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**ADDIS ABABA UNIVERSITY**  
**ADDIS ABABA INSTITUTE OF TECHNOLOGY**  
**School of Civil and Environmental Engineering**

**Assessment of Ethiopian Road Construction**  
**in Rainy Seasons**

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Assessment of Ethiopian Road Construction in Rainy Seasons

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## **Abstract**

Road construction is by its nature a complex task that needs a thorough planning and controlled management throughout the lifetime of the project. Its progress can be affected by lots of reasons that results the project to lag behind its scheduled time. Rainy seasons are one of the focal reasons that delay construction projects especially for roads. During rainy seasons, the ground will not be suitable for execution of works, machinery movement and over all construction works. Since most parts of Ethiopia have three months of rainy season each year, these times of the year are usually known to disturb ongoing road constructions.

This thesis basically focuses on the ways followed in road construction of Ethiopia during the rainy seasons. The effect of rain and even the remaining moisture afterwards is explained in detail. It tries first to address view of involved parties in the construction sector towards the practice, the country's existing condition to observe how constructions are carried out during this times and also what kind of methodologies are used. The trend of other foreign countries is also reviewed so as to compare their experience.

In addition to the rain, as there is snow cold and damp moisture in foreign countries the use of Hot Mix Asphalt (HMA) and Warm Mix Asphalt (WMA) is discussed showing both the disadvantages and advantages regarding the fume emissions, energy consumption and other related effects. But as the rainy seasons in Ethiopia are not freezing cold, concrete pavement is cited as a new construction technique in which the types, making and use is discussed especially for concrete paving works in cold weather.

The qualitative research made using interviews and case studies tries to elucidate about the working practice during the months of rainy seasons of Ethiopia and the early planning and management of road constructions. Informants of different educational and work back ground are interviewed and also different local and international road projects are reviewed. Conclusions obtained from the assessment made are presented regarding each objective set at the beginning of the paper. Works recommended as able to be done during rainy seasons, scheduling of works for those times and the experience of foreign contractors is stated in the conclusion from the studies made.

As to meet its critical objective, this paper recommends some alternate working methodologies, early scheduling of projects and management techniques for project owners, contractors and consultants. Further researches on using alternative pavement materials, like concrete road, is also suggested.

Key Words: Asphalt, Road construction, Rainy Season

## **List of Abbreviations**

BSM	Benzene Soluble Matter
ETCA	Ethiopian Transport Construction Authority
ERA	Ethiopian Roads Authority
FIDIC	Federation International Des Ingenieurs-Conseils
FHWA	Federal high Way Administration
GGBFS	Ground Granular Blast Furnace Slag
HMA	Hot Mix Asphalt
HWTD	Hamber wheel Trucking Device
MPa	Mega Pascal
NCAT	National Center of Asphalt Technology
PAC	Polycyclic Aromatic Compound
SGC	Super pave Gyratory Compactor
TTF	Time Tem Preparatory Factor
U.K.	United Kingdom
U.S.	Unites States
WMA	Warm Mix Asphalt

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# **1. Introduction**

## **1.1 Background**

A project is a unique process, consisting of a set of co-ordinated and controlled activities with an assumed start and known finish dates, undertaken to achieve an objective conforming to specific requirements including constraints of time, cost and resources (Lockyer & Gordon, 1996). It also states that the organization is temporary; established for the life of the project; forms part of a large project structure and objectives. In addition it further states that project product characteristics may be defined and achieved progressively during the course of the project.

Abebe Dinku (2003) stated that in project management the above constraints have been identified as the Triple Constraints namely managing Cost, Schedule (time) and Quality simultaneously. Accordingly, projects can be better managed in ways that balance these constraints.

In order to balance these triple constraints in the planning stage, any construction works should consider factors that can affect these constraints before starting the work. When it comes to road construction the consideration should be broadly analyzed as road construction is a long project with different features that are very difficult to estimate. Topography of the project site, material sources, water sources, ground water level, infrastructure facilities, weather and climate condition are some of the most important factors that should be considered while planning a road project

Accordingly, rainy seasons are also known to have their own negative impact on road construction. Especially, in the Middle East, Northern East, Southern and Southern East parts of Ethiopia, there are times in which the rainy season stays for about 2 – 3 months and even sometimes up to 6 months per year. Overflow of rivers and the resulting muddy grounds on the site also contributes to the delay of the construction. Due to this, construction time is extended and

detour roads does not give the expected services resulting in inconvenience of transport.

Therefore, this thesis deals with road construction in Ethiopia particularly road construction in rainy season. The thesis will be strengthened by reviewing the experience of other countries.

## **1.2 Research Objective**

The general objective of this study is to assess the experience of Ethiopian road construction in rainy season and to give a way to our road construction industry by bringing the experience of the other countries. This general objective leads to proceed construction of roads in rainy season which minimizes time and subsequently costs manipulated due to inflation and scarce resources. The specific objective of this thesis is;

- To assess the intention of the involved parties (Client, consultant and contractors) who are participating in Ethiopian road construction industry towards constructing a road in a rainy seasons;
- To assess experiences of local and international projects in Ethiopia on planning and construction of road in rainy seasons;
- To investigate the experience of other countries and their methodologies that are considered while constructing in cold weather;
- To recommend some methodologies that can be used in our county and action that can be taken in the future.

Hence, the research will address the following questions:

- i. Are the months in the rainy seasons considered as working months in Ethiopia road construction industry?
- ii. What is the intention of the involved parties (Client, consultant and contractors) who are participating in Ethiopian road construction industry towards constructing a road in rainy seasons?
- iii. Do the foreign countries consider rainy and cold weather conditions as working environments?

- iv. What methodologies do they use while planning and constructing a road in cold and rainy conditions?
- v. How can we manage our road construction projects in order to effectively execute works in rainy conditions?

### **1.3 Structure of the Thesis**

This thesis consists of five chapters and an Appendix.

Chapter 1 is an introduction to the research and includes five sections that present the background; research objective; scope of the study; structure of the thesis; and research methodology. The second chapter discusses the theoretical frame work for the study. The Research design and methodology is presented in Chapter 3. Moreover, Chapter 4 focuses on the analysis of results and discussions. The last chapter which is Chapter 5 forwards conclusions and recommendations of the research and Appendix 1 contains the sample interview schedule.

### **1.4 Research Methodology**

The research strategy adapted for this research is qualitative research of exploratory type which diagnoses a situation, assess alternatives, and discover new ideas. The methodology followed for the research has four main parts which are described hereunder. Establishing the basis of the research aimed at defining the theoretical basis, and formulating the research questions through the following steps.

- i. Literatures were reviewed to obtain a theoretical basis for the Research, formulate the research questions and define the scope. To this effect, the main authors of textbooks in construction of adverse weather were identified.

The books were then reviewed in order to get a general understanding of the research area. Thereafter, relevant articles from journals and other publications were searched to conceptualize the construction of road in rainy and cold weather. Apart from searching in libraries, internet

sources were used to obtain recent articles and research papers in the area.

- Projects were selected for the case study to examine the planning and execution of the works in rainy seasons.
  - Interview schedule was prepared based on the findings of the literature review and the case study.
- ii. Conducting the study: aimed at finding out how the projects are planned before starting the construction and how they are executed in the rainy seasons.
- Case study of four projects, two international and two local projects, to assess their planning and execution of works in rainy seasons by considering the cost, time and quality of the construction works.
  - A desk study to get a picture of Ethiopian road construction in the rainy seasons, and
  - Interviewing key respondents to get in-depth understanding of road construction in rainy seasons in Ethiopia and other foreign countries' practice, and to explore their opinion on the planning and construction of road in Ethiopian by considering the rainy seasons.
- iii. Analyzing the findings; of case studies in relation to theoretical propositions, and that of the interview using descriptive statistics method of analysis.
- iv. Conclusion and recommendation: aimed at concluding the research findings, and drawing recommendations.

Figure 1 shows the flow and steps of the research methodology that was followed to prepare this thesis.

**Establish basis of the research**

Review literatures to define the theoretical framework of the research and to find out the experience of other countries

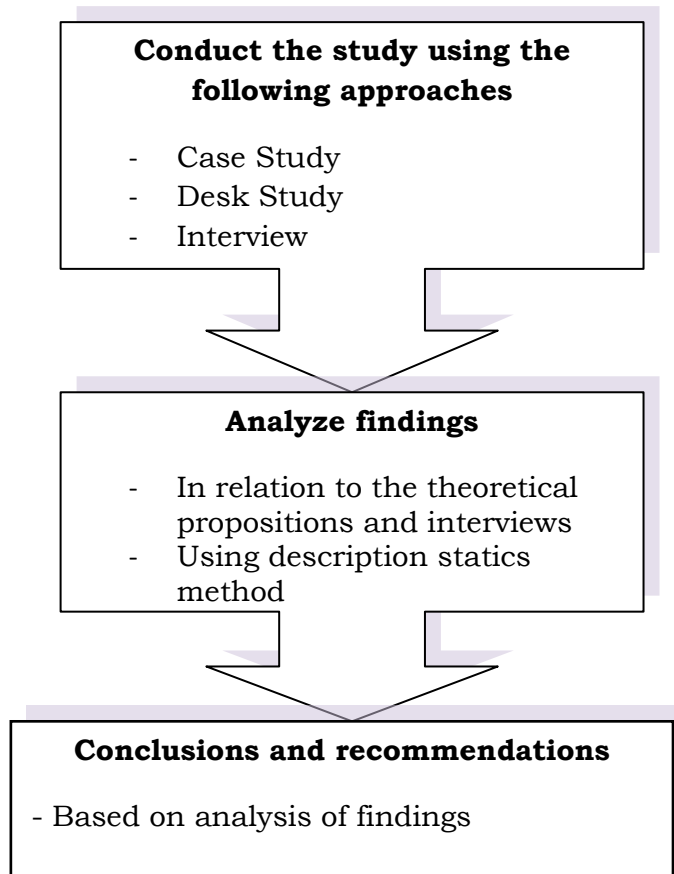


Figure 1-Flow Chart Showing Research Design

## **2. Literature Review**

### **2.1 Climate Condition of Ethiopia**

#### **2.1.1 General**

The great East Africa Rift Valley, which runs from Northeast to South across Ethiopia, the mountains and the highlands to the right and the left of this rift

valley, the low land surrounding these mountainous and highlands in every direction can be described as the country's main topographic features.

As described in NMSA, 1996, the climate of Ethiopia is divided into 11 zones, which are principally come under dry climates, tropical rainy climates and temperate rainy climates. The North Eastern and South Eastern part of the country are dominated by the dry climate with mean annual temperature ranging from 27°C to 30°C and the mean annual rainfall is less than 450mm. Usually these part of the country is characterized by strong winds, high temperature and low relative humidity(wikipedia.org).

The Climate in the North Western, South Western and East part of the country where elevation is up to 1750m above sea level, is dominated by tropical rains with mean annual temperature greater than 18°C and mean annual rainfall ranging from 680mm to 1200mm. On the other hand, the central, Southern and Eastern highlands are temperate rainy climate with the mean annual temperature is less than 18°C and the mean annual rainfall is greater than  $20 * (T+14)$ , where T is the mean annual temperature in °C (wikipedia.org).

### **2.1.2 Rainfall Regimes and Seasons**

Season is defined, methodologically, as a period when as air mass characterized by homogenous weather elements such as temperature, relative humidity, wind, rainfall etc., dominate a region or part of a country (NMSA, 1996). In Ethiopia, the seasons and rainfall regimes are classified based on mean annual and mean monthly rainfall distribution. As shown in Figure 2, topographic map of Ethiopia, there are mainly three rainfall regimes (Bekele, 1997). These three rainfall regimes as shown in Figure 2 are delineated as:

- A. Mono-modal (Single Maxima)
- B. Bi-modal type-1 (Quasi-double maxima)
- C. Bi-modal type-2 (Double maxima)

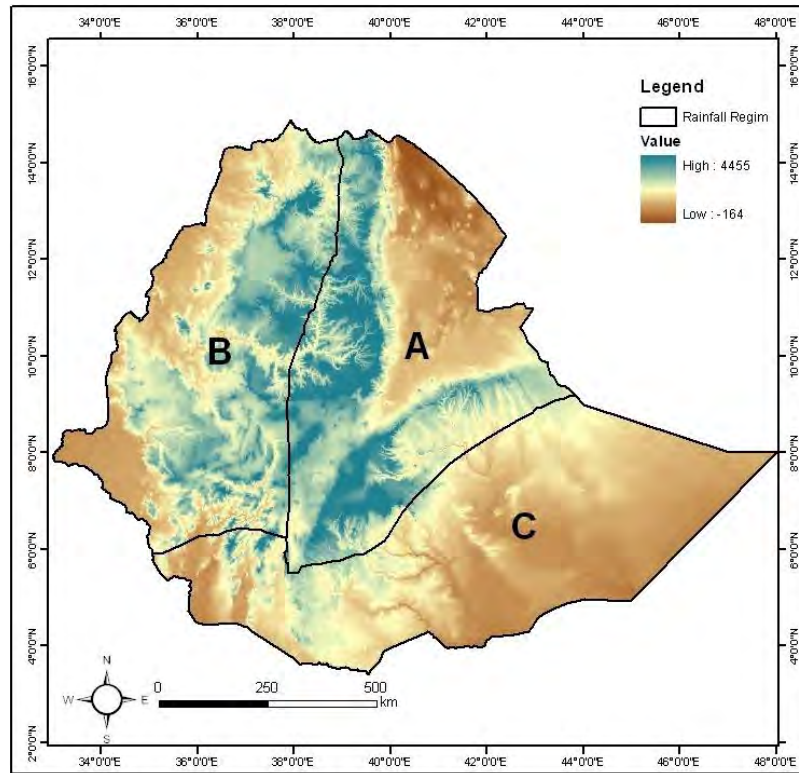


Figure 2- Topographic map of Ethiopia showing Rainfall Regimes(Modified from NMSA, 1996)

### **A. Mono-modal (Single Maxima)**

In the single maxima region, the wet period decreases northwards from about ten month in the south west to only about four months in the north. Thus region-A is where the wet period runs from February/March to October/November, April/May to October/November and from June/July to August/September (NMSA, 1996).

### **B. Bi-modal type-1 (Quasi-double maxima)**

The area designated as region B is characterized by quasi-double maxima rainfall pattern, with a small peak in April and Maximum peak in August.

The central and most of the eastern half of the country is included in this rainfall regime. The two rainy periods are locally known as ‘Kiremt’ (June to September) and ‘Belg’ (February to May), which are the long and short rainy

periods, respectively. Short 'dry' period, which covers the rest of the year (i.e. October to January), is known as Bega.

### **C. Bi-modal type-2 (Double maxima)**

The area identified as region C is dominated by double maxima rainfall pattern with peak during April and October. The Southern and the South Eastern parts of Ethiopia are included in this rainfall regime. Two rainy periods are from March to May and from September to November where as the two dry periods are from June to August and from December to February.

## **2.2 Road Construction in Ethiopia**

### **2.2.1 History of Road Construction in Ethiopia**

As described in the strategic plan of Ethiopian Roads Authority (ERA) (2004), Ethiopia is located between longitudes 33 and 48 degrees East and latitudes 3 and 17 degrees North in North East Africa (Horn of Africa). It is a landlocked country bound by Sudan in the West, Kenya in the South, Somalia in the Southeast, Djibouti in the East and Eritrea in the North and northeast. It is one of the largest African countries with a land area of about 1.1 million sq. km. Ethiopia's topography is rugged, ranging in altitude between 100 m to above 4,000 m above sea level. The central regions of the country are classified as highland areas, while the peripheries of western and eastern parts of the country are at low plateau about 1,500m above sea level (ERA 2004).

As it is explained in the same literature (ERA 2004), the historic chronicles of the 17th and 18th centuries show that there were a number of small road trails and foot paths, in addition to the traditional shoulder portage, animals like mules, donkeys and horses and camels were used as a means of transportation in Ethiopia. In the 18th century, especially during the reign of Emperor Tewodros, although the technology was primitive, it was believed that planned road construction efforts were made. It is also believed that Emperor Yohannes IV, who succeeded Tewodros, was engaged in road building however due to the

danger of invasion by Egyptians, Derbush and Turkish the Emperor was not able to achieve his desires (Strategic Planning of ERA 2004).

It was prior to the first Italian occupation i.e. between the years 1896 and 1936 that progress was made in road construction. Emperor Menilik was said to have been a successful road builder participating himself in the construction. In 1903 the road from Eritrea to Addis Ababa and the road from Addis Ababa to Addis Alem were built. In addition it was during this time that the first Asphalt road appeared in Addis Ababa (EmmeneggerRony,2012).

Emmenegger Rony, 2012 stated in his book that, during the Italian occupation roads were constructed by them and they were established to meet the requirements of the Military control rather than to promote the overall development of the country's economy. Moreover, the roads lacked most of the modern location, design and construction features desirable for present day high speed traffic. The roads and trails built and improved during the 5 years Italian occupation were about 6000km. Approximately 2500 km of them were given a single asphalt surface treatment, drainage structures were usually of stone masonry and at least three tunnels were built. However, when Ethiopia regained her independence, the Italians in fleeing attempt almost undid what they created by blasting bridges and dynamiting roads (ERA 2004). From the time the Italian packed off home to the eventual creation of the Imperial Highway Authority (1941 to 1951) road construction or maintenance activity was almost subsided for a stagnation period of one decade because of lack of funds, equipment and expertise (Emmenegger Rony,2012).

