MATERIALS MANAGEMENT ON CONSTRUCTION PROJECTS: A CASE STUDY OF CONCRETING WORKS ON SITES IN NAIROBI

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A RESEARCH PROJECT PRESENTED AS PART FULFILMENT FOR THE AWARD OF THE DEGREE OF MASTER OF ARTS IN CONSTRUCTION MANAGEMENT OF THE DEPARTMENT OF REAL ESTATE AND CONSTRUCTION MANAGEMENT OF THE UNIVERSITY OF NAIROBI.

NAIROBI

2005

DECLARATION

This research project is my original work and has not been presented in any university.

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ACKNOWLEDGEMENT

This study and the entire course would not have been possible without the grace of God Almighty. To him I give all the glory and honour.

I am very grateful to my supervisor Mr. Philip Muchungu for patiently and faithfully guiding me through the research project. His comments were very valuable.

I acknowledge the input received from the rest of the members of staff and the encouragement from my student colleagues.

Finally, I express my sincere thanks to Grace Ndege for her kind assistance in patiently typing this work.

Thanks to all and God bless.

DEDICATION

To my dear wife Irene Cherotich for her love, support and encouragement; and to our daughters Dasha Muyanzi and Delcy Muhani for their inspiration.

ABSTRACT

Materials management can be defined as the planning and controlling of all necessary efforts to make certain that the right quality and quantity of materials are appropriately specified on time, are obtained at a reasonable cost and are available when needed.

Materials management involves an integrated coordination of all materials related functions. These functions can be carried out efficiently only when sufficient emphasis is placed on early project planning, use of qualified personnel, adequate personnel training and proper communication amongst those involved in the process.

The essential and desired site materials characteristics (materials attributes) of right quality, right quantity, right time and reasonable cost are evidently scarce on construction projects in Kenya as characterized by emergency purchases of materials, inadequate storage, material shortages and sometimes condemnation of materials and works by consultants.

The construction industry is becoming increasingly competitive and materials management is now considered to be one of the frontiers for cost reduction to improve profitability and productivity, as materials can constitute 30-50% of the cost of the project. The problem of poor materials attributes therefore needs to be addressed and minimized.

This study hypothesized that inadequate materials management is the cause of poor materials attributes on construction projects.

The objectives of the study were to establish the extents of materials management and materials attributes on the construction sites, and to establish the relationship between the two.

In order to achieve the objectives, the study carried out a survey of concreting works on accessible active sites in both formal and informal construction in Nairobi. Data from the sites was statistically analyzed. Regression analysis between the two major variables; extent of materials management and extent of materials attributes, was carried out using SPSS software. Inferential statistics was used in hypothesis testing and generalization of the results.

The study concluded that inadequate management of materials has resulted in the poor level of materials attributes on construction sites. The problem was found to be more severe on informal sites than on formal sites. The study recommends that a systematic and integrated approach is needed to manage materials and minimize the costs and effects associated with inadequate materials management.

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ABBREVIATIONS AND ACRONYMS

GPD: Gross Domestic Product

JBC: Joint Building Council

USA: United States of America

GTZ: Germany Technical Cooperation

CII: Construction Industry Institute

CICE: Construction Industry Cost Effectiveness

CAD: Computer Aided Design

FOB: Free on Board

FOR: Free on Rail

CIF: Cost Insurance and Freight

MTO: Materials Take Off

MOW: Ministry Of Works

CBD: Central Business District

ICT: Information and Communication Technology

GOK: Government of Kenya

ILO: International Labour Organization

SPSS: Statistical Programme for Socio-Scientific Data Analysis

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Construction materials can constitute 30-50% of the cost of the project (Dawood 1996). Hence, effective management of building materials is of cardinal importance to the construction project.

Good project management in construction must therefore vigorously pursue the efficient utilization of materials.

It has also been estimated that in the American construction industry, the lack of effective materials management has resulted in work hour overruns of up to 18%, and a basic materials management system can be expected to provide up to 6% improvement in craft labour productivity (Thomas et al 1989).

Though there are no documented figures for the work hour overruns for Kenyan construction industry, given the inefficiency in general management of construction projects in Kenya (Gichunge 2000), the figures are likely to be high for the Kenyan situation.

Materials wastage is also considered to be one of the most serious aspects of site production, though little is done to avoid this financial loss (Edmeads 1972).

It has also been estimated that up to 6% of all construction labour costs could be saved if materials are available when needed (CII 1988). As Construction projects become more competitive, new management techniques are necessary to make construction projects more productive and thus more cost effective. One area of concentration to establish projects of shorter duration and less cost is materials management.

Construction professionals are recognizing the need to focus on the materials management process as a proactive identifiable entity that has a significant impact on the cost of construction.

In America, the Construction industry institute (CII) formed a task force in 1983 to investigate problems in materials management in construction. Construction materials management has then continued to be a major problem of concern in the American construction industry in the last two decades (Cryl 2001).

Many construction contractors have continued to address the problem of materials management by trying to develop integrated materials management systems that combine and integrate; the take off, vendor evaluation, purchasing, warehousing, and distribution functions. Some of the systems are computer based (Thomas et al 1989).

The availability of materials may greatly influence the schedules in projects with fast track or very tight time schedules. Materials management when properly planned and executed could provide project management with an invaluable tool to optimize schedules and improve labour productivity (Bell and Stukhart 1987).

The ability to manage the flow of materials has also been found to have a great impact on the profitability of the firm (Tavakoli and Kakalia 1993).

Locally there is little evidence of efforts towards improved materials management on construction projects. However, large and avoidable costs on construction sites have been associated with materials mainly arising from storage, labour, inventory and wastage (Oketch 2004).

Losses of building materials occur on most construction sites in Kenya (Omondi 1999), and wastage of materials is a major problem on construction sites in Kenya where the levels of wastage are considered to be fairly high (Thairu 1999).

The volume and composition of construction output in Kenya has seen significant changes since the 1980s. The contribution of the construction industry to GDP declined from 6.5% in 1980 to 4.9% in 1990 to 4% in 1999 (Mitullah and Wachira 2003).

This is mainly a reflection of the decline in public sector investment in construction and the harsh economic conditions prevailing in the country. This decline in construction output is likely to continue until the economy recovers.

The trend has also seen increase in private sector developers dominate the building construction market through the informal system where the developer operates as the contractor and mostly with limited financing. These developers mostly hire artisans to carry out the construction and the developer takes the responsibility of management of materials, often relying on advice from the artisans who may not be very experienced in materials management. Most of these developers are not trained or experienced in issues of construction and experience many problems some of them material related (Okaka 2004).

For the formal contracts where the contractor takes charge of the construction, most of the building contracts by implication, confer the responsibility of materials management to the contractor. However, some of the clauses about materials in the contracts leave the contractors very vulnerable to liabilities thus demanding prudence materials management by the contractors. Clause 23.4 of the Joint Building Council's agreement and conditions of contract for building works states that where not so described, the materials, goods and workmanship shall be to a standard "appropriate" to the works and to the "reasonable" satisfaction of the architect (The Joint Building Council, Kenya 1999). It further gives the architect authority and grounds to reject materials and works at the expense of the contractor.

There has been an occasional shortage of materials, increased cost of materials due to inflation and stiff competition amongst contractors. In 2004, though the construction industry was estimated to have grown by 11.9%, the sector was hampered by increases in costs with the overall cost going up by 10%.

Construction material costs have been going up since 2001. For the year 2004 the cost of steel went up by 60%, cement by 10%, aggregates by 16.7% cypress timber by 10.1% and cedar timber by 50% (Daily Nation, Friday 27th May 2005).

Though the fluctuating contracts cover the contractors against inflation and provide allowances for wastage, this is only to a limited extent.

The Kenyan construction industry has occasionally been blamed for general poor quality and there is absolutely lack of general quality assurance in the industry (Dindi 2004) and materials quality is an important component of the general construction quality.

In the face of all these challenges, materials management is now considered to be one of the frontiers for cost reduction to improve profitability and productivity.

The Construction industry is increasingly becoming competitive and good management practices are essential for those who want to remain competitive. However, the essential and desired site materials characteristics (materials attributes) of right quality, right quantity, right time and reasonable cost are evidently scarce on construction projects in Kenya.

Can the Kenyan contractor/developer adequately manage materials for specified tasks on the site?

This study investigates the relationship between the extent of materials management (Planning, organizing and controlling) and materials attributes (availability, right quality, reasonable cost, minimal surplus and minimal wastage) for concreting materials (ballast, Sand, Cement, steel and water) on construction projects in Nairobi.

1.2 Problem statement

Construction projects in Kenya can be said to experience poor materials attributes in terms of availability, right quality, reasonable cost, minimal surplus and minimal wastage.

Observed manifestations of poor materials attributes on the construction site include but are not limited to the following;

i. emergency purchases of materials
ii. stoppage of work due to material shortages
iii. ambiguity in working hours (like concreting in the night)
iv. surplus materials on site
v. inadequate storage space for materials
vi. uncontrolled wastage of materials
vii. damaged materials on site
viii. wrongful purchase of materials
ix. condemnation of materials and works by consultants
x. disappearance of materials from site through theft.

The design and construction of buildings is a balance and compromise in the circumstances existing at the time, between quality, time and cost (Turner 1997).

Building projects in Kenya have been observed to experience time and cost overruns, and increased litigation (Talukhaba 1999). There are also concerns over quality standards (Dindi 2004).

Costly labour delays experienced due to required quantity and quality of materials not being available could lead to increased cost overruns and overall delays in the construction project and could also affect the quality of the constructed facility.

The overall effect of poor materials attributes could therefore significantly lead to increased time and cost overruns, and poor quality for the project. At worst, for the contracted projects, it could also lead to protracted legal battles and arbitration due to cost and time overruns, and bad quality of the project.

The problem under study is the cause of poor materials attributes on construction sites in Kenya.

1.3 Research hypothesis

It is the hypothesis of this study that inadequate materials management is the cause of poor materials attributes on construction projects in Kenya.

1.4 Objectives of the study

The primary objective of this study is to establish the extent of materials management on construction projects in Nairobi.
Pursuant to this objective, the study will therefore attempt to;

I. Examine the performance of materials management activities on construction projects

II. Examine the extent of materials attributes on construction projects

III. Establish the relationship between the extent of materials management and materials attributes on construction sites

1.5 Significance of the study.

It is widely recognized that construction industry plays a vital role in the process of economic growth and development, both through its products (infrastructure, buildings) and through the employment created in the process of construction itself (Gruneberg 1997).

Construction Industry in Kenya is an important source of employment, income and capital formation. The industry creates investment opportunities for individuals, firms and government as well as providing basic infrastructure such as roads, housing, water and sewerage facilities required for development of other sectors (Kinyanjui and Mitullah 1997).

As mentioned earlier in this study, construction materials can constitute up to 50% of the cost of the project thus playing a very significant role in the success of the project and the industry as a whole.

The industry has been very competitive recording only minimal annual growth, 1.2% in 2003 (GOK 2004). Though the annual growth in 2004 increased to 11.9% (Daily Nation, Friday May 27th 2005) this high growth rate cannot be guaranteed. Tendering procedures have also become very competitive. Many contractors are therefore forced to take contracts at very minimal profit margins. Occasionally some of the contractors have had to close down due to losses or have even been unable to complete some projects.

If good materials management can be enhanced, project delivery and profit levels for the contractor or savings for the client will be greatly improved. This will also ensure that they remain competitive and sustainable.

In a survey carried out by GTZ of input content on construction works in a low income housing project in Nairobi (Umoja 11), it was revealed that at least 37% of the project cost demanded foreign exchange for purchasing building materials, equipment and fuel (Kinyanjui and Mitullah 1997). Prudent materials management would therefore be important if it was to be practiced in the entire industry as it could have a direct impact on external trade.

Effective materials management can provide better tools to the work force, improve cost effectiveness and have a significant impact on the ability of the construction industry to compete in both the domestic and international market place.

The informal construction sector within the construction industry has grown since the 1970's. With limited expertise and experience, this sector is likely to experience more negative material attributes and eventually less efficiency. The outcome of this study will also assist the sector to be more efficient.

Even for the established contractors, because of lack of regulated legal framework to regulate those who enter the industry as contractors, most of the construction firms lack qualified personnel to handle the management functions of the firms (Wachira 2003). This study would therefore be helpful to such firms in improving their management of materials.

