direct cost= A+B+C</th></tr>
<tr><th>Type of material</th><th>unit</th><th>Qty.</th><th>unit rate</th><th>Cost per unit</th><th>Labor tread</th><th>No</th><th>UF</th><th>Indexed cost</th><th>out put</th><th>Cost per unit</th><th>Tools</th><th>No</th><th>UF</th><th>Hourly rental cost</th><th>out put</th><th>Cost per unit</th></tr>
<tr><td>Adjustable props 6cm dia. x 2mmthickx 3.9 height</td><td>pcs</td><td>1.56</td><td>18</td><td>29</td><td>Carp.</td><td>1</td><td>1</td><td>35</td><td>1.76</td><td>20</td><td>Tools</td><td>2</td><td>1</td><td>1</td><td>1.76</td><td>1</td><td></td></tr>
<tr><td>Eucalyptus wood dia. 10-12</td><td>ml</td><td>1.03</td><td>2.2</td><td>2.3</td><td>DL</td><td>1</td><td>1</td><td>10</td><td>1.76</td><td>20</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Eucalyptus wood dia. 8cm</td><td>ml</td><td>2.58</td><td>1</td><td>2.7</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Nail 10</td><td>Kg</td><td>0.03</td><td>35</td><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Black wire 2.5</td><td>Kg</td><td>0.02</td><td>35</td><td>0.8</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>35</td><td></td><td></td><td></td><td></td><td></td><td>25.6</td><td></td><td></td><td></td><td></td><td></td><td>1</td><td>62.1</td></tr>
<tr><td colspan="4" rowspan="3">Remark</td><td colspan="14">Use of steel props 60 times and wastage 0%</td></tr>
<tr><td colspan="14">Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%</td></tr>
<tr><td colspan="14">Nail wastage 5%</td></tr>
</table>

Life use For H- frame 100 times
Eucalyptus wood 4 times

Eucalyptus wood metal combination:- H-frame 1.20m (width) x 1.80m (length)x2.4m Height & Eucalyptus wood for joists Spacing 80cm x 180cm 7.2

A. material cost					B. Labor cost						C. Tools and Equipment						
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	indexed cost	out put	Cost per unit	Tools	No	UF	rental cost	out put	Cost per unit	cost= A+B+C
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height	full set	0.14	31	4.3	Carp	1	1	35	1.76	19.97	Tools	2	1	1	1.76	1.1	
Eucalyptus wood dia. 10-12	ml	1.10	2.2	2.4	DL	1	1	10	1.76	5.67							
Eucalyptus wood dia. 8cm	ml	3.97	1	4.1													
Nail 10	Kg	0.03	35	0.9													
Black wire 2.5	Kg	0.02	35	0.8													
				13						**25.64**						**1.1**	**39**
Remark				Use of H- frame 100 times and wastage 0%													
				Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%													

Eucalyptus wood metal combination:- 1.20m (width) x 1.80m (length)x2.4m Height & Eucalyptus wood for joists Spacing 120cm x 180cm 8.6

A. material cost					B. Labor cost						C. Tools and Equipment						
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	Direct cost= A+B+C
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height full set	full set	0.12	31	3.6	Carp.	1	1	35	1.76	19.97	Tools	2	1	1	1.76	1.1	
Eucalyptus wood dia. 10-12	ml	0.92	2.2	2	DL	1	1	10	1.76	5.67							
Eucalyptus wood dia. 8cm	ml	3.97	1	4.1													
Nail 10	Kg	0.02	35	0.7													
Black wire 2.5	Kg	0.02	35	0.8													
				11						**25.64**						**1.1**	**38**
Remark				Use of H- frame 100 times and wastage 0%													
				Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%													

Eucalyptus wood metal combination:-H-frame 1.20m (width) x 1.50m (length)x2.4m(length) & Eucalyptus wood for joists Spacing 120cm x 150cm

6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Galvanized H-frame 1.20m (width) x 1.50m (length)x2.4m Height	full set	0.17	29	4.8	Carp.	1	1	35	1.76	20	Tools	2	1	1	1.7 6	1	
Eucalyptus wood dia. 10- 12	ml	1.10	2.2	2.4	DL	1	1	10	2.16	5.67							
Eucalyptus wood dia. 8cm	ml	4.84	1	5													
Nail 10	Kg	0.03	35	0.9													
Black wire 2.5	Kg	0.02	35	0.8													
				14						**25.6**						**1**	**40.6**
Remark				Use of H- frame 100 times and wastage 0%													
				Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%													

Life use For H- frame 100 times
Eucalyptus wood 4 times

Eucalyptus wood metal combination:- Adjustable props 60cm dia., 2mm thick, 3.9 m length spacing 80cm x80cm,& Eucalyptus wood Joists

2.6

A. material cost					B. Labor cost						C. Tools and Equipment						Direct cost= A+B+C
Type of material	unit	Qty.	unit rate	Cost per unit	Labor tread	No	UF	Indexed cost	out put	Cost per unit	Tools	No	UF	Hourly rental cost	out put	Cost per unit	
Adjustable props 6cm dia. x 2mmthickx 3.9 height	pcs	1.56	11	17	Carp.	1	1	35	1.76	20	Tools	2	1	1	1. 76	1.1	
Eucalyptus wood dia. 10- 12	ml	2.52	2.2	5.5	DL	1	1	10	1.76	5.67							
Eucalyptus wood dia. 8cm	ml	4.35	1	4.5													
Nail 10	Kg	0.04	35	1.2													
Black wire 2.5	Kg	0.02	35	0.8													
				29						**25.6**						**1.1**	**56**
Remark				Use of steel props 100 times and wastage 0%													
				Use of Eucalyptus wood 6 times Spacing :- Eucalyptus wood dia. 10-12 cm 60cmc/c, Eucalyptus wood dia. 8 cm 30cm c/c wastage 10%													
				Nail wastage 5%													