Following the eviction of the Italian occupiers, the Imperial Ethiopian Government was convinced that a Road Agency solely responsible for rehabilitating/restoring and expanding the road network throughout the country had to be established. Accordingly, the Imperial Highway Authority (IHA) was established with specific duties to plan, design, construct, and

maintain roads. Responsibilities for construction and maintenance of roads remained under a single autonomous authority (IHA) for 26 years (1951-1977). The Ministry of Transport and Communication turned out to be the supervising authority of Ethiopian roads Authority (ERA). The Ethiopian Roads authority has been established by incorporating Rural Roads Department to Highway Department.

In 1980, the Military Government that took power in 1974 reformed the agency into the Ethiopian Transport Construction Authority (ETCA) and became accountable to the newly formed Ministry of Construction. The proclamation enlarged responsibility of the Authority by expanding its task and incorporating the construction of Airports, Seaports, Railways, and Municipal Roads (ERA 2004).

### **2.2.2 Road Infrastructure in Ethiopia**

There are three perspectives as explained by Becker/Demissie 2006 why road construction has been a domain of the state in Ethiopia. First, from an economic perspective, road infrastructure is a classic example of a public good that is characterized by non-excludability, consequently, the private sector has no interest in providing roads. Hence, road construction has been a domain of the Ethiopian state throughout its history.

Second, from a political perspective, road infrastructure and the accessibility of peripheral rural areas are of crucial importance for the state's "...monopoly on the legitimate use of physical force in the territory it is said to control" (Herbst 2000:21). From this point of view, it can be argued that the construction of roads has played a significant role in the consolidation of the Ethiopian state since its very beginning (Clapham 2002).

Third, from a development perspective, road infrastructure constitutes a precondition and decisive factor for development and has therefore to be provided by the state. In fact, road infrastructure in Ethiopia has had a great

strategic, political, economic and social significance. The literature and documents on road infrastructure often draw a clear line between different Emperors' and regimes' motivations to construct roads. However, the significance of roads can hardly be reduced to one single aspect for the era concerned, but indicates the discursive justification of its construction for the regime concerned.

### **2.2.3A History of the Road Network and Related Policy**

The history of the Ethiopian road network goes back to the very beginning of the Ethiopian state. This origin can be related to the reign of Emperor Tewodros (1855- 68), who succeeded in fragmenting the traditionally feudal system and centralizing political power (Keller 2005). Although the establishment of a professional and disciplined state army is seen today as Tewodros' main achievement (Keller 2005; Bahru Zewde 1991), he was also the pioneer of road construction in Ethiopia. Associated with his intention to expand the northern highland empire, he recognized the strategic and political importance of roads. Consequently, a relatively small-scale road network was constructed which enabled the Emperor to rapidly move his troops to the centers of rebellion in the conquered areas (Ayele Tarekegn 1987).

Late 19th century, the city of Addis Ababa, founded in 1887 (Gascon 1997:363), replaced the northern highland as the geographical center of political power. Clapham, 2002 uses a center-periphery concept and points to the importance of overcoming physical distance for communication within the empire. He explains that the peripheral position of regions and communities, their political and economic incorporation as well as "...their degree of association with the legitimizing myths of nationhood" could be approximately defined by their physical distance from the capital. However, Tewodros' successors also paid great attention to road construction, especially Menelik II (1889-1913) and his province governors.

During the reign of Haile Selassie (1930-36), the capital-centered (Addis Ababa) road network was intensified and modernized “...for economic and political reasons...” (Ayele Tarekegn 1987). On the other hand, the global economic crises and world depression in 1929-1933 forced the reign to improve the capital’s road communication with the provinces (Ayele Tarekegn 1987). However, despite the intention to expand the country’s road network, it remained poorly developed until the Italian occupation (Keller 1991:96-97). During the Italian occupation (1936-41), considerable efforts were undertaken with respect to road infrastructure (Keller 1991), and the Ethiopian road network expanded from about 1,040 km in 1930 to about 6,400 km in 1941 (Asnake Tadesse 2006). Initially, road construction started as a preparation for war in the early Ethio–Italian conflict.

While these initial roads had been constructed where the Italian’s penetrated the territory, i.e. Eritrea, the activities continued inside Ethiopia after the invasion in 1936. The road making activities followed in the footsteps of the invading forces so that paved roads would allow easier and swifter passage of troops and supplies. From a strategic point of view, the priority was given to roads linking major towns, but also to those linking the ‘colony’ with the outside world. Attention was paid to quantity rather than quality, and several new roads were constructed and pre-war roads maintained, upgraded or elongated (Ayele Tarekegn 1987).

Several political and economic arguments can be found for the improvement of the transport system of the Italian colony most noticeably, the strategic and military importance of roads led to initial construction and maintenance (Ayele Tarekegn 1987). The existence of a road network later helped the Italians to “consolidate its rule over Ethiopia, initiate development projects and pacify unstable areas” (Ofcansky/Berry 2004). In other words, to effectively administer, economically exploit and suppress the resistance of Ethiopian patriots.

In addition to the importance of roads for administering the colony, the link to the outside world also led to the expansion of the road network. As an example, Italy aimed at connecting the colony with the British Somali Port Berbera in order to become less dependent on the French-run Djibouti Railway (Ayele Tarekegn 1987). On the one hand, road construction efforts were a clear sign of the Italians' attempt "...to transform Ethiopia into a self-sufficient export economy linked to the world market" (Keller 1991).

On the other hand, given the deterioration of Franco-Italian relations, it was an obvious expression of the broader geopolitical patterns. With the Italian's involvement in World War II, road construction in Ethiopia suddenly came to an end. In 1941, powerful attacks from the Anglo-Ethiopian liberation movement forced the Italians to flee and strategically destroy parts of the road network established thus far (Ayele Tarekegn 1987). After the liberation of Addis Ababa, Emperor Haile Selassie re-entered the capital on 5 May 1941 (Bahru Zewde 1991:176). While road construction and maintenance activities stagnated in the following years (Ofcansky/Berry 2004), they regained attention in the early 1950s. Haile Selassie had sufficiently consolidated the administrative authority of the state and could now turn his attention to more economic matters (Keller 1991). He recognized the importance of an existing road system for the economic needs of the population and the government (ERA 2004). Accordingly, a Highway Programme (HP) was formulated in order to stimulate the expansion of road infrastructure in Ethiopia key activities throughout the country.

In particular, the programme aimed at creating transport infrastructure, attracting foreign capital investors or opening up remote but economically rich areas of agriculture, mineral .0 capitals, other important towns, as well as the connection of Addis Ababa with the outside world through the port of Assab.

In this sense, the first Highway Programme (HP I 1951) focused on the inherited but deteriorated Italian road network and several existing roads were rebuilt, reconstructed and maintained. Although the road network had initially mainly fulfilled military purposes, the road economic usefulness was not reduced. With the second Highway Programme (HP II 1957) the focus shifted toward the construction of new roads (AyeleTarekegn1987). In the following years, two further Highway Programmes were formulated which increasingly opened up previously inaccessible regions of the country (Keller 1991). The classified road network increased from the inherited 6,400 km in 1951, to a total of 9,260 km in 1974 (Asnake Tadesse 2006).

In 1974, the Derg assumed power and continued with the construction of new roads on a larger scale than ever before. While the new regime initially followed the Highway Programme of its predecessor, it shifted its attention to the construction of the previously neglected rural roads (Ayele Tarekegn 1987). The Derg identified the lack of access to rural areas as a serious bottleneck for agricultural development (ETCA 1986:4). The rural infrastructure, particularly low-cost and low-standard roads, were given increasing attention.

On the one hand, rural infrastructure was seen as a means for the achievement of socio-economic development. while it was considered a precondition for the expansion of further socio-economic infrastructure. The economic role of rural roads for the country and its population was emphasized with respect to market access in general, and the possibility for the rural population to bring their products to the market in particular. Concerning social development, the importance of rural roads was justified by highlighting their ability to help and rehabilitate drought-affected people.

As a consequence of this increasing focus on rural road, the first Sector Programme (SP I 1977/78-1981/82) was formulated and replaced the Highway Programmes. The Sector Programme expressed the government's intention to

construct a “...vast network of systematized low-cost and low-standard roads...” and to unite the existing main highways with the projected rural roads (Ayele Tarekegn 1987:65). From a political perspective, the value attached to rural roads by the Derg can be interpreted as a means for raising political consciousness in the countryside (Ayele Tarekegn 1987:61-67) or a way to enforce the regime’s intrusion into the rural areas (Dessalegn Rahmato 2008b:329). However, until 1990, the Derg had increased the classified road network to 19,020 km (ERA 2008).

### **2.3 Definitions and Classifications**

While considering the weather and climate condition, the meaning of both should be clarified. According to Trend of Natural Disaster by Petter Hoeppe, weather is the day to day state of the atmosphere, and its short-term (minutes to weeks) variation (Peter Hoeppe, 2003). Popularly, weather is thought of as the combination of temperature, humidity, precipitation, cloudiness, visibility and wind. We talk about the weather in terms of ‘what will it be like today?’, ‘How hot is it right now?’, and ‘When will that storm hit our section of the country?’.

On the contrary climate is defined as statistical weather information that describes the variation of weather at a given place for a specified interval in popular usage, it represents the synthesis weather; more formally it is the weather of locally averaged over some period (usually 30 years) pulse statistics of weather extremes (Wikipedia/Climate.org).

In addition to the selection of material type and work methodology, considering the weather and climate condition helps while claiming time extension. According to FIDIC 1992 Clause 44.1 exceptional climate condition is one of the reasons which give extension of time for completion. Exceptional adverse climate condition includes earth quake heavy snow fall, heavy rain or any climate change that is unfavorable for work and which was not registered as occurrence of the past 10 to 30 years (FIDIC 1992).

On the other hand, cold weather is defined as a period when, for more than 3 consecutive days, the following conditions exist:

- 1) the average daily air temperature is less than 5° C (40° F) and
- 2) the air temperature is not greater than 10° C (50°F) for more than one-half of any 24-hr period. The average daily air temperature is the average of the highest and the lowest temperatures occurring during the period from midnight to midnight (Wikipedia/Climate.org).

## **2.4 Effect of Moisture on Road Construction**

The presence of water or moisture has lots of adverse effects on pavement performance. In fact, moisture damage in asphalt pavements is not only a headache for Ethiopia but it is of a global concern. That is why we should look in to the effect of moisture while talking about construction of road in rain.

Water or moisture often results in premature failure of asphalt pavements in the form of isolated distress caused by debonding of the asphalt film from the aggregate surface or early rutting/fatigue cracking due to reduced mix strength. Generally, moisture damage can be defined as the loss of strength and durability in asphalt mixtures caused by the presence of water (Stuart, K. D 1986). Hence, it is needed to correctly identify the problem and isolate contributing factors like material variability and construction practices for a better understanding of the effect of water on pavement deterioration.

As Stuart K.D describes, moisture damage is induced by the loss of bond between the asphalt cement or the mastic (asphalt cement, the mineral filler and small aggregates) and the fine and coarse aggregates. Moisture damage accelerates as moisture permeates and weakens the mastic, making it more susceptible to moisture during cyclic loading. Finally, moisture damage mechanisms results in the following distresses (Stuart, K. D 1986).

- Stripping: Debonding of aggregates and binder at the bottom of hot mix asphalt layer.
- Bleeding: Formation of asphalt binder film on the pavement.
- Rutting: Surface depression along wheel path.
- Corrugation and Shoving: Plastic movement typified by ripples or an abrupt wave across the pavement surface.
- Cracking, Water Bleeding and Pumping.
- Raveling: Progressive disintegration of Hot Mix Asphalt layer.
- Localized failures: Progressive loss of adhesion between binder and aggregates or progressive loss of cohesion in aggregates and in binder.

Historically, six contributing mechanisms associated with moisture damage have been identified. These are; detachment, displacement, spontaneous emulsification, pore pressure induced damage, hydraulic scour and the effects of the environment on the aggregate–asphalt system. However, moisture damage is not limited to a single mechanism but is the outcome of a combination of these mechanisms (Stuart, K. D 1986). Santucci and Aschenbrener (2003) have identified five factors that contribute to the adverse effects of water in asphalt pavement.

- a. Mix Design** includes binder and aggregate chemistry, binder content, air voids and Additives;
- b. Production** includes percent aggregate coating and quality of passing the No. 200 sieve, Temperature at the production plant, Excess aggregate moisture content;
- c. Compaction**—high in-place air voids, permeability—high values, mix segregation and changes from mix design to field production (field variability);
- d. Climate** High-rainfall areas and Freeze–thaw cycles;

- e. **Other Factors like** Surface drainage, subsurface drainage and rehab strategies chip seals over marginal HMA materials are also some of the factors that contribute to adverse effects of water in asphalt pavement.

## **2.5 Road Construction in Foreign Countries**

### **2.5.1 General**

The aim of this study is to assess Ethiopian road construction in the rainy seasons and to bring the experience of foreign countries in order to develop Ethiopian road construction. Accordingly, it can be seen from different literatures that the problem in most of other countries is not only the rain but also the cold weather and snow that occurs in those seasons. Therefore, this section will include the experience of different countries in construction of road in cold weather condition and the methodology they follow as well as the materials they use to pave.

### **2.5.2 Hot Mix Asphalt Construction in Cold Weather**

The issue of continuing to place Hot Mix Asphalt (HMA) in cold weather might come up in rainy season, when the weather turns cold and damp. Specifications generally set weather and temperature limits beyond which paving is to be stopped; but, jobs often need to be completed in spite of the specification limits.

A recent industry survey conducted and analyzed by a group of researchers at Auburn University, United States revealed the prevalence of paving hot mix asphalt in cold weather condition (Peter Hoeppe, 2003). NAPA 1981 showed that in the north-central region of the United States up to 5% of all projects get placed outside the normal paving season of April to November, and an even higher percentage are placed in adverse weather conditions overall.

The challenge of hot mix asphalt paving in cold weather is to achieve adequate compaction. There is general consensus that, if adequate density is obtained, the pavement will perform as expected. Thin courses and surface courses are

at the greatest risk of low density and poor performance when placed in cold weather. Intermediate and base courses greater than 5 cm thick generally can be adequately constructed with little change in normal procedures [NAPA 1981].

#### **a. Time for Compaction**

NAPA, 15-77 C.E minor, 1981 describes that cold weather compaction depends upon having enough time and enough rollers to obtain adequate density while the temperature of the Hot Mix Asphalt being placed is still within the compaction temperature range, approximately, 135 to 80°C. The same literature states that all weather factors affect the time it takes for the Hot Mix Asphalt to cool below 80°C. The weather factors are air temperature, wind speed and the presence or absence of sunlight. The type and temperature of the surface on which the Hot Mix Asphalt is to be placed is also added as a factor. But, the two most important factors are described as the temperature of the mix and the thickness of the course being placed.

Plant production mix temperature is one of the most influential factors on time available for compaction. So, an obvious solution is to produce hotter mix. But how much can the mix temperature be raised without causing damage and what is the cost? Binder suppliers normally recommend a mixing temperature based on viscosity tests. The NAPA publication on Cold Weather Compaction suggests that it is probably safe to mix at a temperature -8°C above the recommended temperature. Above that, one risks excessively aging the binder or placing too thin a coating on the aggregates. Raising the mix temperature takes extra fuel and lowers the production capacity of the plant. An examination of the plant production tables in the Hot-Mix Asphalt Paving Handbook indicates that raising the mixing temperature 4°C can reduce the production capacity of the plant by 15% or more. Likewise, increased aggregate moisture contents reduce the production capacity even more dramatically.

Given the combination of need for a higher mix discharge temperature and the presence of colder aggregates with higher moisture contents, it is easy to see that the plant production rate may be cut in half to produce mix in cold weather. This means that, twice as much fuel may be required to produce mix in cold weather(NAPA, 1981).

#### **b. Placement**

If the Hot Mix Asphalt course is to be placed on an aggregate base, the base must be solidly compacted, at or below optimum moisture. Excess moisture zaps the heat out of Hot Mix Asphalt rapidly and may contribute to soft spots in the base. If being placed over an existing paved surface, the surface must be dry and the tack coat material set. As stated in NAPA, in order to get slow setting emulsion tack coat to break and dry in cold and damp weather, rapid-curing liquid asphalt for tack could be used.

The literature further pointed out that instances have been reported where contractors have used jet racetrack dryers or infrared heaters to dry the surface before placement of the Hot Mix Asphalt. In addition, areas that require handwork or feathering of the mix can probably not be placed rapidly enough to permit adequate compaction. Construction of this type of work must be avoided during cold weather or considered to be temporary. Further, it is explained that construction of transverse joints are placed with good technique, starting off with the screed at the joint and on starting blocks so that time is minimized and the need for handwork is eliminated. And they regulate the Paver speed to allow the available rollers to complete compaction within the time and temperature constraints.