1.6 Scope and justification

For practical purposes, the study has been limited in scope to management of materials and does not indulge into other management aspects of the project that could also affect project performance.

The materials under study have been limited to major materials that constitute concrete (ballast, Sand and Cement). Water which is also an ingredient of concrete has also been briefly covered. However, formwork which is a component of the concreting process has not been considered in data collection in order to maintain the scope to manageable levels.

The activity of study is major concreting works like casting of slabs and columns, which mainly have to be done at once.

Concreting works were convenient to study, concrete being an end product of several materials mixed together under defined standards/specifications. The simultaneous use of many materials to give this end product is likely to strongly expose aspects of inadequate management of materials.

Concrete in its varied forms is used on virtually all building projects mainly due to its unique properties and it being readily available. Consumption of cement, which is the main constituent material of concrete, is used to establish the growth of the building industry (Daily Nation, Friday 27th May 2005).

Timber, steel and stone are supposedly substitute materials to concrete. However due to various limitations of these substitutes, even when they are used, they are always used together with concrete for anchoring, binding or finishing. A study of concrete and its constituent materials is therefore likely to receive wider application.

Although other factors could also be contributory to poor materials attributes, in depth analysis has only been carried out on the relationship between extent of materials management and materials attributes.

This scope covers sites where concrete is prepared and cast on site (in situ) as well as where ready mix concrete is used but not where precast concrete is used since the first two are the most used on construction sites in Kenya.

This scope is meant to narrow down the study to a manageable level and enable the researcher to carry out focused analysis.

1.7 Limitations of the study

By geographical coverage, the study is limited to the city of Nairobi due to financial and time constraints.

Active construction sites within the city where reasonable concreting works have been carried out have been considered to form the population.

Time constraints, lack of adequate resources and denied access to sites limited the actual number of sites studied.

1.8 Study assumptions

It is the basic assumption of this study that the sites studied follow conventional construction procedures where regardless of the construction procurement method used, designs are taken to some reasonable level of completion before construction work begins.

It is assumed that the problems of poor materials attributes face both formal and informal construction projects. However, it should be noted that there are differences between the two groups particularly in terms of objectives, resources, personnel, equipment, working procedures and general site operations, which could impact on materials management. The study therefore considered almost equal number of cases for both formal and informal construction sites. Data presentation and analysis was therefore mainly separated and also contrasted between formal and informal.

The size of the project, method of financing and size of the contractor could also have influence on materials management. However, the study did not dwell on these influences in details.

The study also assumed that the contractors or developers on sites studied are not scrupulous and that they are interested in good project delivery, particularly in terms of time, cost and quality.

Concreting was selected to form the basis of this study because concreting is done on virtually all major construction works and the process of concreting encompasses most of the major issues about materials management and materials attributes. Thus concrete was assumed to be representative enough to study. However, it is assumed that the findings of this study are applicable to the rest of building materials.

Since Nairobi has the highest level of construction activities and all the projects studied are in Nairobi, it is assumed that it would be representative of other regions of the country. Nairobi is the capital city and the most active economic centre of the country. Operations of economic activities in other parts of the country are mostly typical to similar activities in Nairobi.

1.9 Organization of the Study

The Study has five chapters;

Chapter one gives a general introduction including background of the study, problem statement, research hypothesis, objectives of the study, significance of the study, scope and justification, limitations, assumptions, organization of the study and definition of terms.

Chapter two covers literature related to management of materials and materials attributes. This forms the theoretical basis of the study and the basis for evaluation of primary data to make research conclusions.

Chapter three covers research methodology. This includes research design, population and sample, data collection procedures, data analysis procedures and measurement of variables

Chapter four contains the actual data from the survey. It gives the findings and analysis related to the problem of the study.

Chapter five contains conclusions and recommendations of the study.

1.10 Definition of terms

Materials attribute - an essential and desired site materials characteristic

Level/extent - magnitude or measure

Informal - not fully regulated by law

Formal - fully regulated by law

Overruns - continue beyond or exceed the expected

Inadequate - not sufficient or good enough for a particular purpose

Variables - a measurable characteristic that assumes different values amongst subjects

Primary data - original data collected by researcher from the population

Contractor - person or firm that has been awarded a contract for the construction and completion of a building

Client - employer to contractor/building owner/developer

Client contractor - where the building owner undertakes responsibility of building himself without engaging a contractor

Vendor/supplier - One who provides construction materials or equipment

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter contains an extensive and thorough review of relevant publications and studies related to the research problem under investigation in order to obtain detailed knowledge about the area under study.

2.2 Theoretical framework

2.2.1 Management approaches

Despite the inexactness and relative crudity of management theory and science, the development of thought on management dates back to the days when people first attempted to accomplish goals by working together in groups. Although the modern operational management theory dates primarily from the early twentieth century, there was serious thinking and theorizing about managing many years before (Weihnrich and Koonz 1993).

There are three broad models of management which encompass most of the ideas put forward about management over time. These are; the traditional model, the behavioural and management science model, and the systems approach.

The traditional model of management is a broad body of knowledge, which was put forward by early management thinkers to replace the rule of thumb method, which was used prior to the formation of a coherent body of management knowledge. The aspects of traditional model include Fredrick Taylor's scientific management, Henri Fayol's administrative management and Max Weber's bureaucratic model.

The behavioural science model of management seeks to understand, explain and predict human behaviour in the same sense in which scientists understand, explain and predict the behaviour of physical forces or biological factors.

The management science (operations research) approach is an improvement of Taylor's scientific management with an addition of more sophisticated methods, computer technology and an orientation towards broader problems.

All the approaches explained above view an organization as an independent entity whose success is governed by the appropriateness and consistency of the tools of internal management (Kithinji 1988). These approaches contrast heavily with the systems approach discussed below.

2.2.2 Systems approach

The systems approach realizes that a solution is achieved through the interaction of many forces in the environment. The appeal of the systems approach is the emphasis on the interrelatedness of the component parts.

Materials management is an organizational philosophy that has evolved through applications of systems approach to management (Magad and Amos 1995)

A system may be defined as any group of interrelated parts or components that function together to achieve some goals (Datta 2003).

This concept is used in manufacturing where for example a large manufacturing organization viewed in its entirety, is a social system, having many decisions which in turn may have departments, each of which is again a system, or more precisely a subsystem.

The components of a system may themselves be systems with their own components.

2.2.3 Ingredients of a system

There are four distinct and essential ingredients of a system. The first is the input. In a manufacturing organization this could constitute, machinery, raw and other materials.

The second ingredient is the process, which means a series of operations performed by people and machinery, which transform raw and other materials into finished goods.

The third ingredient is the output, which are the finished goods.
Finally is the control which gives rise to the need of management.

An open system does not exist in a vacuum but in an environment over which it has little or no control, this control element is always present and works through feedback loop (Weihnrich and Koonz 1993).

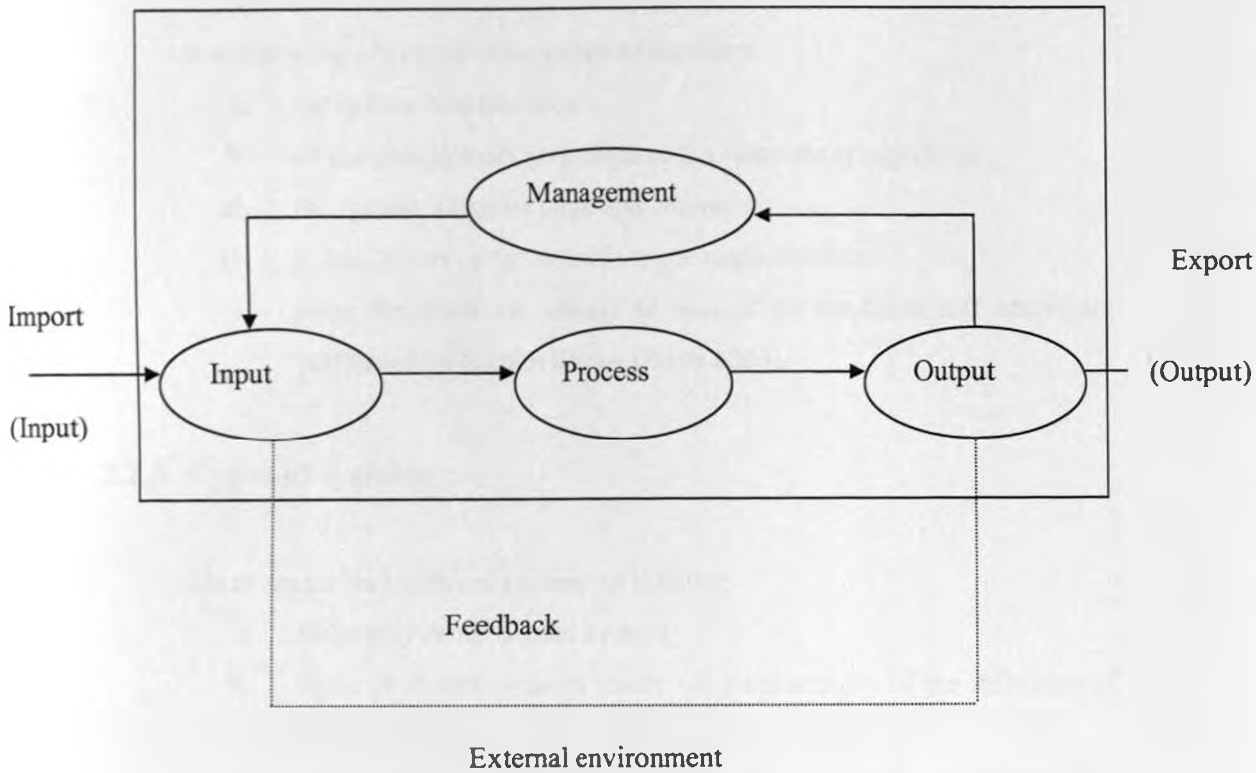


Figure 2.1: Illustration of systems theory

Source: Koontz and Weihrich (1993)

This loop is an important means through which management controls the operations of the enterprise taking corrective measures when needed to achieve the desired goals.

Environment here means the set of all objects, which are influenced by/or influence a system.

2.2.4 Characteristics of a system

The following are the characteristics of a system

i. the system is man-made
ii. all the components contribute to the same set of objectives
iii. the system is can be large and complex
iv. at least a part of the operations are unpredictable
v. some functions are always performed by machines and others are performed by human beings (Datta 2003).

2.2.5 Types of systems

There are various types of systems as follows;

i. Natural systems created by man
ii. Open or closed systems where we take account of the influence of the environment on the systems under examination.
iii. Adoptive or non adoptive systems where adoptive systems can be described as learning from experience
iv. Stable and unstable systems, a system being regarded as stable if the values inherent in the system are constant or can be held within defined limits.
v. Feedback systems or non-feedback systems (Chandler 1978).

2.2.6 Materials management and systems theory

When we use the systems concept as a framework for managing materials, we find that it not only interacts with its environment, that is to say, anything external to the system itself, but also interacts with the system's components. In particular when outside constraints limit operation, management must take steps that will provide for a change.

Materials management can be defined as an integrated system which emphasizes specific activities or functions and in which its relationships with others are pronounced. Therefore it is not tied up to any specific structure, rather it is system oriented. It takes account of the functional dependence with an organization structure as a secondary consideration.

An integrated systems approach considers the entire flow of materials as opposed to a partial flow. Any study which does not deal with this entire range of factors may tend to be simplistic. It is a dynamic management function, which is again characterized by high level of sensitivity. Thus a change in one sub-function is related to the changes in others, depending on the degree of sensitivity (Magad and Amos 1995).

While the structure is static, the realities it attempts to fit into are dynamic. Conversely structural models should be settled on the basis of similarities of a given situation. Thus it will be seen that some of the materials management functions require some basic modifications due to the changes in the industrial management dynamics, which characterize the industrial society of today
The task involved requires a sound approach in principle and its application to obtain the desired results. It is this thinking which has given rise to the concept of integrated materials management.

2.3 History and evolution of materials management

Since creation, humans have been concerned with obtaining, moving and controlling materials.

The term materials management came in use after world war II. Beyond an enormously increased production capacity, the American military requirements of the war, demanded a means to reduce the time required to produce needed products. Through the 1950's and 1960's fluctuation in national and international markets requirements and economic conditions highlighted the need for total control of materials.
Total materials management began to spread as an organizational concept in America during the 1950's and 1960's.

During the 1970's businesses in the USA were confronted with scarcity of money, price controls, ecological concerns, energy shortages, and rapid increases in energy costs. They therefore increasingly adopted materials management as a way of controlling costs and operations.

In 1969, individuals concerned with the inflation in the cost of construction created the Construction Users Anti-Inflation Roundtable. In 1972, other organizations merged with the Construction Users Anti-Inflation Roundtable to form The Business Roundtable. The goal of the committee was to promote "quality, efficiency, productivity and cost effectiveness in the industry''.
In 1978 in response to deteriorating productivity in the industry, the construction industry cost effectiveness (CICE) project was formed. In response to one of the CICE recommendations the construction industry institute (CII) was formed in 1983. CII formed a task force in 1983 to investigate problems with materials management in construction (Cryl 2001).

From the Business Roundtable study, the CII developed a handbook, Project Material Management Handbook, and a tutorial of a database type system. The study tied proper management of materials to increased productivity on projects.

The purpose of the CII publications was to assist owners, designers and contractors in employing modern, successful materials management techniques.

A study by the CII in the 1980s showed that 20% of the craftsperson's time was spent waiting on materials. It was also determined that materials and equipment make up 50-60 percent of a construction project cost, and the lack of materials was the leading cause of construction delays (Stukhart 1995).

2.4 Functions of materials management

2.4.1 Definition

The term "management" has many facets. Mainly it is characterized by reference to a group of individuals in an organization having the authority and responsibility to make decisions, the total sum of the tasks performed by the individuals, or the body of knowledge underlying the performance (Mbatha 1993).

Different authors may give different definitions for management though the underlying principle and meaning remain the same.

Management is the process of designing and maintaining an environment in which individuals, working together in groups, efficiently accomplish selected aims (Weihnrich and Koontz 1993).

The "Functions Approach" to management considers management functions as its most fundamental.
The indisputable managerial functions are planning, organizing and controlling. A fourth function is the role of the manager in starting the system and keeping it together. For some it is directing and for others it is leading. Staffing has also become a significant function in the utilization of human resources. Co-ordination, on the other hand, began as a separate function but it is now considered an integral part of the entire management process (Weihnrich and Koontz 1993).

Managing is concerned with productivity, which implies effectiveness and efficiency.

Materials management can therefore be defined as the planning and controlling of all necessary efforts to make certain that the right quality and quantity of materials are appropriately specified in a timely manner, are obtained at a reasonable cost and are available when needed (Bell and Sturkhat 1986).

Management of materials is therefore not just a concern during the construction phase of the project but should actually begin when a materials take off is performed to produce a bill of materials.

Different authors give different listings for functions and sub-functions of materials management. However, in this study, the following functions and sub-functions can be listed as logical boundaries of materials management.

i. Planning, organizing and communication
ii. Materials take off
iii. Vendor selection
iv. Purchasing
v. Expediting
vi. Quality assurance and control
vii. Transportation
viii. Site materials management
ix. Management of surplus
x. Management of wastage

2.4.2 Planning, organizing and communication

Planning is a decision making process in advance of action which endeavors to design a desired future and effective ways of bringing it about.
Material planning is a scientific technique of determining in advance the requirements of materials as dictated by the production program. Construction process relies to a great extent on the exchange of information and permanent interactions of entities and resources.

The interrelations of relevant participants in a construction process are considerable and their management will have a different impact on the success of the project.

Adequate material management may involve complex communication mechanisms, education activities and training programs that must be established early in the project.

Decisions that are made early in the planning stages of the project appear to be critical to the overall success of the project.

It is important to develop a project material plan which is a fundamental and important document unique for each project.
In developing the materials plan, various factors must be considered such as project size, scope, location, cash flow requirements, schedule and lead times of critical purchases, owner philosophy, owner approvals, number of project participants, inspection roles, acceptable suppliers list and extent of prefabrication.

There must be a clear understanding of the materials required, their packaging, quality available or required and other associated materials like thinner for paint.
It is also important to understand the equipment and tools needed in the work process.
The materials plan should record the assignment of responsibilities for functions involved in materials management.
Engineering materials including equipment are the most visible, costly, complex and quality critical. Engineered materials will usually drive the project schedule, and major equipment lead times will influence the engineering schedule.

Bulk materials' planning is more difficult because bulk materials are more numerous and quantities are never exactly known until the job is over.

Design evolution causes continual updating of the bulk requirements (CII 1988).

Scheduling the entire materials program is essential to meeting the project timetable. Materials schedules are as critical as those of engineering and construction and span all phases of the project from defining and approving the requirements to purchasing, vendor lead time, transportation and site management. The schedule must determine sequential distribution of quantity over a period of time to avoid cash flow problems and other problems associated with excess storage of materials like theft and damage.

International materials management schedules should include time for transportation, import licensing and customs clearance.

Planning must also consider responsibility for purchasing (home office and site) including vendor selection, terms and conditions of the purchase order, forms used in purchasing, and procedures and schedules. Particular care should be given to invoicing and payment procedures, which should be discussed with accounting and the vendor to avoid any misunderstandings.

The transportation plan should consider safety, cost, timely delivery, hazardous material content and point of title transfer. Of particular concern are foreign shipments, which involve considerable, additional complications in terms of export regulations, delays, tracing of shipments and licensing and import requirements.

Planning for site materials management includes consideration for receiving, storage, control and distribution of materials at the construction site. This includes layout and organization of lay down areas and warehouse facilities, development of storage and maintenance plans, and planning for access to and within the site. Preparations for field purchasing, materials control and expediting must also be addressed. All of these functions should be planned to allow craft labor work planning to proceed on the basis of known materials availability.

An elaborate planning should be continuously reviewed to establish minimum and maximum stock levels required at any given time of the project in order to facilitate purchasing of materials.

The stock levels would depend on the rate of minimum average daily consumption, maximum storage space, ordering and lead time required, storage risk on the site, economic order quantity, working capital, available interest on financing and the likelihood of steep price fluctuations

The materials quality plan is designed to ensure conformance of vendor supplied materials to project specifications. The plan should provide for the use of realistic, achievable, specifications and address the quality aspects of purchasing documents, shop fabrications and shop tests. The inspection plan for each piece of equipment is developed during the design and preaward phases. It includes an evaluation for the need for and level of shop inspection, including hold points.

Special construction techniques (prefabrication, preassembly and modularization) have significant impact on materials management. Materials' planning is usually more complex because of the additional levels of activities at multiple sites. Early decisions are needed on the assignment of responsibilities among the owner, design contractor, fabricator and the erection contractor.

Organizing is that part of managing that involves establishing an intentional structure of roles for people to fill in an organization (Mbatha 1993).

An integrated materials management organization plays a significant role in determining the ultimate cost of a construction project. The organization must be structured to provide for the timely performance of the work, with materials personnel located at appropriate levels of project management to contribute to and influence the decision making process.

In some cases, particularly on larger projects the entire scope of materials function may be consolidated into one unit. On smaller jobs, various materials functions sometimes are assigned to individuals who have other responsibilities and assignments. This poses significant challenges to the individual responsible for managing all materials functions. A single focus for the management of these functions is essential, even though the assigned individual may have other project duties.

The organizational structure of materials management must take into consideration the size, scope, contracting strategy and location of the project. A primary requirement is the coordination between the home office and the field, which is achieved by individuals and computer systems complementing each other through out the materials cycle.

Large projects regardless of location will require a full staff of skilled professionals with a direct reporting line to project management. These materials organizations continue to rely on home office guidance in procedure and policy development and the selection and supply of key field materials management personnel.

It is essential that the organization be staffed with professionals possessing skills consistent with the scope of work. The requirements are changing to fewer semi-skilled and more professional personnel. The required key personnel must have a thorough understanding of the projects materials plan and its functions within the total project. Prior experience in requirement definition, procurement, quality assurance/quality control, transportation and site materials management is highly desirable. Computer conversancy is increasingly important as the benefits of materials management automation become practical for even small jobs.

Although proper selection of personnel will minimize the necessary training, some training for the particular requirements of each project will be required. Much of this training can be on the job, but formal training in management, business and computers is increasingly required. Lack of training especially of site personnel has bee a frequently sited factor on "problem" projects (CII 1988).

Materials management personnel must be able to operate in the project environment, to anticipate the requirements of other organizations, to administer their program within a complex set of organizational arrangements, and to communicate the importance of materials management.

The control function of materials management runs across the rest of the functions and sub functions of material management. Although planning must precede controlling, plans are not self achieving.

Controlling is measuring and correcting individual and organizational performance to ensure that events conform to plans (Weihnrich and Koontz 1993). It involves measuring performance against goals and plans, showing where deviations from standards exist, and helping to correct them. Thus control facilitates the accomplishment of plans.

2.4.3 Materials take off

Materials management process actually begins when a materials takeoff is performed to produce bills of materials. Before bills of materials can be created, materials specifications must be established.

In developed industries materials coding or numbering systems/standards have been devised and high percentage of material takeoff information is being generated using computer aided design (CAD) systems. As CAD software becomes more common, more efficient procedures for transferring data between computer systems have been developed. It is often easier to create a bill of materials computer file if a master or project specification file is created first.

A project specification file contains a list of all the materials items that will be used on the project, material code number, a description, a specification and the unit of measure. Unit prices and unit man-hour rates can be established for certain material items (Dawood 1996).

Developing detailed bulk materials requirements is laborious and time consuming. Judgment and experience are required to determine the level of detail of the material take off.

From the perspective of control and accountability, the level of detail of materials takeoff must be commensurate with the level of control detail and consistent with plans for construction work planning.

2.4.4 Vendor selection

Vendor performance has been observed to be a serious problem on construction projects. When vendor performance deteriorates, the potential for achieving benefits in the areas of improved labor productivity reduced materials surplus and reduced management manpower decreases accordingly (Bell and Sturkuat 1987).

Vendor selection therefore forms the success or failure of the project.
Vendors must be selected on the basis of their capabilities, geographical location, prior experience and owner preference.

Measurement of capabilities includes such considerations as past performance, financial condition, bargaining agreements, shop capacity, engineering support, quality assurance/quality control programs, competitiveness, responsiveness and schedule adherence.
It is important to keep a register of public vendors/suppliers and keep updating the register for easy sourcing of the materials.
In a well managed vendor selection system, it is always advisable to send inquiries to identify vendors and invite them to make an offer.
The inquiry must contain the descriptions of the goods, specifications, quantities required, supply schedule, place of delivery, delivery date, validity period and request for free sample if possible.
Offers can then be received and evaluated and prices negotiated before a supply contract is entered into.

2.4.5 Purchasing

The purchasing function is central to material Management. The purchasing has the responsibility and the authority to commit project funds for materials. The activity may be accomplished by the home office, the field or a combination of both depending on the size and scope of the project. Without successful purchasing it is impossible to achieve the results for which the project intends.

The following are some broad well recognized principles of scientific buying (Datta 2003).

i. Buying the right quality
ii. Buying the right quantity
iii. Buying the right price
iv. Buying from the right source
v. Buying at the right time and place

i. Right quality

First and foremost, quality must be properly defined. No general description of the character of the material or desired attributes will be sufficient, like "high quality" or "poor or low quality".

The definition must be in greater detail and this must be described in the purchase order. This description then becomes the essence of the purchase order.

Significant elements like dimension, physical, chemical and other properties, suitability and purpose must all be clearly stated.

ii. Right quantity

Since quantity is a mathematical measure, there have been many attempts to determine the optimum quantity which is most economical.

iii. Right price

Price is an important economic consideration that is a guidance factor in the terms and conditions of the purchase order.
A most common equation used in determining the right price is;

$$\text{Value} = \frac{\text{Quality}}{\text{Price}}$$

Thus value varies in direct proportion to quality and inversely to the price paid.

But quality is defined in a specification, it is constant and the comparison of value can be made in terms of price alone. It would follow then that, the lower the price, the greater the value (Datta 2003).

iv. Right source

Source selection and its importance has already been discussed under vendor selection.
Vendor selection is usually considered as part of purchasing but in this paper it has been considered separately.

v. Right time

Right time implies that in order to be effective, purchases should be made, in such a way that stores and materials are made available in time when needed, it being purchasing department's duty to see that the delivery schedule is honoured.