#### **c. Hauling and Temperature Segregation**

In the literature 'Procedures and Protocols for Bad Weather and Road Condition, 2004' it is mentioned that the other challenge while placing Hot Mix Asphalt in cold weather, is to get the mix into the paver with as much of that

heat left as possible,. The first thought was to tightly tarp the truck beds. However, as it is mentioned in the literature, a research has shown that to tarp loads has little effect on the average temperature of the load for normal haul times. This raises the topic of temperature segregation. Temperature segregation is the presence of masses of mix in the mat with temperature differentials that prevent uniform compaction [9]. When a load is transported in cold weather without a tarp, the cold crust that forms on the load may be placed through the paver as a cold spot in the mat that cannot be adequately compacted. It is recommended to tightly tarp the loads at least for longer hauls and to prevent exposure to precipitation. If tarps are used they should tightly cover the load and seal over the sides of the truck bed. Loose, flapping tarps may actually increase heat loss. Therefore, all of the foregoing speaks to the basic objective in cold weather paving: they keep the total time from mixing to compaction as short as possible.

#### **d. Summary and Conclusions**

It has been made clear that Hot Mix Asphalt paving can be successfully accomplished in cold weather without compromising the performance of the pavement, but costs will be higher. The goal is to obtain adequate time to finish compacting the mix, while it is still in the compaction temperature range (135 to 80 °C). Time available for compaction is most dependent up on the temperature of the mix and the thickness of the layer being placed and less dependent upon the environmental conditions. Availing adequate time for compaction can be accomplished by taking steps to alter these dependent variables and minimizing the time of exposure of the mix between mixing and compaction.

Specific actions may include any or all of the following as necessary:

- Increase the mix temperature
- Increase the layer thickness
- Minimize the time/length of haul
- Work the rollers as close to the paver as possible

- Use more and/or higher capacity rollers
- Use warm mix asphalt

### **2.5.3 Warm Mix Asphalt (WMA)**

#### **2.5.3.1 General**

Several new processes and products have been developed to reduce the mixing and compaction temperatures of Hot Mix Asphalt without compromising the quality of the mixture or the resulting pavement. This section discusses the warm mix asphalt concept and a few of the different processes that have been developed.

Traditional Hot Mix Asphalt is usually produced at temperatures between 140 and 180°C (284 and 356°F) and compacted at about 80 to 160°C (175 to 320°F)[11]. The temperature of the asphalt mix has a direct effect on the viscosity of the asphalt cement binder and thus on compaction. As hot mix asphalt temperature decreases, it results in a smaller reduction in air voids for a given compactive effort. Eventually, the asphalt binder becomes stiff enough to prevent any further reduction in air voids regardless of the applied compactive effort. The temperature at which this occurs, the cessation temperature, is considered to be about 79°C (175°F) for dense graded HMA mixes. These high temperatures for hot mix asphalt are required to achieve the right balance between (Koenders, B.G., D.A. Stoker, C. Robertus, O. Larsen, J. Johansen, 2002):

- Low viscosity of the bitumen to obtain full aggregate coating;
- good workability during laying and compaction;
- rapid increase in mechanical strength, and;
- durability during traffic exposure.

The goal of the WMA process is to reduce the high temperatures at which traditional asphalt mixes are produced and placed without adversely affecting these properties. Its benefits, as addressed in literatures, are reduction in the

energy consumption that is required to heat traditional HMA to temperatures above 150°C (300°F) at the production plant, and reduced emissions from burning fuels, fumes, and odors generated at the plant and the paving site(Asphalt Technology News, volume 17, number 2, 2005).

### **2.5.3.2 History of Warm Mix Asphalt**

The discussion of lowering the heat used to produce asphalt mixes is not new. The idea of saving energy and lowering emissions in the asphalt industry has been discussed for decades. In 1956, Dr. Ladis H. Csanyi, a professor at Iowa State University, realized the potential of foamed bitumen for use as a soil binder. Since then, foamed asphalt technology, which allows lower mixing temperatures, has been used successfully in many countries. The original process consisted of injecting steam into hot bitumen. In 1968, Mobil Oil Australia, which had acquired the patent rights for Csanyi's invention, modified the original process by adding cold water rather than steam into the hot bitumen then the bitumen foaming process became more practical(NAPA, 1981).

In 1994, Maccarone examined developments in cold mixed asphalt based on the use of foamed bitumen and very high binder content emulsions. He reported that the use of cold mixes for use on road works are gaining greater acceptance around the world. As Cold mixes do not emit hydrocarbons and use less fuel in manufacturing, such systems are energy efficient and environmentally friendly (Washington State Department of Transportation Pavement Guide Interactive Module).

Despite many good properties, cold mixes have not affected hot mix asphalt's position as the primary road surfacing material because they have not achieved the same overall long-term performance as hot mixes. In 1999, Jenkins *et al.* introduced a new process: half-warm foamed bitumen treatment. Their paper explores the considerations and possible benefits of heating a wide variety of

aggregates to temperatures above ambient temperature but below 100°C before the application of foamed bitumen (Koenders, B.G., D.A. Stoker, C. Robertus, O. Larsen, J. Johansen, 2002).

A warm asphalt mix process (WAM) has been developed in Europe and was reported by Harrison and Christodulaki at the First International Conference of Asphalt Pavements in Sydney, 2000(Washington State Department of Transportation Pavement Guide Interactive module). A more complete report was given by Koenders *et al.* at the Eurobitumen congress in 2000(wikipedia.org). Their paper describes an innovative warm mixture process that was tested in the laboratory and evaluated in large-scale field trials (in Norway, the UK and the Netherlands) with particular reference to the production and laying of dense graded wearing courses. Their work resulted in the development of WAM Foam, Warm Asphalt Mix with foamed bitumen (NAPA, C.E minor, 1981).

At the Eurobitumen congress in 2004, Barthelet *al.* introduced the use of a synthetic zeolite additive to produce warm mix asphalt. The zeolite creates a foaming effect that results in a higher workability of the mix (Rand, D. A., 2002). Warm mixes have received some attention in Europe and Australia since around 2000. The pavement industry in North America started to give warm mixes some interest a few years later and in June 2005 the National Center for Asphalt Technology (NCAT) published two reports about the use of Sasobit, a synthetic wax, and Aspha-min, a synthetic zeolite, in warm mix asphalt(Laramie Wyoming, 2002).

The following are some of the benefits of Warm mix Asphalt while paving in cold weather condition.

### **a. Emissions**

From the measurements that have been conducted and reported, it is clear that fume emissions during WMA production are significantly lower than during hot mix asphalt production. TPM, BSM and PAC measurements for a WAM Foam production were in the range 2-10% of that for a HMA production. Other emissions measurements were between 20 and 70% of that for HMA. For paving projects that are not in open air, for example in tunnels, workers exposure to emissions is multiplied and therefore the reduced emissions of WMA could be especially desirable for such situations as well. Studies reported in the NIOSH review indicate significant changes in pulmonary function in 1 of 44 workers engaged in open air asphalt paving but in 3 of 9 workers engaged in underground asphalt paving (Koenders, B.G, 2002). The importance of this WMA property will greatly depend on environmental awareness and regulations in each country and at each location within a country. Where emission regulations are getting stricter, which is the case for most countries participating in the Kyoto Protocol for example, the reduced emissions can become a very important benefit. Within each country, the reduced emissions are likely to especially encourage WMA usage in densely populated areas where day to day air quality is most important, and according to the considerations above, perhaps also in non open air situations. However, unless there are requirements from authorities or special incentives for asphalt producers to lower emissions, there is no direct benefit for the asphalt producer. If there is no an economical benefit for the producer, the realistic importance of this WMA benefit in practice is limited.

### **b. Energy Consumption**

The reduced energy consumption is another benefit of WMA that is greatly emphasized in literatures. When the energy consumption for a WMA production was measured, it was 60-80% of that for HMA production, depending on how much the production temperature was lowered. The

importance of this benefit depends on what sort of energy is used for the production process and how polluting and expensive it is. In most countries the energy cost is relatively high and therefore this benefit can be very important for the asphalt producer. Where sustainable and/or relatively inexpensive energy sources are used for asphalt production, this benefit is less important. It also needs to be taken into account that there is additional cost involved in using WMA, i.e. equipment modifications, patent fees for the WAM Foam method and cost of additives for the Aspha-min zeolite and Sasobit wax methods(Asphalt Technology News, 2005).

### **c. Mixture Viscosity**

Other possible benefits that have not been as prominent in literature as the reduced emissions and energy consumption are various benefits related to the lower viscosity of the warm mixtures. Generally, improved workability can have various effects throughout the production and placement process. For example, the improved workability has the potential of allowing the following benefits.

- i. Lower working temperatures, leading to:
  - energy savings during production;
  - reduced emissions;
  - decreased cooling rate due to smaller difference between ambient and compaction temperatures.
- ii. Increased temperature gap between mixing and compaction (by using regular HMA mixing temperatures), allowing:
  - increased haul distances;
  - increased time available for compaction, thereby for example extended paving season into the colder months of the year.
- iii. Easier compaction (by using regular HMA mixing temperatures), which are beneficial:
  - during extreme weather conditions;
  - for stiff mixes and mixes with RAP;
  - for reducing amount of necessary roller compaction.

- iv. A combination of items 1 and 2 or items 1 and 3, by reducing production temperatures by some amount and increasing the temperature gap or facilitating compaction by some amount.

### **2.5.3.3 Cold Weather Paving of WMA**

In order to evaluate WMA's suitability for cold weather conditions, a few general issues regarding cold weather paving are discussed in this section. As it is described in other sections too, compaction is especially important during cold weather paving. As ambient temperatures decrease, HMA cool down rates increase and the time available for compaction, before cessation temperature is reached, is reduced. Literatures indicate that 20 Pa-s (200 poises) is a reasonable lower viscosity limit for compactability, i.e. cessation temperature (Cold Weather Compaction, 1998). Dense and well compacted pavements have close aggregate-to-aggregate contact and will be more stable and have lower permeability. Achieving low permeability is especially important when compacting in cold weather. The grade of asphalt cement in HMA influences compaction such that lower viscosity (soft) grades are mixed, placed and compacted at lower temperatures than harder grades. Soft grades are normally mixed at lower pug mill temperatures and have lower cessation temperatures. A mix made with softer grades than normal in order to improve compaction may be easier to compact at lower temperatures but it is likely to be unstable under summer traffic.

Total compaction time between placement and cessation temperature for different grades is roughly the same. Asphalt modifiers such as hydrated lime, fibers, anti-oxidants, chemical anti-stripping agents, carbon black, rubber and polymers can each affect compaction in a different way. Cold weather compaction is not increased by the use of additives that increase viscosity. More viscous asphalt will probably have higher cessation temperatures. The mix design process does not need to be altered for cold weather conditions but particular care must be taken to ensure that mixtures are not overly

susceptible to moisture damage. Surface water infiltration can cause rapid deterioration under traffic when pavement surfaces compacted in cold weather are more permeable. The relationship of base and mix temperature is important. With a cold base and low initial mat temperature, thin lifts cool rapidly. Compacting HMA pavements on a frozen base results in two problems; more rapid cooling will prevent adequate compaction and a wet thawed base can cause support failure. If the frozen base contains moisture the temperature drop is even greater (Prowell, B.D., G.C. Hurley, 2005).

Of these issues discussed here, compactability and permeability, moisture susceptibility and binder grade, are of special interest regarding WMA for cold weather conditions. Compactability is indeed well accounted for by the warm mix methods, since they all reduce the viscosity of the asphalt and have the capability of increasing compaction and thereby reducing permeability. Rutting measurements give an indication of in-service stability. Sasobit and WAM Foam appear to have adequate rutting resistance and Sasobit is said to increase in-service stability but Asphamin does not affect rutting. All three methods should result in adequate stability but WAM Foam's and Sasobit's performances are more definite. It seems clear that for cold weather paving with WMA, use of anti-stripping agents will be desirable, whether it will be necessary depends on other factors as well, for instance aggregate quality and moisture content. Considering the issues that have been discussed here above, WMA appears to be a viable option for cold weather paving. This can be said about all of the three methods, although there are slight differences in some of their measured properties. However, anti stripping agents are likely needed to decrease rutting and moisture susceptibility. Many of the advantages gained when WMA is produced at regular hot mix asphalt temperatures are particularly beneficial for cold weather conditions.

### **2.5.4 Concrete as Road Making Material**

Except in air port run way projects, asphalt is being the only choice as road pavement material in Ethiopia. However, concrete is being used as road making material in the world. For instance, concrete played a major role in the construction of the U.S. Interstate Highway System during the past 50 years. The national focus has shifted from building new highways to maintaining and repairing the existing highway network. Recent advances in concrete technology has enabled highway contractors to rehabilitate the nation's 160,000 mile (275,000 km) national highway system and extend its useful life with minimal disruption of traffic (IrA. Jasiensk, 2001).

The national highway system, which includes the nearly 45,000 mile interstate system, carries 40% of the nation's total traffic, including 70% of the commercial traffic and 90% of the tourist traffic, according to the Federal Highway Administration. About 60% of the interstate system is concrete, especially in urban areas where FHWA anticipates heavy traffic loads. Concrete was selected, in part, because of its durability.

Concrete can support heavy loads, such as truck traffic, with less deformation than asphalt. Although the initial cost of concrete used to be higher than asphalt, today concrete has become the least expensive alternative for new construction on a first-cost basis in addition to maintenance costs being generally lower. In addition, concrete generally has a useful life of twice that of asphalt. Concrete commonly serves 20–30 years without needing major repair, while asphalt typically lasts only 8–12 years before resurfacing or significant repair is required (IrA. Jasiensk, 2001).

#### **2.5.4.1 History of Concrete Highways**

The first concrete highway constructed in the United States was a 24 mile (38.6 km) long, 9 ft (2.7 m) wide, 5 in. (12.7 cm) thick strip of concrete pavement built near Pine Bluff, Arkansas, in 1913, five years after the introduction of the Model T Ford. By 1914, Portland cement concrete had been used to pave 2,348

miles (3778 km) of roadway. Highway construction received a significant push forward two years later when President Woodrow Wilson signed the first Federal-Aid Highway Act directing the federal government to help states finance road building. In 1919, Oregon became the first state to level a fuel tax on gasoline to finance road construction. Today this is still the primary method of financing road building and maintenance. The Pennsylvania Turnpike, built on a railroad right-of-way during the 1930s, was the first major intercity turnpike or toll road in the United States and was constructed of concrete significant technical and design developments during the 1930s and 1940s made concrete paving faster, less expensive, and more durable. Road designers stopped requiring contractors to build roads that were thicker at the edges—concrete highways were generally 6 in. (15 cm) thick at the middle and 8 or 9 in. (20 or 23 cm) thick at the edges—and permitted construction with a uniform concrete depth, saving time and money. Designers began to require that subbases of gravel, crushed stone, or slag be placed beneath concrete highways in the late 1930s, when an increase in heavy truck traffic caused pumping, a phenomenon in which a concrete slab loses support and cracks as wet clay and soil particles underneath shift and are pumped from beneath the slab at its edges.

In the 1940s, some highway departments began to use soil-cement as a sub grade for highways. At this time, contractors also changed their method of creating pavement joints. Rather than forming the joints when the concrete was fully plastic by lumping it up to either side of the joint, contractors began sawing the concrete once it was partially hardened to create a smoother joint. This change in procedure helped create more even highway surfaces, and eliminated the familiar "bump, bump" drivers feel at some aging slab joints.

At this time, concrete pavement also exhibited problems with scaling, the flaking or peeling away of the surface, which studies determined to be the result of freeze-thaw cycles, accelerated through the use of deicing salts.

Studies showed that the introduction of tiny air bubbles in the concrete mix could reduce the problem. This led to the development of air-entrained concrete, now used in virtually all U.S. road building. The invention of the slip-form paver in 1949 was another milestone in the development of concrete paving technology, as it allowed road crews to place wide sections of concrete continuously, and therefore far more efficiently than before. Slip-forming is now used for highway paving projects in almost every state. Many consider the construction of the interstate highway system, during the 1960s and 1970s, to be a heyday for concrete paving, and road building in general. But even as thousands of miles of concrete highway were formed, research and development continued, improving methods of placing and maintaining concrete. In 1976, the U.S. Congress recognized the need to specifically finance maintenance of the highway system, and approved federal funding for the 3R program: restoration, rehabilitation, and resurfacing.

#### **2.5.4.2 New Construction Techniques**

Several relatively new techniques make it possible for contractors to efficiently rehabilitate and resurface highway with minimum traffic interruption. Among these is fast-track concrete pavement technology, in which high-early-strength concrete is used to allow reconstructed roads to open more quickly. While conventional concrete mixes might require a curing time from 5 to 14 days, fast-track concrete can meet roadway opening strengths in 12 hours or less. Although combinations of ingredients vary, high-early-strength concrete commonly includes a higher proportion of the standard.

Type I cement to water or contains high-early-strength cement, known as Type III cement. Type III cement is virtually identical to Type I, except that Type III cement particles are ground much smaller. The smaller cement particles increase the surface area, allowing more cement contact with the water in the concrete mix, meaning faster hydration is achieved. Generally, fast-track concrete provides good durability because most of these concretes are air

entrained and have a relatively low water content—factors that improve strength and decrease the chloride or salt permeability that damages steel reinforcement which contributes to deterioration.