As such, timing is an important element in every purchase order, except when such purchases are made for stock purposes. Even then, in order to get some price advantage when some seasonal purchases are resorted to, timing plays its due role.

vi. Right place

Right place means right place of delivery. Every purchase contract, in addition to time of delivery, must clearly state the place of delivery and such other terms like free delivery or ex-factory delivery.

Generally, F.O.B. (Free on Board), F.O.R. (Free on Rail), C.I.F. (Cost, insurance and freight) paid terms are part of the price agreement.

From these basic principles, the following fundamental objectives of purchasing are derived.

a) to maintain continuity of supply to support production schedules,

b) in doing so, minimum investment in stores and materials inventory must be ensured, consistent with safety and economy,

c) duplication of purchases, wastes, obsolescence and costly delays must be avoided,

d) proper quality standards based on suitability criteria, must be maintained,

e) materials must be procured at lowest possible cost, consistent with quality and service requirements, and

f) It must maintain, in so far as materials costs are concerned, company's competitive position in the market.

For informal construction, the owner mainly assumes control of purchasing while holding the contractor/builder/site manager responsible for the other materials related functions.

When executing either cost-reimbursable or fixed price contracts, the owner may wish to purchase the engineered and fabricated materials and assign other purchase to the contractor.

Whereas the bills of materials define the project materials, the resulting purchase orders define the actions that were taken to meet those requirements. (Bell and Stukhart 1986).

Once the vendor has been selected, orders must be placed within the validity period. For good management there must be a written purchase order for the purchase of any material regardless of quantities involved.

The purchase order should include information on the description of the materials, quality, quantity, price, discounts, time and place of delivery, terms of payment, packing and dispatch instructions, inspection testing, and test certificates to accompany the materials, invoicing instructions, freight insurance, servicing and warranty.

2.4.6 Expediting

Expediting is an extremely important materials management function that does not always receive proper emphasis. The purpose of expediting is to provide timely information regarding anticipated materials deliveries to all concerned project personnel.

Several types of expediting exist, each with a different level of intensity and cost.

The least intense type of expediting is simple status reporting. Periodic telephone contact is made with the vendor to determine the status or progress of an order, and the information is reported to the project in some systematic format. This type of expediting provides basic information to the project, but does little to prevent or overcome delays or problems with an order.

Reactive or corrective expediting is more intense than the simple status reporting, but is initiated only in response to some event or action. Vendor contact may be made in response to a problem of delayed or late delivery.

Finally, proactive or preventative expediting is the most intense and aggressive type of expediting. Here, vendor and subvendor contact is initiated as soon as the order is issued and continues through the life of the order. The expediter will review all elements of the order to ensure that the vendor understands the various submittal, testing, and delivery requirements (Tavakoli and Kakalai 1993).

The expeditor will seek to gain a thorough understanding of the vendor's engineering, purchasing, and manufacturing operations as they relate to the particular order. This enables the expediter to monitor all elements of the vendor's performance with the intent of anticipating and resolving problems before they seriously impact the project.

Experienced professional expediters serve as a key bridge between the engineering and purchasing activities that specify and order materials and the field operations that are dependent on those materials for their progress.

Accurate and dependable expediting information is essential for informed management of the project, and facilitates the mobilization of buyer and vendor resources in response to problems or delays.

2.4.7 Quality assurance and quality control

In everyday usage the word 'quality' usually carries connotations of excellence. However, in engineering context quality is not necessarily indicative of special merit, excellence or high status.

Quality in engineering conveys the concepts of compliance with a defined requirement, of value for money, of fitness for purpose, or customer satisfaction. Thus a palace or a bicycle shade may be of equal quality if both functions as they should and both give their owners an equal feeling of having received their money's worth.

Quality therefore is a summation of all those characteristics which together make a product acceptable to the market (Ashford 1989). Products which are lacking in quality will in the long term prove unmarketable, and the purveyors of such products will go out of business. Therefore the need to promote and control quality is of fundamental importance to any enterprise.

The management of construction quality has become a major concern of owners and contractors because they now realize that quality affects the project schedule, ultimate cost, and performance of the constructed facility.

Materials quality, which is an important component of construction quality, depends for its success on an unbroken chain of positive actions by many different parties, (See Figure 2.1).

Quality assurance includes verification that all participants in the fabrication and inspection program follow established and specified procedures. Management must emphasize that quality is one of the most important, if not the most important, function of materials management. Owners and contractors should emphasize that quality performance is a major factor in the selection of suppliers. Thus, supplier quality is an important link in the quality of the constructed facility.

Owners and contractors must continually impress on their own employees as well as suppliers the need for quality products. The purchase order specification and inquiry documents should state the requirement for inspection. Details of the inspection such as test dates, forms and certifications should be established with the vendors prior to the actual inspections. Shop documentation must be meaningful, with required data reflecting actual results of fabrication and testing.

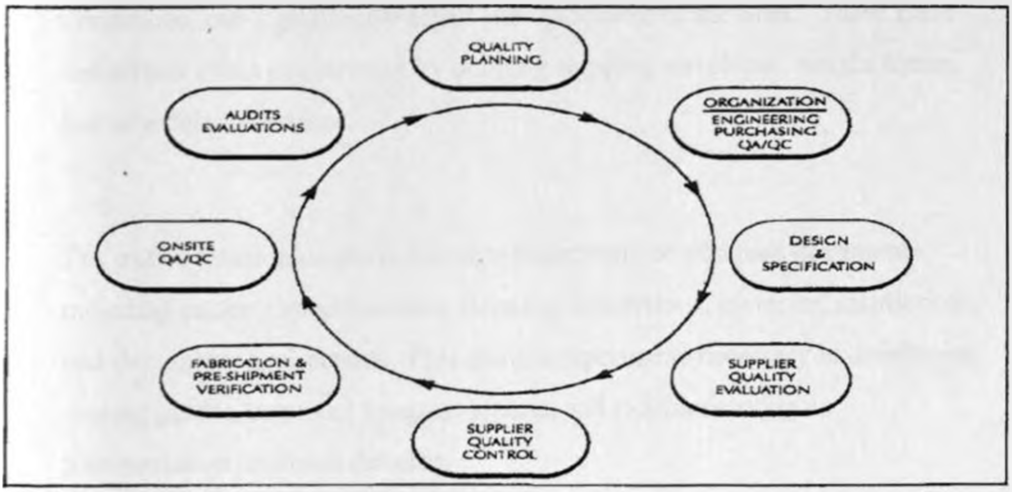


FIGURE 2.2: The "Quality Process" of Construction Materials

Source: CII 1988

2.4.8 Transportation

The movement of equipment, materials, and personnel to the job site represents a unique and specialized element of materials management. Experienced traffic personnel can have a positive impact on the execution of the project while minimizing transportation cost.

Significant savings are possible through the use of national agreements or negotiated project transportation agreements, and through various commercial arrangements for the transportation of goods, materials, documentation, or personnel.

Special consideration is required in setting terms, thereby determining the proper point for transfer of materials ownership and liability. The prime contract, especially insurance clauses, may have a direct impact on the purchasing terms and conditions concerning transportation.

Early specialized activities in the project planning phase, such as Properly performed route surveys and consideration of local traffic Conditions, can significantly affect later execution of the work. These front end efforts affect engineering by defining shipping envelopes, weight limits, and schedule limitations.

The traffic function or group has significant input to purchase documents including packing specifications, shipping instructions, invoicing instructions, and document requirements. This group's expertise is necessary in developing routing guides, shipment progress reports, and troubleshooting as transportation problems develop.

Transportation or traffic expertise aids the materials management team in handling numerous types of special loads from delicate electronics to massive modules, each requiring transport equipment that is specially designed or of limited availability. Knowledge of the requirements, source, and availability of this equipment may be critical to successful execution of the work.

Transport permitting requirements also must be considered early in the project. Assigning the above responsibilities to suppliers may present an easy upfront decision, but can later lead to painful lessons if the expertise is not available to the materials management team to ensure that traffic functions are handled properly.

Traffic or logistics for foreign sites presents an added dimension to the transportation requirements for a project. Each phase of the transportation effort is more complex, with often stringent requirements due to ocean shipment and transportation to remote areas of the world. Each country's customs requirements are unique with potentially significant duties, taxes, and delays that must be considered in the planning efforts.

2.4.9 Site materials management

Site materials management extends beyond the functions of receiving, storing, and issuing materials. It is affected by other elements of project management including engineering, procurement, expediting, and quality control.

It is important, therefore, that the site functions be well planned and executed, and that they be an orderly and logical continuation of an overall materials plan. Site materials management functions are detailed functions that increase in complexity with the size of the project, and may require specialized skills and talents.

The large volumes of structural, piping, and electrical materials that must be dealt with on large industrial projects make the use of computer systems at the site a requirement. The ability of these systems to catalog, sort, and combine materials by drawing, systems, areas, or other category and to allocate materials to a specific work plan can be a significant aid to craft planning. Full benefit is realized, however, only if the systems put in place on the job site are fully understood, accepted, and utilized by the crafts. This interface is the key to achieving the substantial cost savings that are possible through the use of this technology.

Properly managed site procurement is important to the success of the construction effort because of the potential to impact craft productivity by late identification, purchase, or delivery of field purchased items. The crafts depend on this group not only for permanent plant materials, but also for parts, supplies, tools, equipment, and services needed in the erection process.

Materials handling functions (receiving, storage, control and distribution of materials) at the job site are functions that appear routine on the surface, but can significantly affect project cost and schedule. Lost, damaged, misplaced, or improperly stored and maintained equipment and materials can result in expensive delays and disruptions. These and many other materials problems can be reduced or eliminated with the proper planning and implementation of the necessary materials management systems and procedures.

Materials handling should be planned to coincide with other site activities and success will be achieved by:

- **i.** Understanding the situation;
- **ii.** Discussing the form of packaging beforehand;
- **iii.** Controlling the sequence of deliveries;
- **iv.** Using the right equipment;
- **v.** Adopting firm control of all the operations

Materials handling is not a site problem; it is affected by the designer, the manufacturer and the contractor. Design will determine the shape, weight and consistency of the materials; presentation of the package will depend upon the manufacturer; and the contractor's policy for mechanical handling on site will influence the total operation. Unnecessary handling of materials increases site costs, and yet often materials waste could be reduced by redirecting under-employed plant and equipment (Johnston 1981).

An effective site materials control should be able to verify that the materials being delivered conform to what was ordered in terms of quantities and specifications and that what is delivered conforms to what is in the purchase order. The supplier should immediately be notified of any defects, shortfalls or failure in specifications and remedial action immediately taken to avoid delays.

Once the materials have been received, any special handling and instructions should be followed to avoid damage and deterioration of materials while on site.

Materials handling at the construction site can be broadly divided into:

i. Unloading from wagons/lorries and stacking in the storage yard, transportation from there to the site, unloading at the site, shifting, hoisting etc; of heavy contract materials; and
ii. Handling of light and medium stores (Joy 1990).

For the first type of handling, there will be requirements of hoisting and transport machinery and facilities like; cranes, tractors, trailers, power trucks, loading and handling attachments such as hooks, grabs and clamps; wire rope slings and chains for hoisting and hauling, wooden sleepers, planks, used tires, etc, to avoid damage while unloading; lifting tackles, drums, sheaves and sprockets, power driven conveyers for handling civil engineering materials of bulk quantity, if involved and sufficiently large handling and storage area with solid approach road. These machinery and facilities shall be used both for handling of materials and erection, to avoid idling.

For the second type of handling, the requirements shall be; wheelbarrows, trolleys and forklift trucks.

There also must be an orderly requisition of materials from the stores and special attention taken to minimize theft of materials.

Continuous physical inspection and verification of materials is necessary to ensure that the materials are available in the right qualities and quantities and also minimize misuse and theft.

2.4.10 Surplus materials

All projects can expect a certain amount of surplus; however, the key to successful surplus materials management is a well conceived and well executed materials management plan. Various shortcomings in the engineering, materials control, procurement, and field materials management phases of the work may result in surplus materials. Understanding and anticipating these potential problem areas are the first steps in minimizing surplus (Handrickson 1998).

Many causes of surplus can be identified. Surplus can be caused by a poorly performed materials takeoff (MTO). Engineering revisions and changes are yet another cause of surplus, particularly if the MTO occurs early and systems are not adequately responsive to change.