#### **2.5.4.3 Types of Concrete Roads**

There are different types of concrete roads as discussed by IrA. Jsiensk, 2001 in Road Pavement of Cement Concrete:

##### **I. Plain concrete - short pavement slabs**

This type of pavement consists of successive slabs whose length is limited to about 25 times the slab thickness. At present it is recommended that the paving slabs not be made longer than 5 m, even if the joints have dowels to transfer the loads. The movements as a result of fluctuations in temperature and humidity are concentrated in the joints. Normally, these joints are sealed to prevent water from penetrating the road structure. The width of the pavement slabs is limited to a maximum of 4.5 m.

##### **II. Reinforced concrete**

###### **II-a Continuously Reinforced Concrete**

Continuously reinforced concrete pavements are characterized by the absence of transverse joints and are equipped with longitudinal steel reinforcement. The diameter of the reinforcing bars is calculated in such a way that cracking can be controlled and that the cracks are uniformly distributed (spacing at 1 to 3 m). The crack width has to remain very small, i.e. less than 0.3 mm.

###### **II-b Reinforced Pavement Slabs**

Reinforced concrete pavement slabs are almost never used for road construction, except for inside or outside industrial floors that are subjected to large loads or if the number of contraction joints has to be limited.

###### **II-C Steel Fiber Concrete**

The use of steel fiber concrete pavements is mainly limited to industrial floors. However, in that sector they are used intensively. For road pavements steel

fiber concrete can be used for thin or very thin paving slabs or for very specific applications.

#### **2.5.4.4 Construction of Concrete Road**

While construction concrete road some steps are followed. The main steps followed while constructing concrete steps are discussed below in order to give a high light how concrete roads are constructed in other world.

##### **I. Preparation of the Subgrade**

In order to realize a pavement structure of an adequate and uniform thickness, the road sub grade has to be prepared carefully. This allows to provide a homogeneous bond between the concrete slab and its foundation which is important for the later behavior of the pavement structure (Washington State Department of Transportation Pavement Guide Interactive, Module). For roads with base, drainage of the water must be provided and mud, leaves, etc. have to be removed. When the base is permeable, it should be sprayed with water in order to prevent the mixing water from being sucked out of the concrete. However, if the base is impermeable (e.g. if the concrete is placed on a water tight asphalt concrete interlayer) it can be necessary under warm weather conditions to cool down this layer by spraying water on the surface (Koenders, B.G., D.A. Stoker, C. Robertus, O. Larsen, J. Johansen, 2002).

The following points are important for roads without a foundation:

- drainage of all surface water;
- good compaction of the sub grade;
- filling and compaction of any ruts caused by construction traffic;
- it is forbidden to level the subgrade by means of a course of sand. If the subgrade has to be leveled, it is advisable to do this by using a granular material: either slag or coarse aggregate e.g. with a grain size 0/20;
- provide an additional width of the subgrade for more lateral support. The sucking of water from the cement paste into the substructure or the base must always be avoided. This can be accomplished by either

moderately moistening the subgrade, or by applying a plastic sheet on the substructure of the pavement. The latter work must be done with care, to prevent the sheet from tearing or being pulled loose by the wind.

The properly and improperly prepared subgrade surfaces for concrete road are shown under Figure 3 and 4 (Koenders, B.G., D.A. Stoker, C. Robertus, O. Larsen, J. Johansen, 2002).



Figure 3- Carefully prepared subgrade



Figure 4-Improper prepared subgrade

## **II. Mixing and Transport of Concrete**

### **a. Concrete mixing plant**

The concrete mixing plant must have a sufficient capacity in order to be able to continuously supply concrete to the paving machines. The mix constituents and admixtures have to be dosed very accurately. The bins shall have raised edges to prevent contamination of the aggregate fractions. The equipment for loading the materials shall be in good condition and shall have sufficient capacity to be able to continuously feed the bins. The bucket of the loaders shall not be wider than the bins. The content of the cement silos and the water tank are in proportion to the production rates

### **b. Transport of the Concrete**

Sufficient trucks must be available to continuously supply the paving machines. The number depends on the yield at the construction site, the loading capacity of the trucks and the cycle time (i.e. the transport time plus the time required to load and unload a truck). The loading capacity and the type of truck to be used depend on the nature of the work, the haul roads and the concrete paving machines. Usually, the specifications prescribe that the concrete has to be transported in dump trucks as paving concrete consists of a relatively dry mix having a consistency that makes transport and unloading in

truck mixers difficult (Cold Weather Compaction, NAPA,QIP 118, 1998). Furthermore, dump trucks can discharge the concrete faster. For small works and in urban areas, the use of truck mixers is increasingly accepted. Under these circumstances an admixture (e.g. a super plastifier) can be mixed just before discharging the concrete. The necessary measures have to be taken to prevent changes of the water content and temperature of the concrete during transport. To this end, the specifications prescribe to cover the dump trucks by means of a tarpaulin.

### III. Placing the Concrete

As can be clearly shown under figure 6, usually concrete is placed using slip form paving machines which applies for all categories of roads. This equipment meets both the requirements for quality and for the envisaged rate of production. Conventional concreting trains riding on set up rails are hardly used any more for road works in U.S. However, as it is shown in figure 7, the technique of manually placing the concrete using forms is still applied in certain cases, such as for the construction of roundabouts with a small diameter, at intersections, for repair work or when the execution conditions are such that slip form pavers cannot be utilized. This occurs increasingly often in urban areas for the construction of pavement surfaces of exposed aggregate and possibly coloured concrete.



Figure 5- Placing Concrete

Figure 6- Placing Concrete

Figure 7-Concrete Finishing with Hand tool



All the necessary to or hardened present at the saw blades the quality of hardness and

#### **IV. Execution of Joints**

equipment that are make joints in the fresh concrete must be construction site. The have to be suitable to the concrete, i.e. to the the abrasion resistance

of the aggregates. It is useful to have spare equipment available in case of a defect. The beam for making a construction joint shall be rigid and shall allow the realization of a straight joint perpendicular to the axis of the road. This beam has to be adapted to the type of pavement (jointed pavement, continuously reinforced concrete pavement).

#### **2.5.4.5 Concrete Paving in Hot and/or Dry Weather**

Hot and/or dry weather can have different adverse effects:

- faster drying out of the concrete, which is accompanied by shrinkage deformation (cracks forming due to plastic shrinkage);

- thermal deformations as a result of the concrete mass heating up. At air temperatures above 25°C, or at a relative humidity below 50 %, special measures have to be taken to protect the fresh concrete against drying out and being warmed up by the sun:
- apply additional curing compound to the fresh concrete;
- moisten the concrete as soon as it has hardened sufficiently. Other measures, having the same purpose, can also be considered,
- sprinkling the foundation just before the concrete is deposited;
- adding a setting retarder to the concrete mix;
- shifting the working hours

#### **2.5.4.6 Concrete Paving in Cold Weather**

Paving in cold weather is often necessary due to tight construction schedules, liquidated damages, incentives, and expedited project requirements. Existing guidance on cold weather concreting such as ACI 306 has not changed substantially in recent years, although the knowledge about concrete's early age behavior has increased.

Concrete placed during cold weather will develop qualities only if it is properly produced, placed, and protected. The necessary degree of protection increases as the ambient temperature decreases.

When placing concrete in cold weather, the setting and hardening time of the concrete increases due to the slower hydration of the cement. Cement hydration in a freshly placed concrete mixture is an exothermic reaction, which means that it gives off heat. Most of the heat of hydration is generated during the first three days after placement and finishing (IrA. Jasiensk, 2001).

ACI 306R-88 recommends that concrete should be protected from freezing if air temperature is expected to fall below 4°C (40°F) in any of the three days following paving (Terrel, R. L. and J. W. Shute, 1989). The Colorado

Department of Transportation's new cold weather paving specification allows contractors to maintain the concrete temperature above 4°C (40°F) until the pavement reaches 13.8 MPa (2000 psi) compressive strength to continue the cement hydration reaction (Are Hot Mix Tarps Effective, NAPA, 1981). To date, experience with and results of the new specification have been very positive. Insulating blankets (Figure 8), mats, or foam sheets are commonly used in cold weather concreting to protect fresh concrete from freezing and maintain its temperature at a higher level. This allows hydration to occur at a more rapid rate, generating higher temperatures and promoting faster strength gain. However, insulation blankets do not negate the need for curing compound, which should be applied prior to the blankets, to form the membrane required to hold in moisture.



Figure 8- Insulating blankets in place on freshly-placed concrete

If the temperature of a freshly-placed concrete pavement is measured over time, and those data points are plotted on a graph, the area under the curve can be called the time-temperature factor (TTF), which is a measurement of the concrete's maturity (IrA. Jasiensk, 2001).

In developing the maturity curve for a particular concrete mixture, multiple specimens must be cast, their temperatures measured over time, and their

strength determined by conventional destructive testing (flexural or compressive) at various intervals to determine the maturity-strength relationship. This relationship is then valid for that mixture in any condition.

The benefits of maturity include:

- Identifies earliest possible opening to both construction and public traffic;
- Allows determination of optimum time to saw cut joints;
- Facilitates both fast-track and cold-weather construction operations;
- Requires fewer specimens to fabricate and test;
- Facilitates earlier agency acceptance and contractor payment;
- Using the maturity method with cold weather paving allows contractors to not only monitor the strength gain to determine when a pavement is strong enough to support construction traffic, but also to monitor the internal concrete temperature;
- Armed with this information, contractors can better determine how to manage the concrete insulating blankets, paving operation, and when to suspend operations.

### **2.5.5 Summary**

IrA. Jasiensk, 2001 noted that concrete pavements are well-suited to rainy and cold weather. They can be designed, constructed, and maintained in cold weather, as long as a few important factors are considered. Poor soil in the subgrade that is susceptible to frost action must be addressed to prevent frost heave and pavement damage. Paving in cold weather is acceptable, as long as the concrete does not freeze and gains adequate strength before construction and public traffic are allowed on the pavement. The maturity method is a helpful tool for paving in cold weather, as it allows both temperature monitoring and strength determination.

Therefore, it can be concluded that using concrete road in Ethiopia is suitable since freezing and very cold weather does not occur.

## **3. Research Design and Methodology**

### **3.1 Introduction**

As mentioned in section 1.3 of this thesis the aim of the research is to assess the experience of road construction in Ethiopian rainy seasons and to give a way to our road construction industry by bringing the experience of the other countries toward the road construction in their rainy and cold weather. The main objective of the study is to find a way for the Ethiopia road construction while planning and executing projects in the rainy season, and make recommendations based on the findings. The research design and methodology followed towards this end are discussed as follows.

### **3.2 Research Design**

The research strategy adapted for this research is qualitative research of exploratory type which diagnoses a situation, assess alternatives, and discover new ideas. The overall approach, as described in chapter 1 of this thesis, followed by a four stage process; having established the basis of the research, necessary data were collected, analyzed, and conclusions and recommendations were made based on the findings. The methods of data collections employed for the research were case study, desk study, and interview. The case study and desk study were analyzed in relation to theoretical propositions, and the responses obtained from the interview were also analyzed using descriptive statistics method. The next sections discuss the tools used for data collection and method of analysis.

### **3.3 Data collection**

#### **3.3.1 Interview**

The 1st research question was “Are the months in the rainy seasons considered as working months in Ethiopia road construction industry?” The answer for

this question and supplementary information for the other research questions were gathered from key respondents in order to deepen the findings of the case study and desk study. The interview schedule shown in the Appendix consists of four main questions as enumerated from No. 2 to 4, Question 1 being inquiry about the respondents' profile. The questions (2-4) focus on the following issues.

**Question No.2** focused on “whether rainy seasons are considered as working months”, “Do the specification in use mentioned not to schedule a work in the rain?” and “Which activities usually are done in the rain seasons?”. These questions were intended to achieve the 1<sup>st</sup> and the 2<sup>nd</sup> specific objective of the research which assess the intention of the involved parties (Client, consultant and contractors) who are participating in Ethiopian road construction industry towards constructing a road in rainy seasons. This helps to see whether the rainy season is considered as working months in Ethiopia road construction industry.

**Question No. 3** was meant to investigate the experience of foreign countries in constructing of road in the rain and cold weather condition by gathering information from participants who has a working experience outside Ethiopia. These questions were intended to achieve the 3<sup>rd</sup> specific objective of the research which is to investigate the experience of other countries and their methodologies that are considered while constructing in a cold weather.

**Question No. 4** looked into the opinion of the participants in managing the road construction in rainy seasons. These questions were intended to achieve the 4<sup>th</sup> specific objective of the research which is how to manage our road construction projects in order to effectively execute works in rainy conditions.

The following steps were followed in preparing the semi-structured questionnaire for the interview schedule:

- i. The general purpose and specific requirements were first determined: The general purpose of the interview was to assess the practices and perceptions of key respondents who participate in the planning and construction of local and international road projects, toward road construction in rainy season. The specific requirements were focused on Ethiopian condition.
- ii. The questions that need to be asked were then developed: Semi-structured questions with open and closed-ended questions were formulated so that they could generate relevant answers to the research questions.
- iii. The questionnaire was structured in two main parts: The first part was a covering letter with information about the research project, contents of the questionnaire, and how the responses would be utilized. The second part was the questionnaire. The type of sampling adapted for this research is selected sampling. The key respondents targeted for this research were professionals from the Client (Ethiopian Roads Authority), Contractors and Consultants. Those professionals who specifically worked in local and international projects under Ethiopian Roads Authority and who have participated in foreign counties' road construction project were selected for the interview. Accordingly, 12 key respondents were interviewed with pre-distributed questionnaire. The respondents profile is shown under Table 1, 2 and 3 below.

Table 1: Educational Status of Respondents

Educational Status	Number of Respondents			
	Client	Consultant	Contractor	Total
MSc	2	1	1	4
BSc	1	3	4	8
Total	3	4	5	12

Table 2: Experience in road sector

No. of Years	No. of Respondents
0-5 years	2
5-10 years	4
>10 years	6
Total	12

Table 3: Country of Experience

No. of Respondents	Country of Experience
5	Ethiopia
1	Ethiopia and Angola
1	Ethiopia, India, Malawi and Tanzania
2	Ethiopia, China and Uganda
1	Ethiopia and Germany
1	Ethiopia, China, Rwanda and

	Kenya
1	Ethiopia and China

### 3.3.2 Case Study

The 2nd research question was “Are the months in the rainy seasons considered as working months in Ethiopia road construction industry?” In order to obtain answer for this question, study of cases of two local and two international projects were used as one of the tools to find out the answer for this question. The approach used to select samples/projects for the case study was selected sampling. The projects were selected first by gathering all projects under Central Region of Ethiopian Roads Authority which have full data of their monthly status report for each month for the total project duration. In addition, the projects included were projects that was started with in the recent ten years. Finally, two International projects and two local projects were selected since they have full data’s of their monthly status report.

### 3.3.3 Desk Study

The 3rd and 4th research questions examine “Do the foreign countries consider rainy and cold weather conditions as working environments?” and “What methodologies do they use while planning and constructing roads in cold and rain conditions?” respectively. Desk study was chosen as one of the instruments to assess the practices from relevant studies, reports, specifications and documents.

### 3.3.4 Data Analysis

The case study and desk study were analyzed in relation to the theoretical propositions. The method used to analyze the interview data is descriptive statistics method. This method of analysis helps to analyze the responses in actual numbers. Accordingly, frequency distribution was used to distribute the data into categories and determine the number of individual or cases belonging to each category, which were presented in the form of table.

## **4. Results and Discussions**

### **4.1 Road Construction in Ethiopian Rainy Seasons**

A response by all respondents to a question that inquires whether the design consultants consider the rainy seasons as working months while preparing a tender document has revealed that some of the design consultant do not consider the rainy season as working months while calculating the duration of the project. Besides the contractors do not usually assume that the duration of the project considers the rainy season as working months. However, the contractors schedule to work in the rainy seasons some activities which are suitable to work. The respondents mentioned the following activities as some activities which are done in rainy season in Ethiopia:

- excavation works especially in rocky areas (but unless it is done with great care it could in land sliding);
- production and installation of drainage pipes;
- crushing of stones;
- production and installation of precast products (including side drain);
- continuous surveying and design preparation works (especially surveying works unless interrupted by heavy rainfall and fog giving unclear vision);
- equipment maintenance and early purchase preparations has been made.

It is also revealed from the 75% of the respondents that the specifications in use do not say anything about stopping construction work in the rainy seasons. There is no chance of using different paving materials other than bitumen for road construction, however it is mentioned that concrete runway is usually used while constructing airports. And all the respondents agree that road designers should get a chance in using different paving materials while designing road projects.

## **4.2 Road Construction in Foreign Countries**

58% of the respondents had a chance to work in different countries like Angola, Tanzania, Uganda, India and China. 25% of the respondents had no working experience out of Ethiopia however they had a chance to work with professionals with the same experience and had a chance to share such experience in different workshops in and out of Ethiopia. The rest 17% of the respondent didn't have any experience out of Ethiopia.

75% of the respondents explained that with long cold and rainy seasons, efforts have been made in other countries like China, Germany, India and Tanzania to use these seasons for construction. There has been some success in carrying out a lot of construction activities in rainy seasons by:

- Using different technological findings such as additives for concrete work, special type of bitumen, stabilization for earth work, styrohome for fill work;
- Using prefabricated products especially for structural works;
- Bringing raw materials from outside the site for the construction works and storing the materials in a safe and secure way;
- Preparing plans and schedules thoroughly and with proper care;
- Giving employees sufficient health and safety provisions;
- Using construction equipment that can efficiently move and work in watery and muddy grounds of the site (sheep foot roller, steel cover for tires, sheet piles).

In addition, they were able to perform better construction activities than seen in Ethiopia in the rainy seasons, because they have initiation to work at days when there is no rain even for half a day.

### **4.3 How to Manage Ethiopian Road Construction Projects**

The main reasons that restrict effective work in the Ethiopian road construction in the rainy season pointed out by contractors and consultants are:

- Not thoroughly investigating the works and preparing schedules ahead (less planning effort)
- Less preparation for purchase process of construction materials;
- Unavailability of sufficient safety and health provision for employees that decreases their initiation and productivity;
- The design studies do not help speeding up of construction work and to work in rainy seasons;
- The undeveloped culture and attitude of people who participate in the construction industry to challenge difficult conditions and having motivation to look for solutions;
- Contractors do not want to work and schedule the works in the rainy seasons with the intention of requesting time extension claims;
- Not having an advanced way of design and construction technologies.

In addition to the reasons stated above, by taking into consideration Ethiopia's general conditions, the respondents pointed out the following as reasons that hinders effective road construction in rainy season:

- As the soil type in most parts of the country is clay, it retains moisture which results in mud and needs more time to dry making it difficult for cut and fill work;
- Even if it is for small hours, the intensity of the rain is very high (more than 1000mm/day) so that the construction raw materials, the ground and also the constructed area doesn't get dried out for so many days;
- Due to the difficult terrain condition, there are lots of rivers which overflow;

- Unavailability of detailed meteorological data that covers the whole regions of the country;
- Decrease in number of labors in relation with harvesting times;
- At mountainous areas, long duration of rain and fogs makes the construction work more difficult.

However, since road construction takes a long time and complicated designs, we don't have a habit in revising and preparing design templates during the rainy season. Instead we demobilize during the rainy season and then mobilize again while the dry season starts with all the design problem and unrevised schedule and planning.

On the other hand, while visiting the Chinese Construction Company who constructed Addis –Adama Express way project, they use subcontracting method in their country. There was a project which had similar scope and it was started in the same month. However, the project in china was completed in less than a year while ours took more than four years. As explained, the reason was they have different subcontractors in china who work for every item of construction works, earth works, casting concrete for different structures, paving asphalt etc. For instance, in order to cast concrete of overhead bridge or any other structures, there are subcontractors who deliver the required amount of concrete with the required quality at the desired time. Similarly, there are different suppliers for delivery of sub base materials, base course material, mixed asphalt; pre cast materials and other required material that can help for the construction of the project. Working with this system encourages and helps the contractor to plan and work in the rainy seasons since the construction works on site will become limited.

In addition, this helps the contractor;

- to transfer the risk;
- to solve the financial problem that occurred on the contractor, for example, the contractor doesn't need to import and own huge construction machineries and plants.
- Since the subcontractors or the suppliers will deal with a specific work or product, they will begin to use modern technologies that can maximize their production and quality;
- To minimize the time that the contractor could waste on shipping, mobilizing to site and installation of huge plants. Since this is one of the activities that is interrupted due to rain;
- The supplier will have a permanent production and storage place that can work on rainy seasons. This also will help the contractor to work on rainy season by ordering those products.
- The time and money that could be lost by solving the Right of way problems for the production of different materials will be saved

## **4.4 Case Study**

### **4.4.1 Overview of Road Project Implementations**

In Ethiopia, the key parties involved in road projects implementations are the Government of Ethiopia represented by the Ethiopian Roads Authority, Contractors and Consultants. ERA is charged with the duties and responsibilities of providing adequate road infrastructure to support the socio-economic development of the country. The task involves improving the condition of existing roads and expanding the network. ERA was established in 1951 as Imperial Highway Authority and was responsible for the design and implementation of road projects for about 40 years from its establishment by making use of in-house design and own force unit for construction. Later, the authority is restructured and the in house design preparation was transferred to consultants who are entrusted with the task through competitive bidding. In

addition, the responsibility of the own force unit was reduced and most projects have been put for competitive bidding for Contractors.

Currently, the Contractors taking part in road projects implementations are National (Local) and international companies. Most of the local Contractors are of limited capacity and rarely meet the requirements to participate in donor financed projects. Hence, international Contractors, who meet the requirements, have been participating in donor financed projects. The contracting company after winning the contract will take the responsibility to complete construction of the project in accordance with the contract document. Consultants, like Contractors, will also take the responsibility for the design and/or supervision services they render in accordance with the contract document. International Consultants' have also been participating in donor financed projects.

The project delivery method widely practiced by ERA is the traditional design-bid-build approach. This approach has three separate phases. First, the feasibility and/or design of a project are undertaken by a Consultant, then a bid is floated to procure a Contractor, and finally the selected Contractor completes the construction.

#### **4.4.2 Case Study of the Road Projects**

This study has used four projects, two local and two international sample projects, under Ethiopian Roads Authority in order to see the progress of the projects in the rainy season.

It can be seen from the sampled case studies that are taken from ERA projects that some of the project schedules do not include the rainy season as working months, they don't even plan to work in rainy months. However, some of them

plan but do not perform many activities in the rainy seasons. We can see from this that the contractor have its own choice whether to plan or not to plan to work in the rainy months since the client and consultant already consider these months as non working months. In this thesis the Contractor's accomplishment is compare in accordance to their physical and financial accomplishment. Physical accomplishment means physical work done divided by physical planned work for the specific month at the beginning of the commencement of the project. In the other hand financial accomplishment means the amount of the work will be converted to birr (any other currency in use) and it will be divided to the finance that was planned at the commencement of the project.

#### **I. Modjo-Edjere-Arerti-Gobensa Roads project**

Modjo - Edjere – Arerti - Gobensa Road project is a 33 km road being constructed under the Ethiopian Roads Authority which is located in Amhara National Regional State North Shewa Zone. The consultant is a local consulting firm named Best Consulting Engineers Plc and contractor is also a local construction company called YENCOMAD Construction Plc. The commencement date of the project was on April 06, 2010 and the completion of the project period is planned to be on October 04, 2013. June, July and August are the rainy season of the project site.

As it can be seen from the physical and financial plan and accomplishment of the project schedules, which is shown in Figure 9, 10, 11 and 12 graphically, the project duration has passed through two rainy seasons. In the first rainy months of the year 2011, which were July, August and September, there were no activities planned however Earth work and drainage works were executed. It was reported in the monthly reports of the above mentioned months that the contractor could not do additional work due to the following reasons.

- To mobilize required plant and equipment according to the plan;
- To mobilize explosive for excavation of rock;
- To organize the machinery maintenance crew well to maintain down machineries as soon as possible;
- To provide required laboratory equipment for concrete work;
- To speed up construction of Engineer's and Contractor's camp construction;
- To identify additional sub-base and base course sources;
- To mobilize sand and gravel for structure work;
- To provide permanent laboratory equipment were also mentioned as some of the problems encountered in those months.

On the other hand, in the rainy months of 2012, drainage works, earth work and structure were executed even though there were not planned. However, in this reporting months rain was not mentioned as one of the problems encountered in the rainy season. Though failure to remove obstructions and electric power lines and poles were mentioned as problems encountered from the client side and failure;

- To complete the erection of mobilized crusher plant for base course material;
  - To commence construction of reinforced concrete drainage by mobilizing required resources;
  - To commence the reinforced concrete open drain construction;
- were also mentioned as problems encountered from the contractor side.

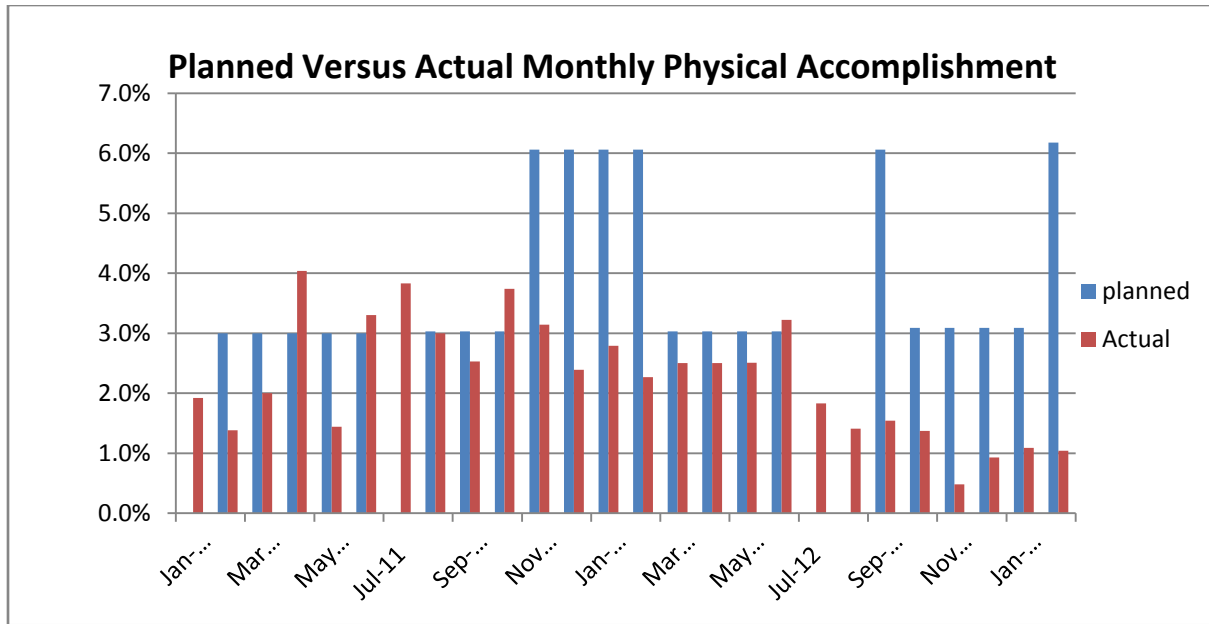


Figure 9- Planned Versus Actual Monthly Physical Accomplishment of Modjo- Edjere- Arerti- Gobensa Road Project

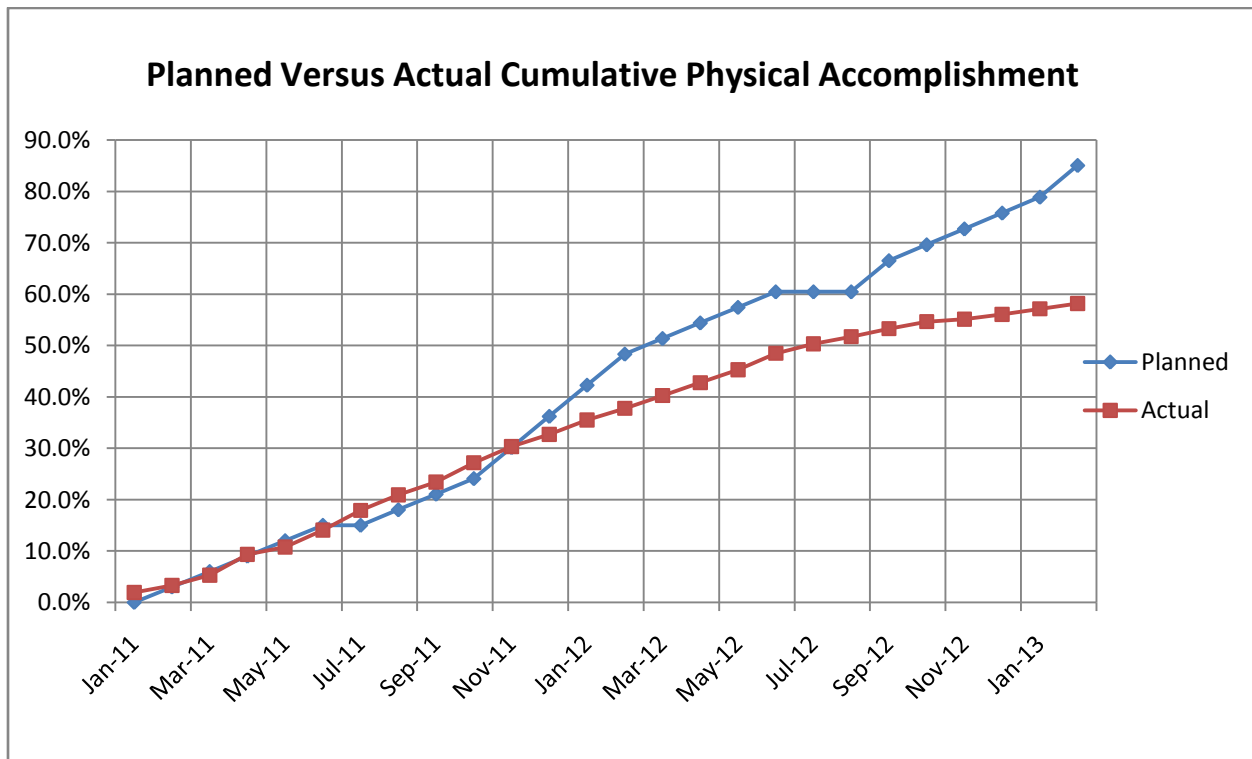


Figure 10- Planned Versus Actual Cumulative Physical Accomplishment of Modjo- Edjere- Arerti- Gobensa Road Project

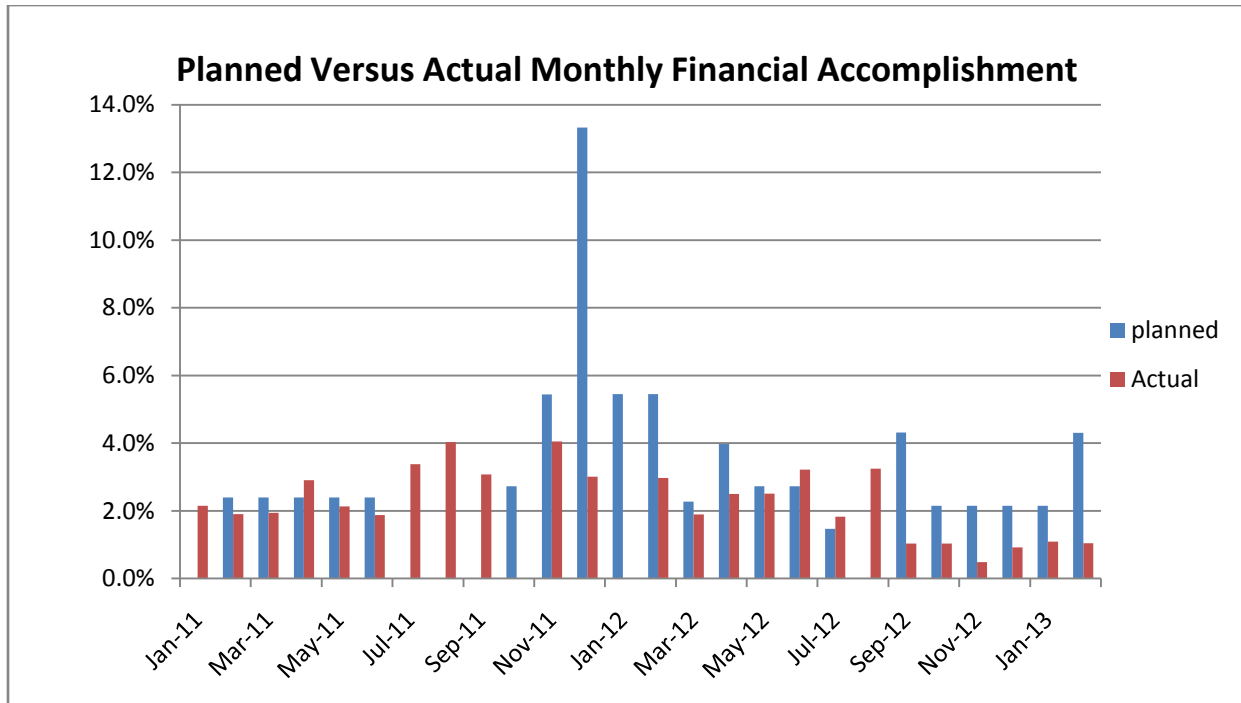


Figure 11- Planned Versus Actual Monthly Financial Accomplishment of Modjo- Edjere- Arerti- Gobensa Road Project

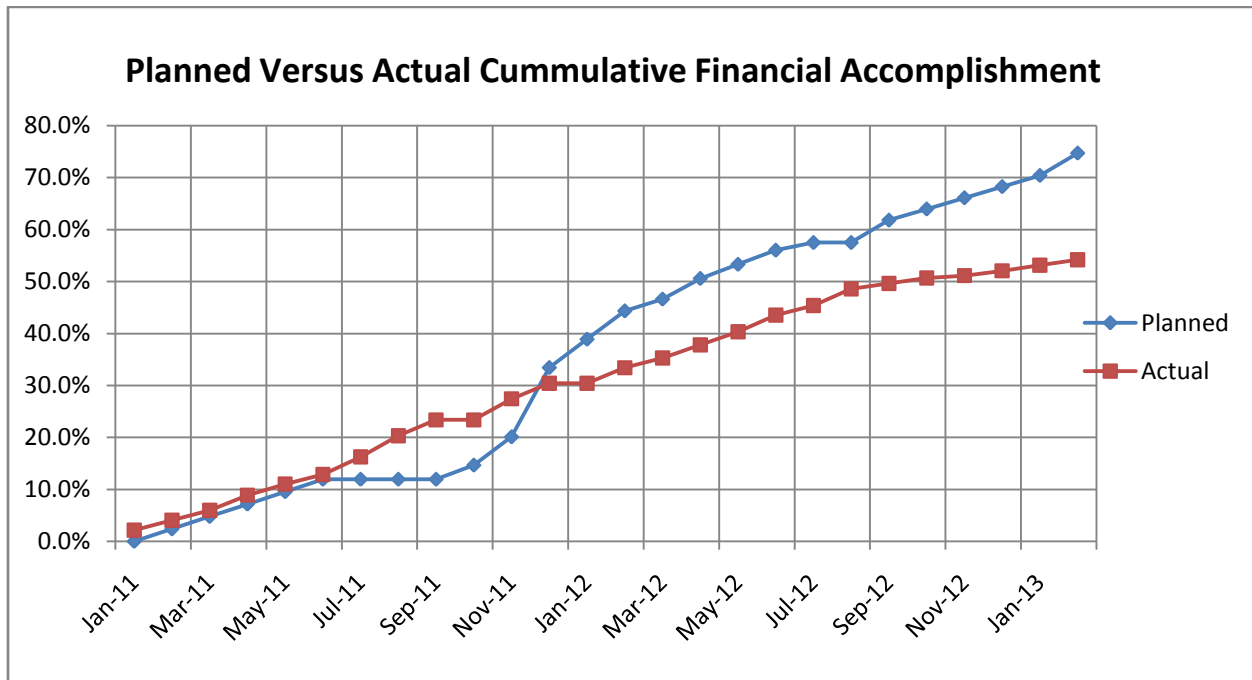


Figure 11- Planned Versus Actual Cumulative Financial Accomplishment of Modjo- Edjere- Arerti- Gobensa Road Project

## **II. Sembo-Sholagebeya-Gorfo-Gobensa Road project (59 Km)**

Sembo-Sholagebeya-Gorfo-Gobensa Roads project, 59.44 km road project being constructed under ERA with a total contract amount of ETB 543,316,542.07. The project site is located in the Amhara National Regional State North Shewa Zone. The consultant is an International consultant named CCCC First Highway in JV with Gondwana Engineering & RAMA Consult Plc and the contractor is a local construction company called AKIR Construction Plc. The commencement date of the project was on July 01, 2010 and the completion date was expected to be on June 30, 2013. June, July and August are the rainy season of the project site. The physical and financial plan and accomplishment of the project schedules are shown below graphically.