Inadequate construction materials management practices also may lead to surplus, particularly on fast track projects.

Primary causes are duplicate buying and poor control systems/procedures leading to procurement of unnecessary materials.

Minimizing surplus on a project requires a proactive and timely system of communication among all functions involved in the materials acquisition and installation cycle. For example, design changes must be immediately communicated to halt the acquisition of materials no longer required.

Similarly, substitutions in the field must be immediately communicated so unused materials may be considered in the remaining design. An individual should be identified as the focal point with the responsibility to track these types of changes as well as to periodically review and adjust minimum/maximum inventory limits.

Certain procurement practices can reduce surplus through the use of blanket price agreements. Releases are issued when engineering is sufficiently complete yet will still meet field requirements. Purchase orders for bulk materials and other commodities should include a materials return provision allowing return of surplus (CII 1988).

Options for disposal include using the surplus in alternative services, using the surplus materials on other projects, returning them to the vendor, or selling them to a third party. All options require complete records and timely reporting to achieve optimum results. The best option is to do the necessary planning and to implement the necessary materials management systems to reduce surplus at the source.

2.4.11 Materials wastage

Material wastage may be defined as the difference between the net measurement on drawings and the necessary allowance for any wastage that is unavoidable. Material wastage that is attributable to problems of poor materials handling is due to one or a combination of the following factors: -

- **i.** Poor workmanship
- **ii.** Construction errors
- **iii.** Excessive use of materials e.g. mortar and concrete
- **iv.** Breakage
- **v.** Poor storage
- **vi.** Misdemeanour (Johnston 1981).

Building materials wastage falls into two categories i.e. avoidable and unavoidable.

Avoidable wastage can be controlled and reduced through sound site management.

Unavoidable wastage refers to that part of materials considered by the estimator to be normal to the production process.

According to the Standard Method of Measurements of Building Works all quantities must be given net, as they will appear in the completed building. The material wastage must be reflected in the unit prices. The wastage allowance depends on the skill and experience of the estimator. This will also vary from firm to firm depending on the efficiency of the site foremen.

Unavoidable wastage can be further classified into six broad categories as follows:-

i. **Conversion wastage** - when cutting small timber scantlings from bulks of timber of logs.
ii. **Cutting wastage** - when sheet materials have to be cut for a specific component e.g. plywood, block boards, plasterboard and felt.
iii. **Application wastage** - occurs with most wet building materials such as plaster and other finishings. This includes wastage on many other materials such as bricks, tiles and timbers, which are cut to length.
iv. **Stockpile wastage** - when most loose materials are dispersed on the site because of partial use e.g. aggregate and sand.
v. **Residue wastage** - occurs with paints, glues and other materials, which are normally delivered in containers, and are never completely used.

vi. **Transit wastage** - occurs with brittle materials, which break on transit such as glass and tiles (Wainwright1970).

The extent of unavoidable wastage is generally known within reasonable limits and is taken into account with some precision when taking off or tendering.

The standard for unavoidable wastage of building materials will depend upon various factors as indicated above including nature, of work, type of material, method of application etc.

Table 2.1 below, illustrates typical unavoidable wastage considered when estimating materials for housing.

No.	Type of materials	Planned wastage
1.	Cement	2%
2.	Sand	10%
3.	Aggregate	5%
4.	Concrete structural	2%
5.	Concrete blinding (lean)	10%
6.	Reinforcement steel bars	3%
7.	Reinforcement steel mesh	10%
8.	PVC sheeting	15%
9.	Steel for windows	7%
10.	Timbering in trenches	5%
11.	Stone Masonry	5%
12.	Marble lining	20%
13.	Wood for door frames	5 to 7.5%
14.	Wood for shutters	10%
15.	Wood for flooring/walling	5 to 10%
16.	Sheet roofing	21/2 %
17.	Tile roofing	5%
18.	Floor tiling	2 to5%
19.	Wall tiling	3%
20.	Pigments (for colours other than natural grey)	5%
21.	Paints	5%

Table 2.1: Construction materials wastage planning norms

Source: (Mbaya 1997)

The avoidable wastage is mainly caused by: -

i. Designer's specification of non-standard materials

ii. Wrongful purchases

iii. Wastage in transportation

iv. Damages

v. Poor storage resulting in deterioration, obsolescence

vi. Poor workmanship

The minimization of avoidable wastage depends on site management.

2.4.12 Bulking and shrinkages

In wet construction, a reduction in bulk of the constituent materials takes place due to the finer materials filling the interstices of the coarse aggregate, the compaction and the addition of water. Shrinkages in concrete for example would vary depending on the estimator. Table 2.2 below shows some of the typical allowances for bulking and shrinkage.

Mixes	Bulking/Shrinkage allowance
1:4:8	50%
1:3:6	35%
1:2:4	25%
1.:11/2:3	15%
1:1:2	5%

Table 2.2: Bulking and shrinkage allowance

Source: JBC (2002)

Shrinkage and bulking should be included by the estimator as planned wastage.

2.5 Material management and computer systems

The current trend in construction materials management is towards developing computer-based data systems that provide the type of information needed to prevent materials shortages, surpluses, cash flow problems and labour delays. The cost of developing and executing the computer programs has been quantitatively justified through the results they provide and the lack of control apparent in their absence.

Since materials management computer systems are relatively new management tools it is not yet clear what degree of computer control will be most cost effective for a given type or size of construction project.

A computer system is usually required to achieve coordination of the individual functions of materials management. A well designed computer system assists with the generation of materials requirements and then tracks materials requisitions and purchase orders through the purchasing, expediting, and warehousing functions to final issue and installation.

Research has indicated that materials management computer systems can play an important role in improving craft labor productivity, cash flow and vendor performance, and in reducing bulk materials surplus.

Many factors must be considered when developing a materials management computer system. In general, an efficient system will include the following

i. Full integration of all materials management functions throughout the home office and project site, with emphasis on establishing capabilities that will produce project cost saving benefits.

ii. Line item reporting of purchase orders and requisitions.

iii. Sufficient flexibility to respond to various contractual arrangements, facility types, project sizes and locations, as well as a wide range of anticipated owner requirements and constraints.

iv. Online capability to ensure availability of current information to all system users.

v. A menu driven screen format, or some other user-friendly format, to ensure user acceptance and minimum user training time.

vi. Hardware portability, i.e., software that can be used on either small or large computer systems, depending on the project data requirements.

vii. Compatibility with other engineering, accounting, cost estimating, and project control computer systems.

To be cost effective, the computer system must effectively combine and integrate all of the individual functions of materials management systems. The system must facilitate the dissemination of current data to a wide range of system users, utilize current hardware and software technology, and possess sufficient versatility to be applicable to a wide range of project conditions.

A major hindrance to effective application of computer systems in management of materials is the reluctance to codification of materials by manufacturers and suppliers of construction materials. The reluctance has been mainly due to general lack of appreciation of information and communication technology (ICT) by the construction industry (Paulson, 1995).
Codification would make identification, description and control of materials much easier. The best way to codify is at the manufacturer's source.

2.6 Classification of Construction materials

In construction projects the type and quality of construction materials differ from project to project. Although some basic materials like steel, cement, sand aggregate, water and timber are common.
The primary purpose of materials classification is to control quality, cost and timely supply.
Factors to be considered when classifying materials are:

i. Storage space
ii. Shelf life
iii. Supply reliability
iv. Inventory cost
v. Case of identification
vi. Construction sequence
vii. Transportation requirements
viii. Prices
ix. Procurement time
x. Procurement source
xi. Project life

Construction materials are generally grouped into the following categories

i. Bulky type – one time purchases, repetitive use and minor materials
ii. Vital – essential and durable materials
iii. Locally available and imported
iv. High price, medium price and low price materials
v. High usage value, medium usage value and low usage value materials.

The last category (category v) is the most commonly used classification (Mbaya 1997).

2.7 Concrete in construction

Concrete consists of a mixture that contains a mass of loose inert particles of graded size (commonly sand and gravel) held together in solid form by a binding agent. The general description covers a wide range of end products. The particles may consist of wood chips, industrial waste, mineral fibers and various synthetic materials. The binding agent may be coal tar, gypsum, Portland cement, or various synthetic compounds (Parker 1994).
The end product range from asphalt pavement, insulating fill, shingles, wall panels, and masonry units to the familiar sidewalks, roadways, foundations, and frameworks.

The most commonly used concrete in the Kenyan construction industry is the concrete formed with the common binding agent of Portland cement, and a loose mass consisting of sand and gravel. This is what most people mean when they use the term concrete. With minor variations, this is the material used mostly for structural concrete for various forms of construction.

Building frames, walls, pavements, sidewalks, parking lots, streets, floor slabs in buildings, interstate highway systems, water control, marine structures, large bridges, tunnels, all use concrete extensively.

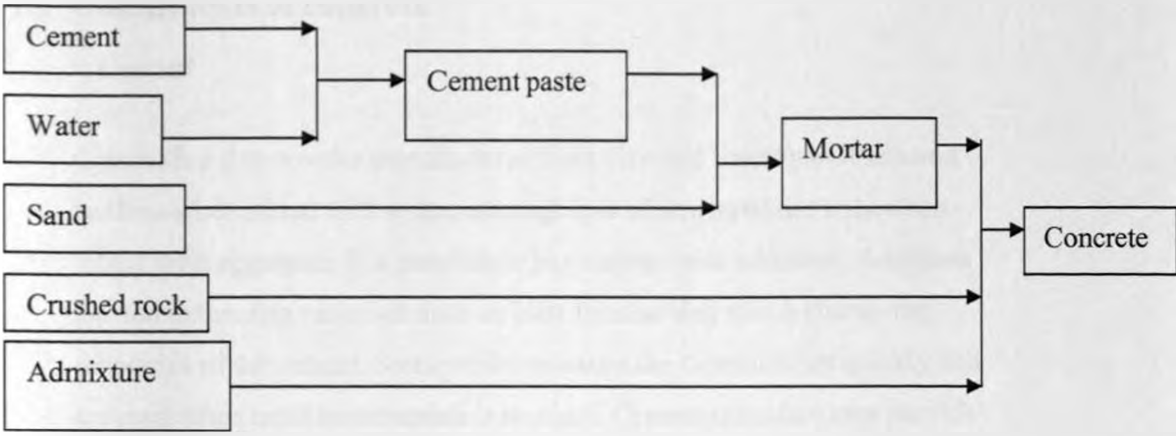


Figure 2.3: Formation of concrete

Source: Parker 1994

2.7.1 Historical background

Concrete made from natural materials was used by ancient builders thousands of years ago. Modern concrete, made with industrially produced cement, was first produced in the early part of the 19th century when the process of producing Portland cement was developed. Joseph Aspdin of England invented Portland cement in 1824 by burning ground chalk with finely divided clay in a lime kiln until carbon dioxide was driven off. The sintered product was then ground and he called it Portland cement named after the high quality building stones quarried at Portland, England.

Because of its lack of tensile strength, however, concrete was used principally for crude, massive structures- foundations, bridge piers, and heavy walls.
In the nineteenth century, several builders experimented with the technique of inserting iron or steel rods into relatively thin structures of concrete to enhance their ability to resist tensile forces. This was the beginning of what we now know as reinforced concrete (http//www.matse.uiuc.edu).

In Kenya, the use of concrete in its current form was introduced by the colonialist towards the end of 19^{th} century.

2.7.2 Constituents of concrete

i) Cement

Cement is a fine powder manufactured from clay and limestone. It sets and hardens when mixed with water, although it is of structural use only when mixed with aggregate. It is possible to buy cement with additives. Additives are non-cementing materials such as blast furnace slag which change the properties of the cement. Some additives cause the cement to set quickly and are used when rapid construction is required. Cement manufacturers provide details of the additives when the cement is bought.

Storage of cement is very important. If cement is unavailable close to the site, it is sometimes bought in large quantities to save on transport costs. However, this may mean that the last bags to be used are several months old and may have begun to set. Cement older than 3 months should not be used for large structures; it may be used after this time for small structures, but if hard lumps are found in the bag, it should not be used.

Cement should be kept dry during transportation and storage. Bags should be stored on pallets or another form of support which will allow ventilation and prevent ground moisture entering the bags. Bags should not be piled more than six bags high, although if space is limited and the bags will not be stored for long, they may be piled up to ten bags high.

ii) Filler

Filler is a very fine material and is used to fill the voids between the fine aggregate particles. It is often omitted if the fine aggregate used is sufficiently fine initially.

iii) Fine aggregate

Sand is nearly always used as the fine aggregate in concrete. It is a material with particle size ranging from 2 to 0.3mm. Up to 10% by volume of oversized particles (5 to 2mm) is normally acceptable, although if more than 10% it should be screened out by sieving. It is important to know the particle size and the mineral composition of the sand when concrete structures. Some fine aggregate minerals are very weak. If particles can be pulverized by squeezing in the hand, the sand is not suitable for use.

Sand is usually collected from rivers, streams and isolated deposits. It should be free of contamination. If there is organic matter, silt or clay particles or an obvious quantity of non-sand size material in the sand or if there is a noticeable colour change, the sand should be cleaned or rejected. Sand should be obtained as close to the site as possible as it is expensive to transport.

iv) Coarse aggregate

Coarse aggregate contributes most of the concrete's compressive strength through its high particle strength and close particle interlock. Coarse aggregate particles should be between 50 and 7mm, although a reduced maximum size may be specified if the structure is to be reinforced. Coarse aggregate can be produced by quarrying and crushing rock or excavated from a gravel quarry. Coarse aggregate can also be crushed and selected manually. The aggregate should always be sieved to remove undersized particles.

In some areas coarse aggregate or hard rock may be unavailable. Alternatives should be considered. One alternative is to burn and then crush clay bricks. Although not as strong as normal coarse aggregate, burnt clay bricks are durable and strong enough for use in concrete.

v) **Water**

The water used in concrete should be clean and free of organic material and salts, including chlorides, although for low cost structures the salt content and some suspended solids can be ignored. Most surface water is good enough for concreting work, but care should be taken when using ground water. A shortage of water must not disrupt the concreting operation, so water should be either readily available nearby or stored in sufficient quantity on site.

2.7.3 Reinforced concrete

Concrete become a reliable material with the introduction and development of durable 'Portland' cement during the nineteenth century, and was quite widely used for foundations and floors, where its strength under compression was most required.

Before concrete could be safely employed for more complex structures, however, some form of reinforcement was necessary to counteract its weakness under tension, and many methods were tried. Francois Hennebique (1842- 1924), substituted steel for iron and devised hooked connections for reinforcing bars in 1892 (Fletcher 1994).

The advent of reinforced concrete in the years around 1900 therefore introduced a material capable of withstanding great compressive and tensile loads, than steel could do, and with further important advantage of a high degree of fire resistance. Steel was widely used for big structures before.

Reinforced concrete is now a common building material for the construction of facilities and structures. While concrete has a high compressive strength, it has a very limited tensile strength. To overcome these tensile limitations, reinforcing bars are used in the tension side of concrete structures.

Steel rebars have been and are an effective and cost-efficient concrete reinforcement. Steel reinforcement is however susceptible to oxidation when exposed to chlorides.

When properly protected from ion attack, steel reinforcement can last for decades without exhibiting any visible signs of deterioration. However, insufficient concrete cover, poor design or workmanship, poor concrete mix, and presence of large amounts of aggressive agents all can lead to corrosion of the steel rebar and cracking of the concrete.

Welded wire reinforcement is mainly used in ground slabs and pavements while steel bars are used in suspended slabs and columns.

Recently, other forms of reinforcements like fibre based reinforcements, have been introduced though their application in the Kenyan industry is still very minimal.

2.7.4 Forms of concrete

For building structures, concrete is mostly used with one of three basic construction methods.

i. **Site cast concrete**

In this method, wet concrete mix is deposited in some forming at the location where it is to be used. This method is also described as cast in place or in situ construction. The concrete can either be prepared on site or be brought to site when already mixed (ready mix) from another plant or supplier.

ii. **Pre cast method**

This method consists of casting portions of the structure at a location away from the desired location of the construction. These elements described as pre cast concrete are then moved into position, much as blocks of stone or parts of steel frames are.

iii. In the third method, concrete can be used for masonry construction in one of two ways. Pre cast units of concrete (called concrete masonry units) may be used in a manner similar to bricks or stones or concrete fill may be used to produce solid masonry by being poured into cavities in masonry produced by bricks, stones or concrete masonry units. The latter technique, combined with the insertion of steel reinforcement into the cavities, is widely used for masonry structures today in developed countries.

2.7.5 Concreting process

Concreting requires careful planning and preparation. For successful concreting work, the concrete must be the right specification for the job and has to be placed correctly.

Though ready mix concrete is not widely used locally, buying concrete ready mixed is believed to be more convenient, quicker and less wasteful (Flannery 2000).

When concrete is prepared on site, then the responsibility of ordering and storing the ingredients and ensuring that there is adequate and competent labour and equipment for mixing and placing of the concrete rests on the site management. However, by ordering from a ready mix company the responsibility of all these factors rests with the supply company.

Regardless of which kind of concrete (ready mix or site prepared) is used, the site management still needs to deal with many issues including understanding of the stages involved, specifications of the mix, delivery acceptance, issues of wastage and quality control. The process becomes more complex when dealing with reinforced concrete. The reinforcement must have been correctly specified, acquired, fixed and inspected before the concreting. The formwork must also be appropriately prepared in line with the desired level of finish.

Two tests are commonly carried out when concrete is being placed. These are required to ensure that the concrete is of good quality. The slump test is a test to ensure consistent quality. It is carried out on site and gives rapid results so that adjustments can be made immediately to the mix. The other is the cube test where concrete is sampled from a mix, cured and then tested to check that the design strength has been obtained

Concreting is done on virtually all construction projects and this usually in large quantities. The consequences associated with inappropriate management of this process could be great if concrete is considered as a single material.

Achieving optimum efficiency and quality of the concreting process on site therefore requires consideration of the concrete preparation/procurement process as a whole and the interactions between concreting and the inter-related construction processes (fig 2.3).

The above therefore makes concreting an ideal case study for this project.

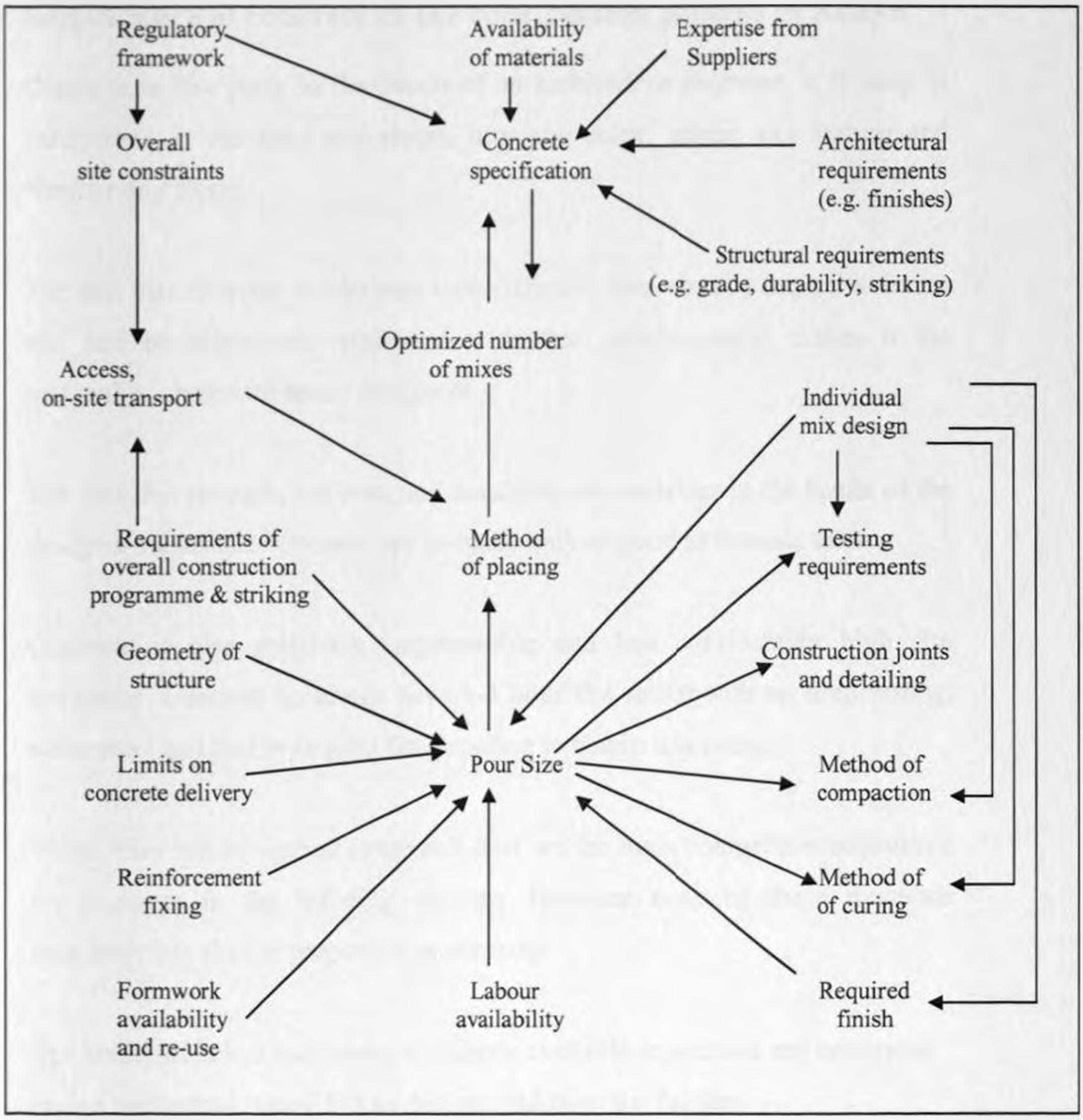


Figure 2.4: Issues and interactions affecting concreting process for in-situ concrete structures

Source: British Cement Association 2000

2.7.6 Significance of concrete in the construction process in Kenya

Concrete is like putty in the hands of an architect or engineer. It is easy to manipulate, it can take any shape, turn any color, mimic any texture and weather any storm.

The fact that concrete can be cast monolithically into visually attractive forms and can be effectively reinforced with steel reinforcement makes it the material of choice for many designers.

The fact that strength, stillness and durability are variables in the hands of the designer means that concrete can be made only as good as it needs to be.

Concrete is also relatively impermeable and has considerably high fire resistance. Concrete buildings have 1-3 hour fire rating with no fireproofing, while steel and timber require fire proofing to obtain this rating.

Wood, clay bricks, natural stone and steel are the main competitors/substitutes for concrete in the building industry however none of these materials singularly has similar properties as concrete.

The breath of colors and textured finishes available in concrete are enormous giving aesthetical appeal but saving on claddings for finishes.

It could be faster to work in concrete if the construction process is properly planned especially with components like floors.

Concrete also has the advantage of lateral stiffness or resistance to horizontal movement, which gives it advantage when constructing in areas of high wind loads.

It can be argued that use of concrete in construction has economic advantage of low maintenance and wide availability of concreting materials (except cement).

The definition of what constitutes permanent structures by planning authorities leave developers with very few options besides concrete in the construction of buildings.

Though there are no available statistics on the use of concrete in its varied forms either by volume or cost on construction projects in Kenya, it can be argued that concrete is extensively used on nearly all construction projects in Kenya. In fact the annual growth and magnitude of the construction industry in Kenya, is measured through the consumption of cement, which is the most important component of concrete (Daily Nation, Friday 27th May 2005).

The cumulative values of cement, sand, course aggregate, reinforcement steel and formwork on any given project may give an indication of the approximate value of concrete on the project. However, these values may vary on different projects depending on project design and specifications. Conservative estimates obtained by the researcher from a few practicing quantity surveyors on projects undertaken, gives the cumulative value of between 25% to 40% of the total cost of construction. No other component except labour was valued close to these percentages. This is still an indication of how important concrete is to the building industry.

CHAPTER THREE
STUDY METHODOLY

3.1 Introduction

This chapter describes the procedures that have been followed in conducting the study. The techniques of obtaining data have been explained.
The study area, population, sampling techniques, sample size, data collection instruments, data collection procedures and data analysis methods are discussed in details.

3.2 Description of study area and population

This study investigates the relationship between the extent of materials management and attributes of materials (availability, right quality, reasonable cost, minimal surplus and minimal wastage) for concreting materials (ballast, Sand, Cement, Steel and water) on construction projects in Nairobi.