This project also passed through two rainy seasons as shown in the Figures no 13, 14, 15 and 16 graphically from the physical and financial plan and accomplishment of the project schedules. In the first rainy months of the year 2011 no activities were planned; activities other than site clearance, drainage and earth work were not started. After a year from the commencement of the construction work, failure of the contractor to mobilize the necessary equipment was mentioned as the main problem.

Similarly, in rainy months of 2012, there were no planned activities however the contractor has done site clearance, drainage, earth works, ancillary and cut to spoil works with a very low performance.

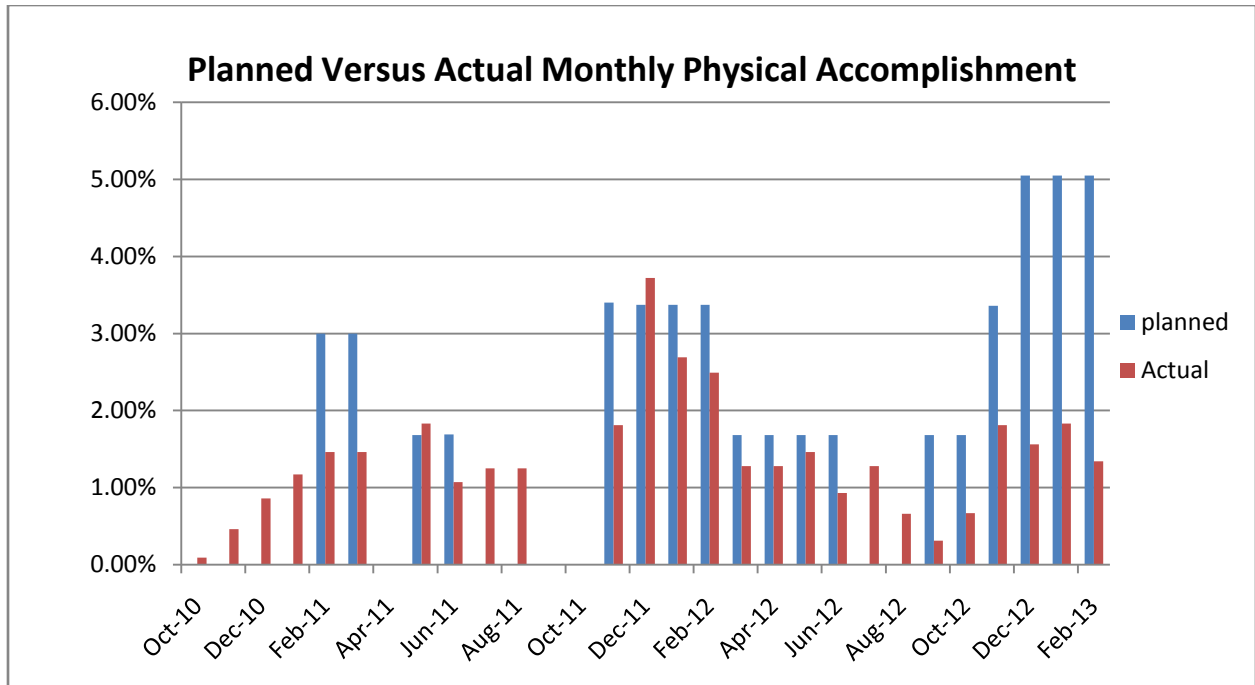


Figure 13-Planned versus Actual Monthly Physical Accomplishment of Sembo – Sholagebeya – Gorfo–GindeberRoad Project

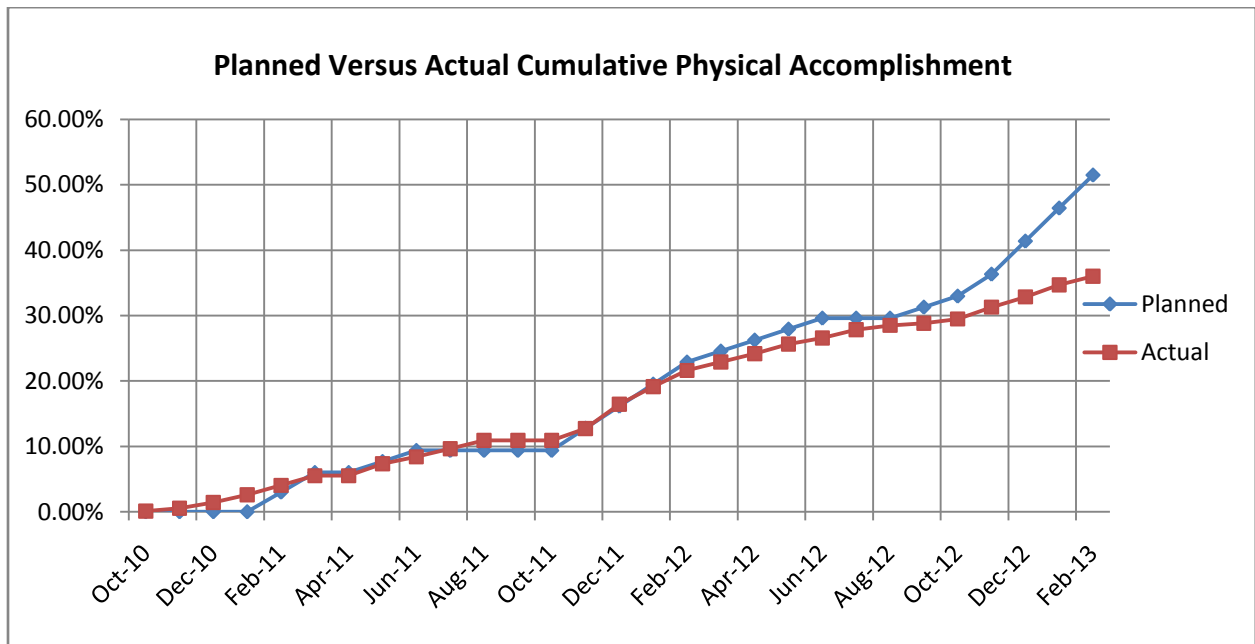


Figure 14- Planned versus Actual Cumulative Physical Accomplishment of Sembo – Sholagebeya – Gorfo–GindeberRoadProject

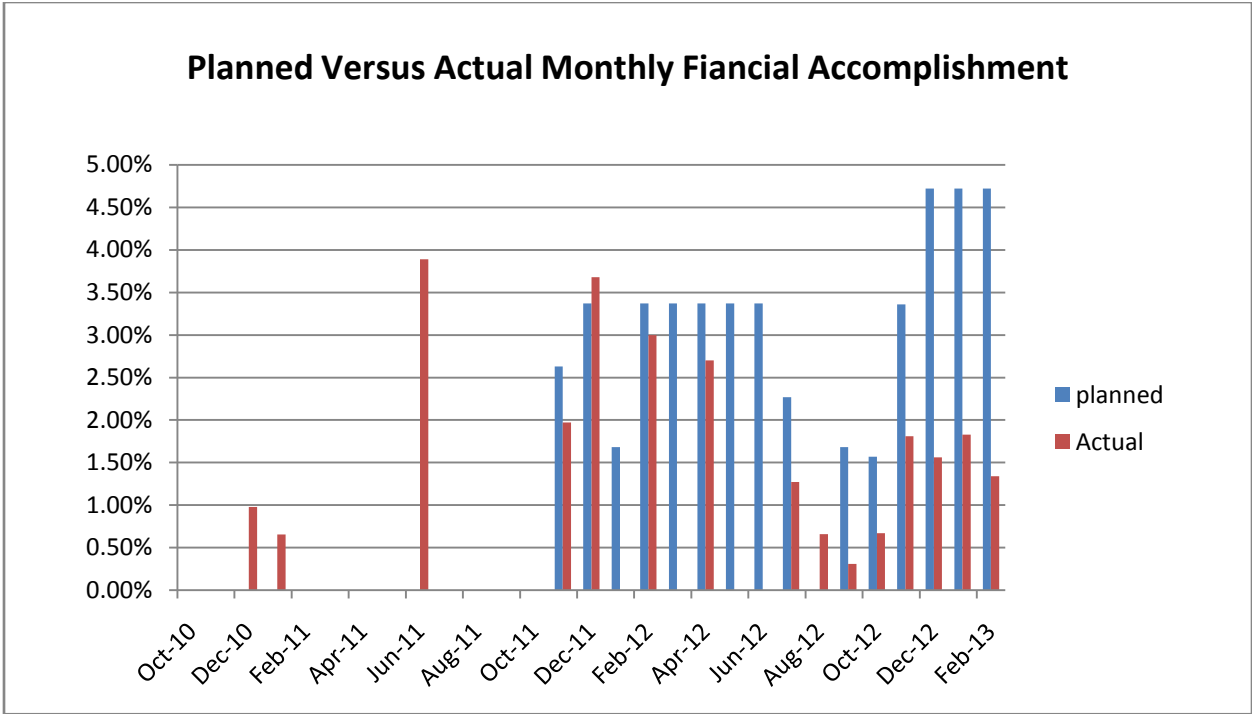


Figure 15- Planned versus Actual Monthly Financial Accomplishment of Sembo – Sholagebeya – Gorfo–Gindeber Road Project

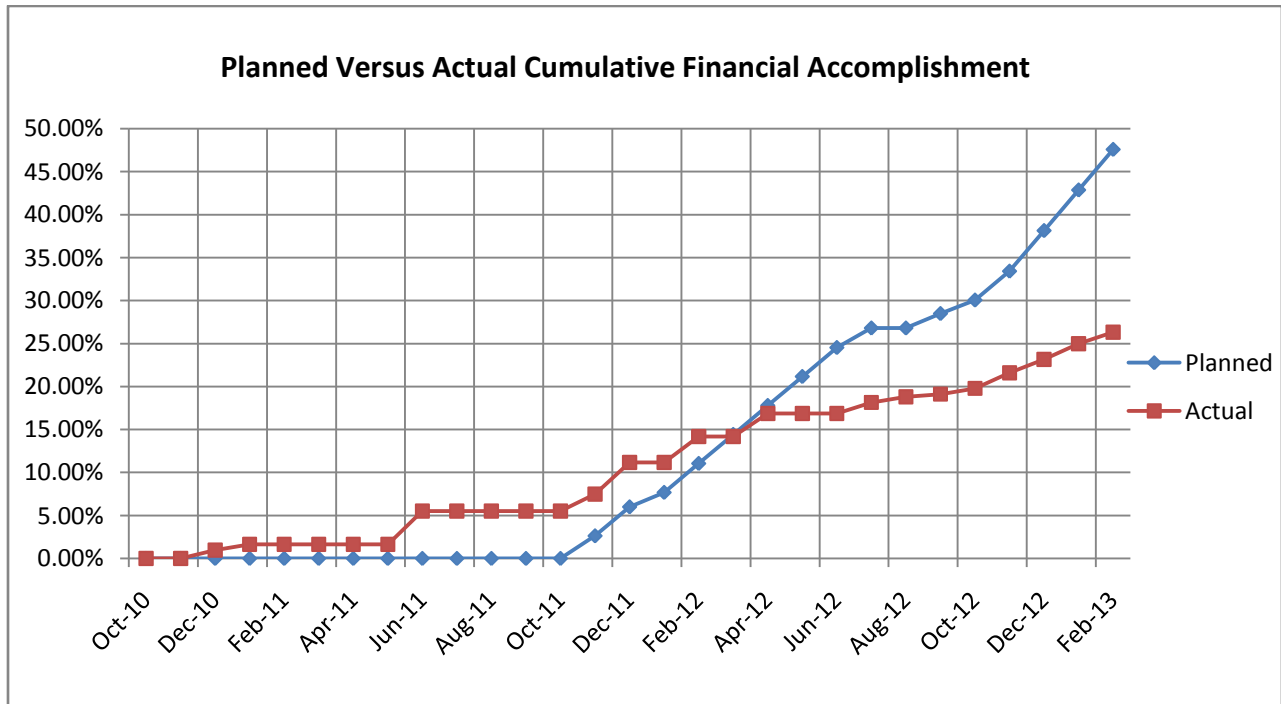


Figure 16- Planned versus Actual Cumulative Financial Accomplishment of Sembo – Sholagebeya – Gorfo–Gindeber Roads Project

### **III. Wolkite-Hosaina Up Grading Road Project, Contract 2: Arekit – Hosaina (km 58+500 + 124+000)**

Wolkite - Hosaina Road Upgrading Project, Contract 2: Arekit – Hosaina (km 58+500 + 124+000) is a 65.5 km road being constructed under Ethiopian Roads Authority with a Contract sum of ETB 618,998,415.32. The project site is located in the Southern part of Ethiopia. The contractor is an International construction company called HAWK International Finance & Construction Co. Ltd and the consulting firm is an International consulting firm called is Comptran Engineering & Planning Associates in JV with Beza Consulting Engineers, Plc. The commencement date of the construction were on October 07, 2011 and the completion date is planned to be on April 6, 2014.

As it can be seen from the physical and financial plan and accomplishment of the project schedules, which is shown in the figures 17, 18, 19 and 20 below graphically, the project duration has passed through one rainy season, which was on 2012. In this rainy season the contractor had planned to work and execute better than the planned. The activities that were done in the rainy season are; clearing and grubbing, base course material production, roadbed preparation, precast curbs and slabs and other activities. The reasons for not accomplishing more were described as:

- Poor quality of cut material that necessitates blending before use for embankment filling;
- Limited activity of the contractor due to need to continue sub base vigorously;
- Higher than realistic expectation to work in rainy season;
- Limited activity in the month due rains and equipment down time.