The intention of this study is to generalize the findings for all construction projects in Kenya. Thus the target population was all the active sites in Kenya.

However for accessibility and given the limitations already mentioned, the study population consisted of accessible active construction sites (both formal and informal) within Nairobi city which were selected through sampling.

Nairobi is the capital and the most active economic centre of the country with the highest level of construction activities.

Nairobi has many construction sites within any given moment due to its rapid growth. Most of the works within the central business district and the suburbs like Westlands, Upper Hill, Hurlingham, Muthaiga, Lavington, Runda, Parklands, Industrial Area and Karen, are predominantly formal construction sites with full design team and full construction contracts between developers and contractors. However even in these high income areas, some developers because of a perceived perception of trying to minimize costs, engage qualified contractors, mainly small and medium sized, but only for labour contracts. In such situations, the developer still retains the responsibility over purchase and control of materials.

The informal sites where the developer undertakes the construction directly with a few masons are mainly found in middle and low income residential areas such as Githurai, Zimmerman, Doonholm, Kahawa, Buruburu, Kariobangi, Riruta, Umoja, Kayole, Dandora, and Mathare North.

The sites that formed the population were both formal and informal construction sites within Nairobi and the ones studied were those undertaking major concreting works mainly casting of floor slabs and columns within the selected areas over the study period.

3.3 Research design

The problem under study is experienced on sites under construction and the relevant information could easily be obtained through interviews on sites.

The study was therefore a survey research where data was collected from members of population in order to determine the current status of the population with respect to the identified variables in the literature review.

3.4 Sampling techniques and sample size

A large sample from the accessible population was desired in order to minimize the sampling error. However given the constraints of time and resources a sample size of 43 sites was used for data collection. This was in order to be above the recommended minimum of 30 members (Mugenda and Mugenda 1999).

The desired sampling frame was all the active construction sites in Nairobi. However due to the limitation of time and resources it was not possible to exhaustively compile this frame given the geographical expansiveness of the city.

For convenience and accessibility, cluster sampling was therefore used. The areas of study were grouped into two clusters; formal and informal. The CBD, Upper Hill, Westlands, Hurlingham, Parklands and Industrial Area were put in the same cluster and formed the sampling frame for the formal sites. These areas were physically visited and the active sites in these areas identified, listed and numbered. A total of 43 sites were found to be active in these areas.

Likewise, Zimmerman, Kahawa, Doonholm, Kayole, Dandora and Umoja, formed the cluster and sampling frame for informal sites. The areas were physically visited and the active sites identified, listed and numbered. A total 66 sites were found to be active in these areas.

To allow for generalization of the findings and to minimize margin of error, simple random sampling was used to select the particular sites to study (units of observation) from all the identified, listed and numbered sites of each cluster. The random sampling was done separately for each cluster.

Random sampling was done by writing the number representing each site on a piece of paper. The papers were then folded to conceal the numbers and placed in a container and then picked at random one at a time. The subjects corresponding to the numbers on the papers picked were included in the study sample.

Every time before a paper was picked, the papers were well mixed in the container to minimize error.

A total of 48 sites (24 formal and 24 informal) were randomly sampled. All the sites were visited, however access was denied on some sites. A total of 43 sites (22 formal and 21 informal) were studied and the data collected from those sites analyzed. This was a very encouraging response of 89.6% given that some sites had to be visited several times before they were eventually studied mainly because those responsible could not honour appointments.

Though there is no statistical evidence on the ratio of the number of formal to informal construction in Nairobi, the number of sites studied for each cluster in this study was almost equal. This was deliberate due to the complications involved in establishing the ratio and also in order to have reasonable number of subjects to study from both clusters to make reasonable analysis and comparisons given the limitations in the overall sample size.

3.5 Data collection instruments

Primary data (original data collected by the researcher from the population) was used for this study.

The instrument used to collect the data was the questionnaire, which was administered directly to the respondents by the researcher and the assistants.

The kind of questions used in the questionnaire were mainly structured (closed ended) for ease of administration and analysis.

3.6 Data collection procedures

Data was collected from active construction sites using the questionnaire. The questionnaire was administered to the site manager/foreman on the respective sites.

Two research assistants with background knowledge in construction and who were trained by the researcher on how to administer the questionnaire were engaged on the study.

Before the questionnaire was used in the study it was presented to a selected sample similar to the actual sample used in the study for testing and further improvement.

3.7 Measurement of variables

A variable is a measurable characteristic that assumes different values among the subjects. It is therefore a logical way of expressing a particular characteristic in a subject. Variables can be expressed quantitatively for example height in metres and others in categories like gender expressed as male or female (Mugenda and Mugenda 1999).
There are different classifications of variables;

3.7.1 Independent variable

An independent variable is a variable that a researcher manipulates in order to determine its effect or influence on another. It is a variable whose available categories are designated in advance by the researcher. Normally these variables are selected because they are seen to be causative or very important to the particular logical purpose of the research project.
The term independent means the categories of the variables are chosen by the researcher independently in the measurement taken in the project and normally prior to it.

In this study the extent of management of materials evidenced through the functions of materials management was viewed as the independent variable. These functions of materials management include planning, organizing, communication, material take off, vendor selection, purchasing, expediting, quality control, transportation, site materials management and management of surplus and wastage.

The measurement of the components of this variable (planning, organizing, communication, material take off, vendor selection, purchasing, expediting, quality control, transportation, site materials management and management of surplus and wastage) was in an ordinal scale as can be derived from the descriptive nature of the study.

An ordinal scale groups subjects into categories and ranks them into some order with numerals reflecting increasing amount of the characteristics but not at intervals. The numerals are used to represent relative position or order among the values of the variables. However, the order indicated in an ordinal scale does not imply a quantitative diction (Mugenda and Mugenda 1999).

Thus, based on the responses from the questionnaire, each site was given a score of either zero (0) or one (1) for each of the components of the independent variable to indicate its performance in that aspect. For example a site that was deemed to have excelled well in purchasing, would score one (1) for purchasing while a site that has not excelled would score zero (0). This was done for all the components of the independent variable for every site studied.

The cumulative score for every site was assumed to form an interval scale and thus a measurement of the level or extent of management. Therefore a site that excelled and scored one (1) in each of the components of the independent variable would have a cumulative total of ten (10). Its score for extent of materials management would therefore be taken to be ten (10). A site that scores zero (0) in every component of the variable will have a cumulative total of zero (0) and its score for the independent variable (extent of materials management) will therefore be taken as zero (0).

In an interval scale the numerals reflect increasing amounts of the characteristic with equal interval (Mugenda and Mugenda 1999).

Function	Maximum score
Planning, organizing and communication	1
Materials take off	1
Vendor selection	1
Purchasing	1
Expediting	1
Site materials management	1
Quality control	1
Transportation	1
Surplus management	1
Wastage management	1
Total	**10**

Table 3.1: Scoring for functions of materials management

3.7.2 Dependent variable

Dependent variables are so named because their results are presumed to depend upon differences in the independent variable. The variation in them is seen as being related to, caused by, or in some way influenced by differences in the independent variable.

A dependent variable therefore varies as a function of the independent variable.

In this study the extent of materials attributes expressed through availability, right quality, reasonable cost, minimal surplus and minimal wastage of materials on site was viewed as the dependent variable because it should vary in some relationship to the independent variable. Its measurement was also based on ordinal scale.

The occurrence or absence of each of the attributes on a particular site was denoted with either zero (0) or one (1), with zero (0) representing negativity and one (1) representing positivity. For example based on the questionnaire a site that was viewed to have materials available for the concreting activity would score one (1) while a site with material shortages would score zero (0).

The cumulative total for each of the sites was then transformed into interval scale such that a site with no negative attribute scored five (5) points while one with no positive attribute scored zero (0).

Function	Maximum score
Availability	1
Right quality	1
Reasonable cost	1
Minimal surplus	1
Minimal wastage	1
Total	**5**

Table 3.2: Scoring for materials attributes

3.8 Data analysis techniques

This is basically a quantitative/empirical research and therefore data presentation and analysis is mainly based on empirical techniques.

Descriptive statistics have been used to explain the various outcomes and relationships. To achieve this, the responses in the questionnaire were assigned numerical values (a process referred to as 'coding') for ease of analysis. This was facilitated with the items in the questionnaire being mainly closed ended. The few open ended questions in the questionnaire were categorized and numerical values assigned to various categories for ease of analysis.

Inferential statistics (using SPSS software) has been applied to assist in testing of hypothesis.

The testing of hypothesis followed regression and correlation analysis between the two major variables in the study; the level of management of materials and level of materials attributes on construction sites.

The inferential statistics is applied to help in generalization of the findings. The hypothesis is tested at 95% confidence level (α=0.05 and 41 degrees of freedom). A significant of 0.01 (that is, it would occur by chance less than one in a hundred times) is used to generalize the findings.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 Introduction

In this chapter data that was collected from the sites is analyzed and explained. Tables and descriptions are mainly used to explain the findings from the field survey. The hypothesis that inadequate management of materials is the cause of poor level of materials attributes is also tested.

Out of the sample of 48 sites, 43 sites provided full response, representing 89.6% which is reasonable and sufficient for proceeding with the analysis. Though some sites were visited several times before actual data could be colleted mainly due to those in charge of the sites not honouring appointments, the good response was mainly due to contractors/developers' keenness to know about materials management, this area not having been studied before. The fact that the questionnaire was administered on site also contributed much to this good response as many of those interviewed considered it very site related.

Responses were received from 21 informal sites and 22 formal sites. Out of the formal sites the breakdown as per the grade of the contractors is as shown in table 4.1.

Grade of contractor	Number of sites	Percentage
A	8	36
B	7	32
C	4	18
D	3	14
Total	22	100

Table 4.1: Categories of contractors

Source: Field survey, March 2005

No site with contractor below grade D was studied. It was not the intention of this study to stratify the contractors as that could complicate the study further. It was therefore not possible to ensure that contractors for every category are studied as the random sample was used. However, it is hoped that the findings of this study would be applicable to contractors of all grades.

Of all the formal sites studied the traditional method of procurement (design separate from construction) was found to be in use.

In line with the objectives of the study, the questionnaire was designed to establish the extent of materials management through the functions of management (independent variable) and the extent of materials attributes through the specific attributes (dependent variable). The findings of these aspects of study are sequentially presented and analyzed.

4.2 Findings and analysis of independent variable

The findings and analysis of the various components of the independent variable are discussed in this section.

4.2.1 Organizing, planning and communication

The study sought to find out the level of training for those in charge of materials management; table 4.2.

Level of training	Number of sites and percentages					
	Formal sites		Informal sites		Combined	
	NO.	%	NO.	%	NO.	%
University technical degree	6	27	0	0	6	14
Polytechnic diploma	9	41	4	19	13	30
Technical college certificate	1	5	5	24	6	14
No formal training	6	27	12	57	18	42
Total	22	100	21	100	43	100

Table 4.2: Level of training for materials managers on sites.
Source: Field survey, March 2005

On the formal sites, most of the staff involved in materials management is fairly well trained. 68% of those in charge have at least a polytechnic diploma, though even on some class A contractor sites, those in charge of materials claimed not to have any formal technical training but to have learnt through experience on site. It should be noted that most of these contractors have evolved as family businesses and members of the family have grown with the businesses.

It was not clear whether the high percentage of trained staff with contractors is as a result of the recent directive by the government that contractors must have certain level of trained staff for them to retain their registration status. The survey did not investigate this fact.

For the informal sites there was no single site where those involved with materials management had a university technical degree. Perhaps the clients themselves were, but this was not investigated. It was only on 4 sites representing 19% of the sites studied where those involved with materials management had a polytechnic diploma and these were sites where there were labour contracts. Therefore on average the informal sites rank poorly in the level of technical training for material management staff.

Overall, only on 44% (less than half) of all sites combined did those involved in materials management have a polytechnic diploma and above, which is fairly inadequate.

It was only on 2 sites, that those concerned with materials management claimed to have further training on issues of materials management, besides their college training.

The total number of those involved with the management of materials varied from site to site. Since the value and complexity of the projects were varying it was not practical to realistically analyze this aspect.