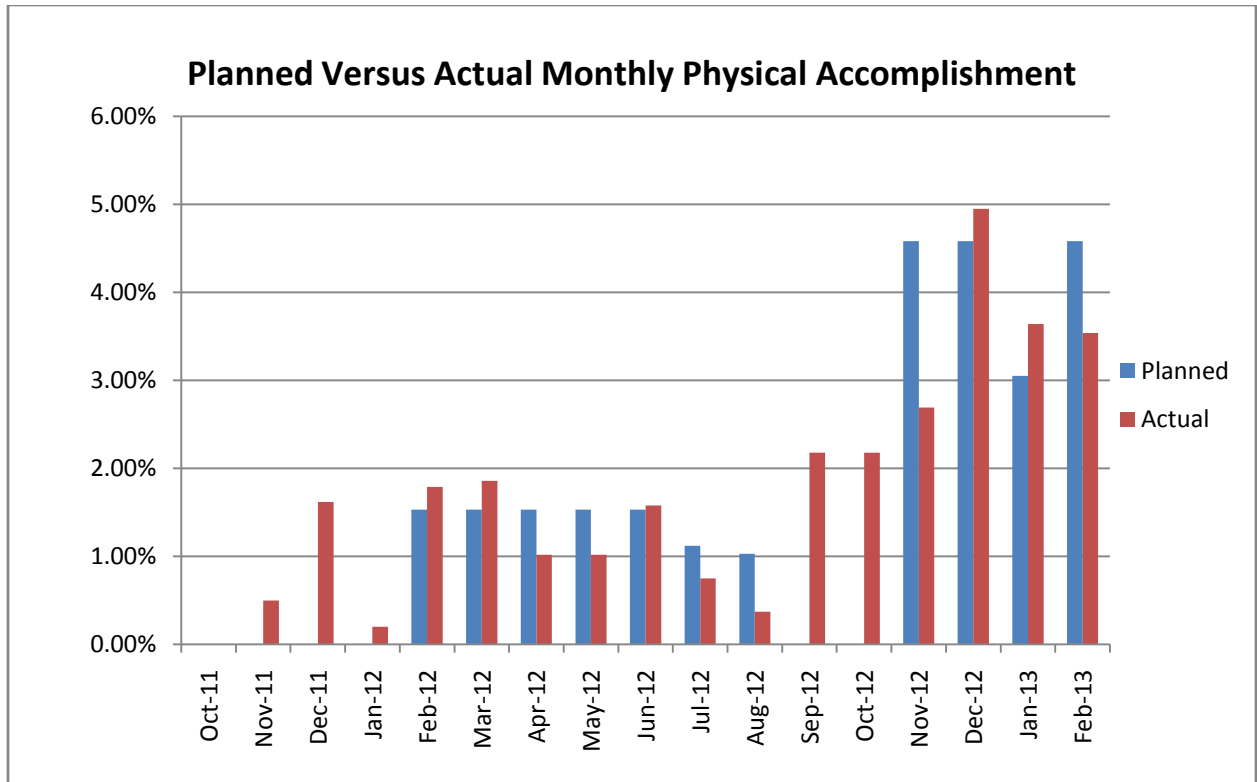


Figure 17- Planned versus Actual Monthly Physical Accomplishment of Wolkite-Hosaina Up Grading Road Project, Contract 2: Arekit – Hosaina (km 58+500 + 124+000)

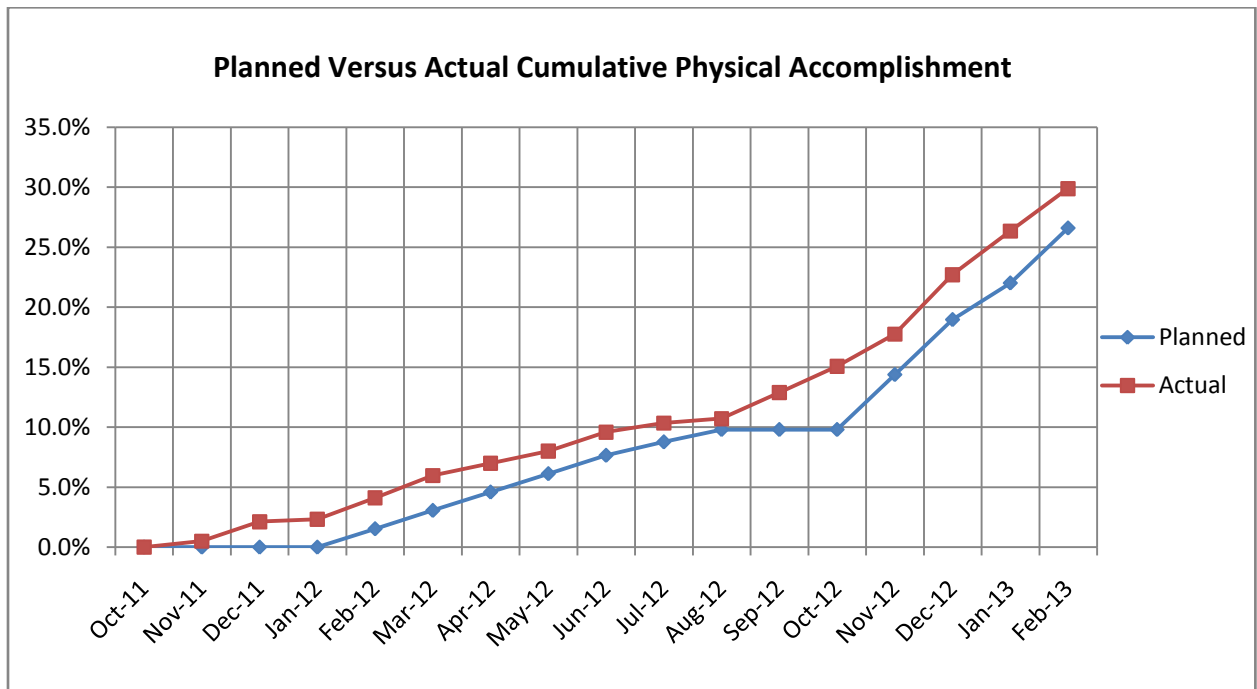


Figure 18- Planned versus Actual Cumulative Physical Accomplishment of Wolkite-Hosaina Up Grading Road Project, Contract 2: Arekit – Hosaina (km 58+500 + 124+000)

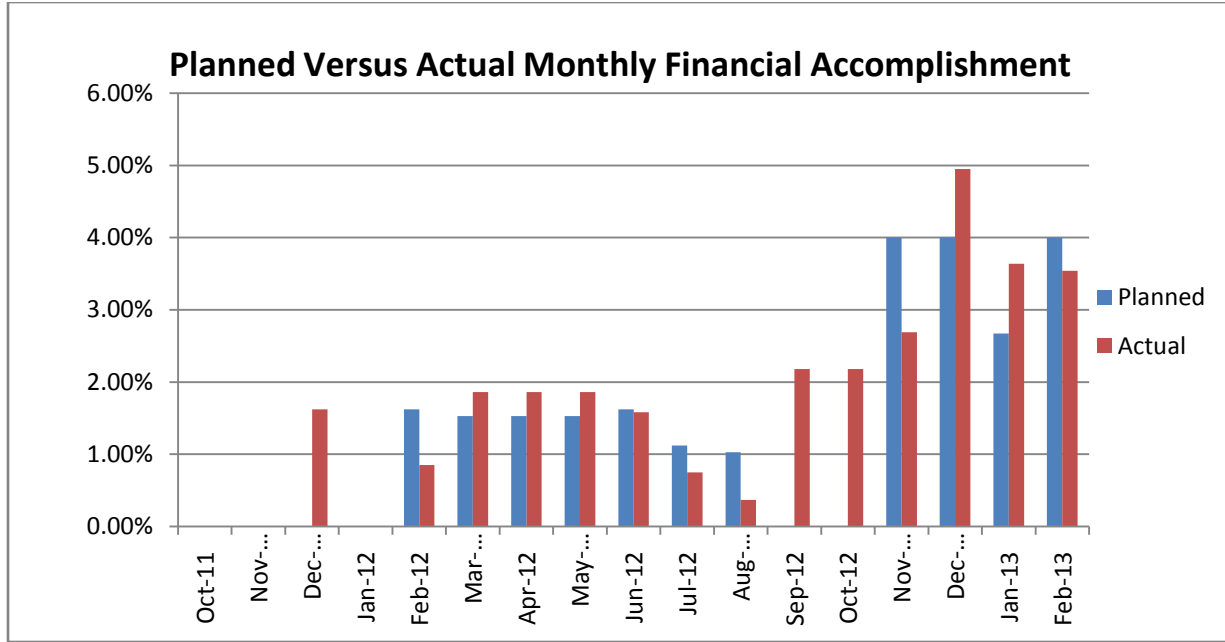


Figure 19-Planned versus Actual Monthly Financial Accomplishment of Wolkite-Hosaina Up Grading Road Project, Contract 2: Arekit – Hosaina (km 58+500 + 124+000)

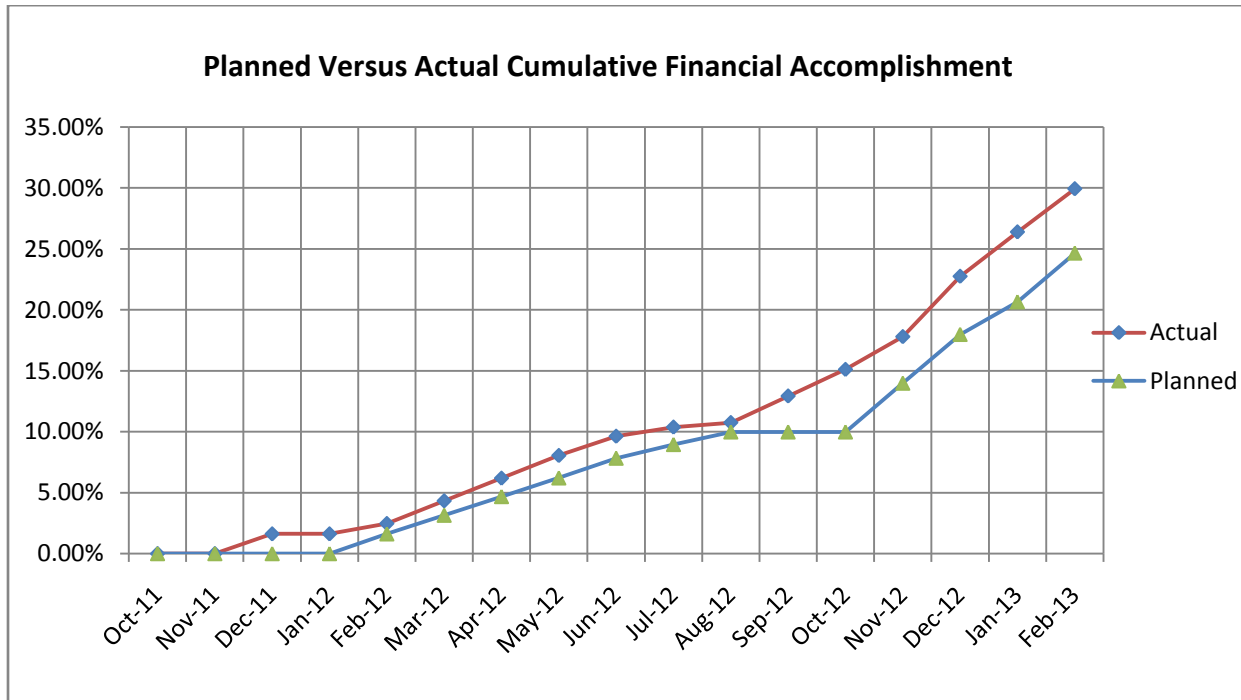


Figure 20- Planned versus Actual Cumulative Financial Accomplishment of Wolkite-Hosaina Upgrading Road Project, Contract 2: Arekit – Hosaina (km 58+500 + 124+000)

#### **IV. Gedo – Nekempte Road Rehabilitation Project Contract 1: Gedo – Bako**

Gedo – Nekempte Road Rehabilitation Project Contract 1: Gedo – Bako is a 66 km road project being constructed under the Ethiopian Roads Authority with Contract sum of ETB 355,784,706.73. The contractor is an international construction company named China Hyway Group Co. Ltd and the consultant is also an international consulting firm called DHV Consultants in association with CWCE. The commencement date was on 21th of January 2010 and the completion date is revised from Completion Date 11th April 2012 to December 16, 2012.

This project passed through three rainy seasons as it is shown graphically on Figures 20, 21, 22 and 23 from the physical and financial plan and accomplishment of the project schedules. However, in the rainy season of 2010, the contractor did not start executing construction works due to delay in submission of the work program as per the contract time, delay in starting cross section surveying of the road and due to lack of compression equipment.

In the rainy season of 2011, some works were planned and executed as planned. However, it was reported in the monthly report that the contractor could have done more but due to the low number of equipment and machineries deployed, poor site management and organization, unclear line of responsibility and cash flow problem the work was not done efficiently.

Though, in the year No activities were planned to be done in the rainy season, the contractor has done some activities with a very low performance. The reason for not performing was described as the same reason that was given for the rainy season of 2011.

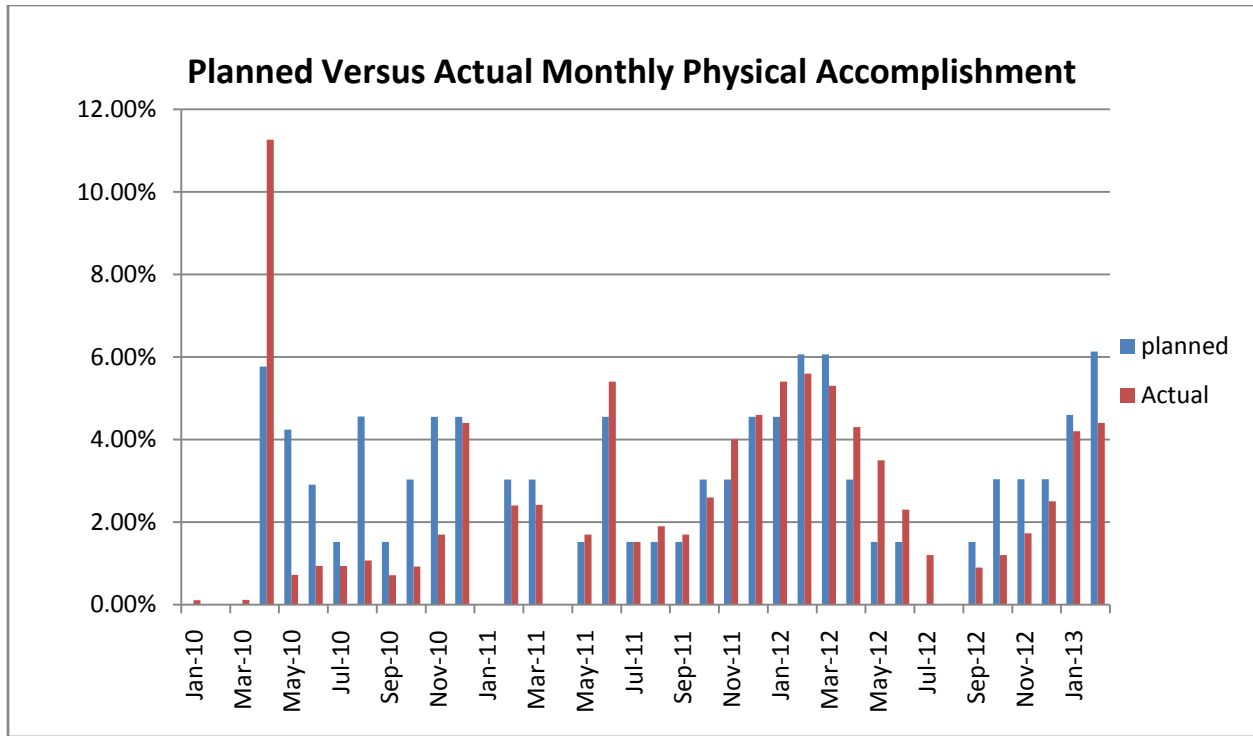


Figure 21-Planned versus Actual Monthly Physical Accomplishment of Gedo – Nekempte Road Rehabilitation Project Contract1: Gedo – Bako

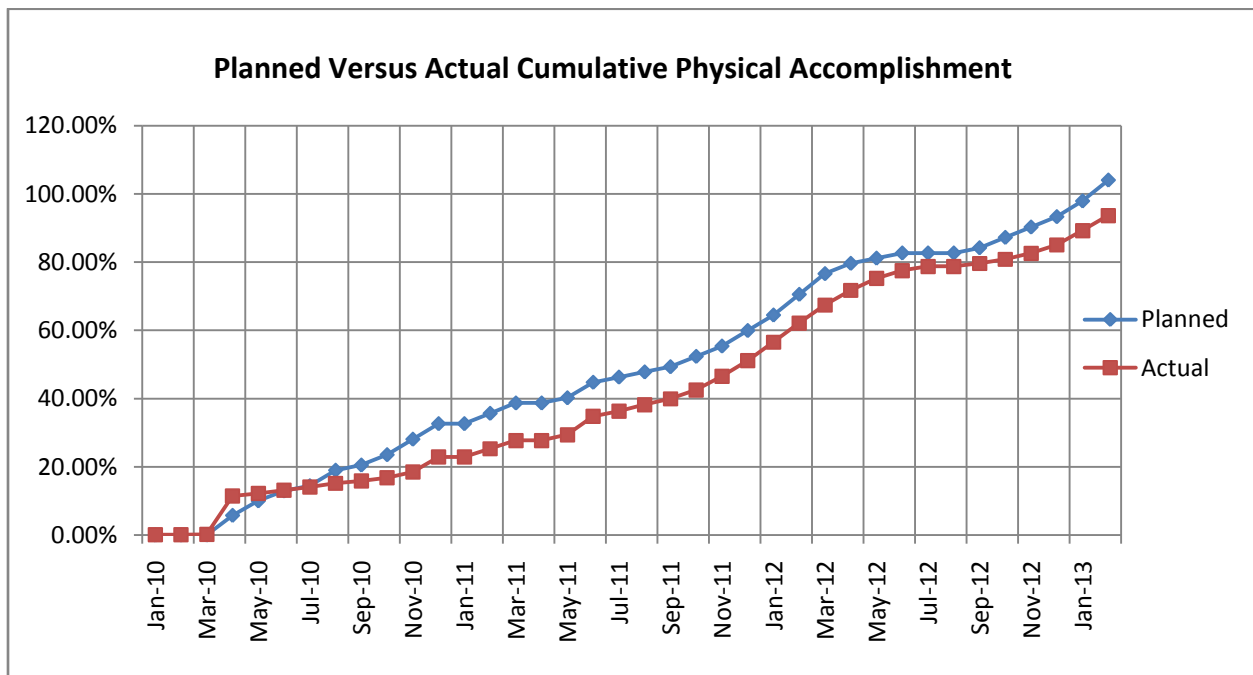


Figure 22- Planned versus Actual Cumulative Physical Accomplishment of Gedo – Nekempte Road Rehabilitation Project Contract1:Gedo – Bako

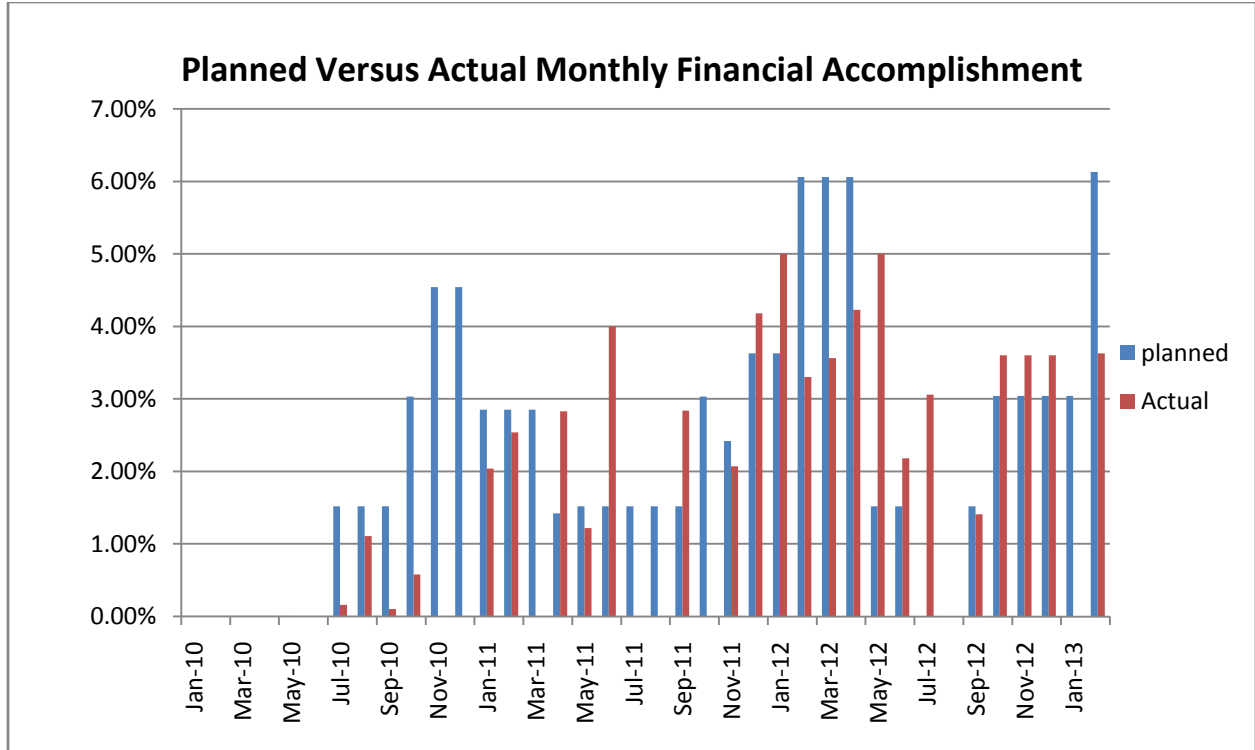


Figure 23- Planned versus Actual Monthly Financial Accomplishment of Gedo – Nekempte Road Rehabilitation Project Contract 1: Gedo – Bako

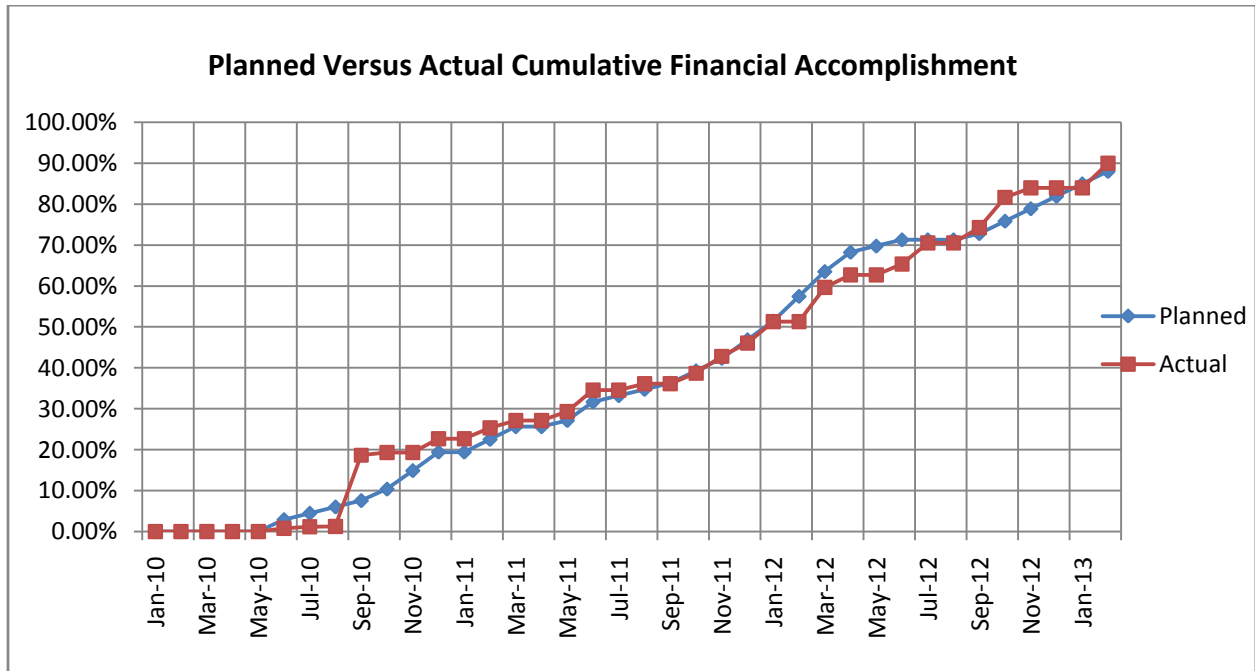


Figure 24- Planned versus Actual Cumulative Financial Accomplishment of Gedo – Nekempte Road Rehabilitation Project Contract 1: Gedo – Bako

### **4.4.3 Summary of Findings**

To summarize whether the above four project consider the rainy season as working months or not.

In project I, nothing was planned to work for three rainy months for consecutive two years. However, the contractor was able to perform some activities even though it is low performance. However, rain was not mentioned as a reason for the low performance.

The same goes to Project II too. nothing was planned some activities was performed with low performance. However, in this project rain was not mentioned as a reason for the low performance of the project.

In the project III, which is an international project, the rainy months were planned and considered as working months. However, the performance was low. Not planning realistic plan was mentioned as one of the reasons for the low performance.

In the project IV, on the first rainy season the rainy seasons were planned and the work was executed as planned. In the other hand on the second year of the rainy months it was not planned and not performed well and rain was not mentioned as a reason for the low performance of the project at those specific months.

## **5. Conclusions and Recommendations**

The aim of the research, as mentioned in section 1.3 of this thesis, is to assess the experience of road construction in Ethiopian rainy seasons and to give a way to our road construction industry by bringing the experience of the other countries toward the road construction in their rainy and cold weather. The main objective of the study is to find a way for the Ethiopia road construction while planning and executing projects in the rainy season, and make recommendations based on the findings. The following conclusions and recommendations are therefore presented.

### **5.1 Conclusions**

- i. The three parties (Client, Consultants and Contractors) believe that some road construction activities like rock excavation work, production and installation of drainage pipes products, aggregate production (crushing of stone), production and installation of precast, surveying works, design preparation works, equipment maintenance and early purchase (Preparation works) can be done in the rainy seasons.

In additions the client, ERA, has started requesting contractors to submit a special work schedule for the rainy season. However, as it has been seen from the work schedules, most contractors are afraid of challenges since most of them consider only activities like precast production and small structural works (side ditches).

Not thoroughly investigating the works and preparing schedules ahead (less planning effort), unavailability of sufficient safety and health provision for employees that decreases their initiation and productivity, the undeveloped culture to challenge difficult conditions and having motivation to look for solutions (attitude of the involved parties) have found out to be the reasons that hinders effective road construction in rainy season.

- ii. Most of local projects do not plan to work in the rainy season however they execute some activities with low performance.

On the other hand, most of international projects plan to work in rainy season but their performance is low. Thus, the findings enlighten that the reason for the underperformance of the projects is not mainly the intensive rain however the low performance mostly occurs due to the low number of equipment and machineries deployed, poor site management and organization, unclear line of responsibility and cash flow problem.

Generally, the basic reason for the underperformance of projects is the low productivity rate even in the longer dry season.

- iii. The foreign countries try to find out solutions for the difficulty they face in construction of road in snow, cold and rainy seasons. First they schedule the project well and prepare a safe place and way for the products they are going to use. They continue construction of road by:
- Using different technological findings such as additives for concrete work, special type of asphalt, stabilization for earth work;
  - Using prefabricated products especially for structural works;
  - Bringing raw materials from abroad for the construction works and storing the materials in a safe and secure way;
  - Preparing plans and schedules thoroughly and with proper care;
  - Giving employees sufficient health and safety provisions;
  - Using construction equipment that can efficiently move and work in watery and muddy grounds of the site (sheep foot roller, steel cover for tires, sheet piles).

In addition, they were able to perform better construction activities than seen in Ethiopia in the rainy seasons, because they have initiation to work at days when there is no rain even for half a day. Besides, involvement of different specialized subcontracts and suppliers in one project helps to facilitate and finalize the project at the planned time frame.

## **5.2 Recommendations**

The following recommendations are forwarded for respective project stockholders (parties).

### **Project Owners:**

- Ethiopian Road Authority and other regional road authorities shall challenge the design consultant about the emphasis he gives to the activities that can be executed in the rainy season;
- Need to give a chance to the design engineer to use different pavement material;
- Give training to consultants and contractors in order to share experiences from international consultants and contractors.

### **Consultant:**

- The design consultants should consider the rainy season as working months, so they can consider different equipment, machineries and work methodologies while estimating project cost;
- Consult and advise the contractor to use different work methodologies that can help him work as effective as needed in the rainy season;
- Should consider different paving material while designing a project.

### **Contractors:**

- Evaluating the progress of the projects and pointing out works that can be executed in the rainy seasons;
- Differentiating project sections that can be done during the rainy season;
- For the above mentioned works, preparing retailed plan and making required preparations. Works that can be done at office or camps concerning design issues, purchase preparations, formats and making any other arrangements that are required for the dry season can be prepared in rainy seasons;
- Developing a work habit to work with subcontractors/suppliers that can facilitate the project works by sharing the works like material production, cement concrete batching and others.
- To motivate workers to work in the rainy seasons by developing safety precautions.

## **6. Recommendation for Future Study**

The following are some of the study areas recommended for the future study;

- Sub contracting and suppliers in Ethiopia Road Construction industry
- Concrete as road making material in Ethiopia

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# **Appendix**

## **Interview Schedule**

### **Introduction**

This interview schedule is prepared to obtain information from key informants with semi-structured questions. The information is required for the academic research entitled “Assessment of Road Construction in Rainy Seasons”, which is being conducted as partial fulfillment of MSc in Construction Technology and Management. The main objective of the research is to assess how Ethiopian roads are constructed in the rainy season. The schedule consists of five sections with a total of 18 questions. Section 1 contains general questions about the informant. Section 2 assesses the road construction in the rainy seasons of Ethiopia. Section 3 examines the foreign practice, and Section 4 investigates how to manage Ethiopian Road Construction Projects, and explores the opinions of informants on how to manage Ethiopian road construction projects in the rainy season. Section 5 is left for general comments on the research. Your response, in this regard, is highly valuable and contributory to the outcome of the research. All feedback will be kept strictly confidential, and utilized for this academic research only.

Thank you,

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Addis Ababa

**Section 1: General Information about the Respondent**

The understated questions in this section are about your organization and yourself relevant to the questionnaire. Would you please fill the appropriate box (es) and/or the blank spaces provided in each question.

1.1 Personal Information (Optional)

Your Name \_\_\_\_\_

Job Title \_\_\_\_\_

E-mail Address \_\_\_\_\_

1.2 The type of organization you represent?

Employer  Contractor  Consultant

1.3 How long have you worked in road projects?

<5 Years  5-10 Years  >10 years

1.4 Type of service you have participated so far

Feasibility Study and EIA

Construction (Supervision/ Works)

Detailed Engineering Design

Others (Please Indicate) \_\_\_\_\_

1.5 Do you have Experience with Clients other than ERA?

Yes  No

1.6 Have you participated in road projects that have been undertaken by international contractors or consultants?

Yes

No

1.7 Have you participated in road projects out side Ethiopia?

Yes

No

If 'Yes' Please mention the name of the countries of your work experience

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### **Section 2 Road Construction in Ethiopian Rainy Season**

The following questions request your opinion towards Road Construction in Rainy Seasons on road projects of Ethiopia. Bear in mind that when it is mentioned as a rainy seasons or rainy months, it means the regular rainy seasons on which we call it 'Kiremt'. Please respond by ticking (√) in the box representing your selection. Furthermore, could you please give suggestion on areas requiring improvements at the space provided under each question.

2.1 Do the design consultants consider the rainy seasons as working months while preparing a tender document?

Yes

No

Your Comment Please: \_\_\_\_\_

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2.2 If your answer is 'No' for the above question, Do you think that the client should force the design consultant to include the rainy seasons as working months?

Yes

No

Your Comment Please: \_\_\_\_\_

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2.3 While bidding a works contract as a contractor, do you assume that the duration of the project considers the rainy season as working months?

Yes  No

If 'No' what is your reason:

\_\_\_\_\_

\_\_\_\_\_

2.4 Do the contractor consider the rainy seasons as working months while scheduling before starting the construction work?

Yes  No

Your Comment Please: \_\_\_\_\_

\_\_\_\_\_

2.5 Do the projects in Ethiopia usually closed completely when the rainy season comes?

Yes No

Your Comment Please: \_\_\_\_\_

\_\_\_\_\_

2.6 Is there any specification that is currently in use in Ethiopia which mentions not to consider (Schedule) works in the rainy seasons?

Yes  No

If 'Yes' Please mention the name of the specification.

\_\_\_\_\_

2.7 Most of our projects are delayed due to different reasons. Do you think not working in the rainy season is also one of the reasons for project delay?

Yes  No

Your Comment Please: \_\_\_\_\_

\_\_\_\_\_

2.8 Which Activities are usually done in rainy seasons of Ethiopia?

Earth Works

Structural Works

Pavement Works

Material Production

Nothing can be done if is a rainy season (Kiremt)

Your Comment Please: \_\_\_\_\_  
\_\_\_\_\_

2.9 While Designing a paved road projects, is there a chance of using different paving materials other than bitumen?

Yes

No

Your Comment Please: \_\_\_\_\_  
\_\_\_\_\_

2.10 Do you think that the road designer have to get a chance to use different paving material?

Yes

No

Your Comment Please: \_\_\_\_\_  
\_\_\_\_\_

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**Section 3 Road Construction in Foreign Countries**

The following questions request your opinion from your experience of road construction in the foreign countries. Please respond by ticking (√) in the box representing your selection. Furthermore, could you please give suggestion on areas requiring improvements at the space provided under each question.

3.1 In the countries of your experience outside Ethiopia, while planning a road, do they consider rainy and cold seasons as working months.

Yes

No

Your Comment Please: \_\_\_\_\_  
\_\_\_\_\_

3.2 What do you think help the developed countries to work in the rainy and cold and rainy months?

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3.3 From your experience of work other than Ethiopia, Do they use road paving materials other than bitumen?

Yes

No

If 'Yes' Please specify the type of material they use to pave a road

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**Section 4 How to Manage Ethiopian Road Construction Projects**

The following questions request your opinion on how to manage Ethiopian road construction projects in order to be effective in the executing of works in rainy conditions. Please respond by ticking (√) in the box representing your selection. Furthermore, could you please give suggestion on areas requiring improvements at the space provided under each question.

4.1 What do you think that restricts the Ethiopian road industry not to work in rainy season as effective as the dry season. (Please put your answer in the consultant and contractors side)

Hint (Management skill, Lack of planning, The design specification in use ,Work methodology, Altitude of people participating in the industry)

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4.2 What do you think that restricts the Ethiopian road industry not to work in the rainy season as effective as the dry season. (Please put your answer in the by considering general condition of Ethiopia)

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Do you think that using paving materials other than Bitumen, like cement concrete, will help for the development of road construction in Ethiopia?

Yes  No

Your Comment Please: \_\_\_\_\_  
\_\_\_\_\_

4.5 What do you think is the reason ceased Ethiopia from using other paving materials?

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**Section 4Your General Comment Please**

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Thank you.