The study also investigated the use of integrated materials management plan encompassing all the aspects and phases of the project and use of computers in organizing for materials. The findings were as shown in tables 4.3 and 4.4

Material management plan	**Number of sites and percentages**					
	Formal sites		**Informal sites**		**Combined**	
	NO.	%	NO.	%	NO.	%
Integrated plan	3	14	0	0	3	7
No integrated plan	19	86	21	100	40	93
Total	22	100	21	100	43	100

Table 4.3 Integrated material management plan

Source: Field survey, March 2005

Organizing for materials	Number of sites and percentages					
	Formal sites		Informal sites		Combined	
	NO.	%	NO.	%	NO.	%
Software	0	0	0	0	0	0
Charts and tables	19	86	0	0	18	43
No formalized method	3	14	21	100	24	57
Total	22	100	21	100	43	100

Table 4.4: Organizing for materials

Source: Field survey, March 2005

Only 14% of the formal sites (table 4.3) had a fairly elaborate materials management planning indicating how to determine stock levels, staffing levels and ordering times as outlined in the literature review. The materials schedules seem to be controlled by the general project planning schedules.

For the informal sites no site was found to have an elaborate materials management planning.

None of the sites (formal and informal) is using computer software to manage the materials. None of the sites was networked between the office and the site.

4.2.2 Materials take offs

All the 22 formal sites studied used the traditional method of construction procurement where the designs are completed first (by different parties from the contractor) and bills of quantities prepared from the drawings, then a few contractors are pre-qualified and invited to tender for the project using the bills of quantities and drawings. A suitable contractor is then chosen and enters into a contract with the developer for construction with the consultants as the agents to the developer overseeing the construction process.

The bills of quantities therefore becomes a vital basis for estimation of materials on formal sites (Table 4.5).

Materials estimation	Number of sites and percentages					
	Formal sites		Informal sites		Combined	
	NO.	%	NO.	%	NO.	%
From bills of quantities	19	86	0	0	19	43
Quantity surveyors	4	14	4	19	2	17
"Architects"	0	0	7	33	7	16
No proper estimation	0	0	10	48	11	24
Total	22	100	21	100	43	100

Table 4.5: Materials estimation
Source: Field survey, March 2005

86% of the formal contractors studied were therefore found to rely on the bills of quantities for their materials estimates and only verified occasionally with the drawings.

Only 14% of the formal sites indicated to have carried out independent materials take off different from tendering bills of quantities. They however indicated to having used quantity surveyors to do the estimates.

However, for the informal sites no site indicated to have used bills of quantities to prepare materials estimates mainly because there may have been no tendering involved. 19% of the informal sites indicated to have some form of materials estimates prepared by quantity surveyors 33% of the informal sites claimed that they had materials estimates prepared by the "project architects" (not sure whether qualified architects were involved in the projects), while the remaining 48% of the informal sites did not have any elaborate way of getting materials estimates.

4.2.3 Vendor/supplier identification and selection

The data on the vendor identification for formal sites is presented in table 4.6 below.

Identification of vendor/suppliers	**Number of sites and percentage for each materials**							
	Ballast		**Sand**		**Cement**		**Steel**	
	NO.	%	NO.	%	NO.	%	NO.	%
Open tendering	1	5	1	5	1	5	1	5
3rd parties and salesmen	10	50	10	50	5	22	3	13
Self inquiry	2	9	2	9	4	18	4	18
Previous relationships	7	32	7	32	14	50	12	59
Self supply	2	9	2	9	1	5	1	5
Total	22	100	22	100	22	100	22	100

Table 4.6: Vendor identification for the formal sites.
Source: Field survey, March 2005

Vendor identifications for formal sites for ballast and sand was mainly through salesmen and third parties at 50%. However for steel and cement (industrial products) the identification was mostly through previous relations from other projects. This was mainly because of credit offer.

Table 4.7 below shows the summary of the data on vendor identification for the informal sites.

Identification of vendor/suppliers	Number of sites and percentage for each material							
	Ballast		Sand		Cement		Steel	
	NO.	%	NO.	%	NO.	%	NO.	%
Open tendering	0	0	0	0	0	0	0	0
3rd parties and salesmen	16	76	16	76	7	33	8	38
Self inquiry	5	24	5	24	13	62	12	57
Previous relationship	0	0	0	0	1	5	1	5
Self supply	0	0	0	0	0	0	0	0
Total	21	100	21	100	21	100	21	100

Table 4.7 Vendor identification for the informal sites

Source: Field survey, March 2005

For the informal sites identification of vendors for ballast and sand was also mainly through third parties and salesmen (76%). However suppliers for cement and steel were mainly through self inquiry at 62% for cement and 57% for steel.

Though open tendering is considered to be the most appropriate and profitable way of sourcing only one site representing just 2% of the total sites studied, indicated to having used the method.

Tables 4.8 and 4.9, indicate the actual number of vendors identified for the supply of each of the concreting materials for formal and informal sites respectively.

No. of vendors identified	**Number of sites and percentage for each material**							
	Ballast		**Sand**		**Cement**		**Steel**	
	No.	%	No.	%	No.	%	No.	%
1	8	36	14	72	17	77	19	86
2	8	36	4	18	3	14	2	9
3 and over	6	28	4	18	2	9	1	5
Total	22	100	22	100	22	100	22	100

Table 4.8: Number of vendors/suppliers for each materials for formal sites

Source: Field survey, March 2005

No. of vendors identified	**Number of sites and percentages for each material**							
	Ballast		**Sand**		**Cement**		**Steel**	
	No.	%	No.	%	No.	%	No.	%
1	12	57	16	76	16	76	20	95
2	5	24	4	19	5	24	1	5
3 and over	4	19	1	5	0	0	0	0
Total	21	100	21	100	21	100	21	100

Table 4.9: Number of vendors for each materials for informal sites.

Source: Field survey, March 2005

For the formal sites, the percentage representation of the sites where only one vendor was identified for the supply of ballast, sand, cement and steel are 36%, 72%, 77% and 86% respectively for each of the materials. While for the informal sites the percentages for selection of only one vendor are 57%, 76%, 76% and 95% respectively for ballast, sand, cement and steel.

The study also investigated the reasons for selection of the vendor for each of the materials. The outcome is as summarized in tables 4.10 and 4.11 below. The tables show the number of sites (also expressed as a percentage of the total sites studied) that indicated the given reason as criteria for selecting the vendor for the respective material.

Reason for selection of vendor	**Number of sites and percentage for each materials**							
	Ballast		**Sand**		**Cement**		**Steel**	
	NO.	%	NO.	%	NO.	%	NO.	%
Past success	15	71	13	61	12	57	13	61
Good price	16	76	14	67	15	71	16	76
Geographical location	4	19	3	33	6	28	5	24
Credit offer	4	19	5	24	15	71	15	71
Quality assurance programme	0	0	0	0	0	0	0	0
Bargaining agreement	0	0	0	0	0	0	0	0
Schedule adherence	12	57	14	67	0	0	0	0

Table 4.10: Reasons for selection of vendors for formal sites.

Source: Field survey, March 2005

Reason for selection of vendor	Number of sites and percentage for each materials							
	Ballast		Sand		Cement		Steel	
	NO.	%	NO.	%	NO.	%	NO.	%
Past success	5	23	4	18	2	9	1	45
Good price	17	77	15	68	14	64	13	59
Geographical location	6	27	7	32	14	64	15	68
Credit offer	5	23	7	32	3	14	3	14
Quality assurance programme	0	0	0	0	0	0	0	0
Bargaining agreement	0	0	0	0	0	0	0	0
Schedule adherence	2	9	4	18	0	0	0	0

Table 4.11: Reasons for selection of vendors for informal sites.
Source: Field survey, March 2005

All the sites had at least more than one reason for selecting a given vendor for the supply of the materials.
Majority of the formal sites indicated good price, credit offer, past success and schedule adherence as the reasons for selecting the particular vendor for ballast, sand, cement and steel. For the informal sites, the selection was based mainly on good price and geographical location.

Though quality assurance programme by the vendor/supplier was included in the questionnaire as part of criteria for selecting a supplier, it was not indicated by any site as having been considered in the selection of the suppliers.

Only one site from the formal cluster was using ready mix concrete and the contractor was supplying the ready mix concrete himself. Therefore the issues of identification of supplier were not applicable in this case.

4.2.4 Purchasing

The study also investigated the method used for placement of orders for the concreting materials. The outcome is outlined in tables 4.12 and 4.13 below.

Placement of orders	Site numbers and percentages for materials							
	Ballast		Sand		Cement		Steel	
	No	%	No	%	No	%	No	%
Telephone & verbal	13	59	15	68	2	9	2	9
Written order	6	27	4	18	20	91	20	21
Direct purchases	3	14	3	14	0	0	0	0
Total	22	100	22	100	22	100	22	100

Table 4.12: Placement of orders on formal sites.

Source: Field survey, March 2005.

Placement of orders	Site numbers and percentages for materials							
	Ballast		Sand		Cement		Steel	
	No.	%	No	%	No	%	No	%
Telephone and verbal (agents)	19	90	19	86	2	10	3	14
Written order	0	0	0	0	2	10	2	10
Direct purchase	2	10	3	14	17	80	16	76
Total	21	100	21	100	21	100	21	100

Table 4.13: Placement of orders for informal sites

Source: Field survey, March 2005

The placement of orders for ballast and sand on informal sites was mainly through telephone and verbal orders through the agents, while for sand and cement the orders were mainly placed through written orders. The latter could be because of credit offers to the contractors by suppliers.

For the informal the ordering was mainly by telephone and verbal contacts with agents for ballast and sand, while cement and steel were mainly purchased directly.

4.2.5 Expediting

Table 4.14 indicates the findings on expediting (follow up) on orders for materials for both formal and informal sites.

Follow up on orders	**Number of sites and percentages**					
	Formal sites		**Informal sites**		**Combined**	
	NO.	%	NO.	%	NO.	%
Follow up made	16	73	10	48	36	60
No follow up made	6	27	11	52	17	40
Total	22	100	21	100	43	100

Table 4.14: Expediting/follow up on orders for materials
Source: Field survey, March 2005

73% of the formal sites indicated that they make some form of follow up with the suppliers once the orders have been placed to ensure that deliveries are made correctly. However, for the informal sites only 48% indicated to be involved with some follow up with the suppliers.

4.2.6 Transportation

This study also investigated the involvement of the contractor/developer in the transportation and packaging of the materials as a means of minimizing transportation costs, damage and wastage associated with transportation. The findings are shown in tables 4.15 and 4.16 below. The mode of transport was also investigated and is shown in table 4.17 and 4.18 below.

Involvement in transportation	**Number of sites and percentages**					
	Formal sites		**Informal sites**		**Combined**	
	NO.	%	NO.	%	NO.	%
Involved	10	45	5	24	15	39
Not involved	12	55	16	76	28	61
Total	22	100	21	100	43	100

Table 4.15: Involvement in transportation of materials

Source: Field survey, March 2005

Involvement in packaging of materials	**Number of sites and percentages**					
	Formal sites		**Informal sites**		**Combined**	
	NO.	%	NO.	%	NO.	%
Involved	10	45	2	9	12	32
Not involved	12	55	19	81	31	68
Total	22	100	21	100	43	100

Table 4.16: Involvement in packaging of materials

Source: Field survey, March 2005

Mode of transportation	Number of sites and percentages for materials							
	Ballast		Sand		Cement		Steel	
	No.	%	No	%	No	%	No	%
Pick up and above	0	0	0	0	9	41	11	50
7 ton lorries and above	12	55	10	45	10	45	9	41
14 ton lorries and above	8	36	10	45	2	9	2	9
24 ton lorries and above	2	9	2	10	1	5	0	0
Total	22	100	22	100	22	100	22	100

Table 4.17: Mode of transportation for formal sites

Source: Field survey, March 2005

Mode of transportation	Site numbers and percentages for materials							
	Ballast		Sand		Cement		Steel	
	No.	%	No	%	No	%	No	%
Pick up and above	2	9	1	5	14	67	16	76
7 ton lorries and above	14	67	16	76	6	28	4	19
14 ton lorries and above	5	24	4	19	1	5	1	5
24 ton lorries and above	0	0	0	0	0	0	0	0
Total	22	100	21	100	21	100	21	100

Table 4.18: Mode of transportation for informal sites

Source: Field survey, March 2005

Of all the formal sites studied only 45% indicated that they were involved with transportation of materials themselves or in directing packaging and transportation process to minimize transportation costs, damage of materials, wastage and delays. Some of the ways they stated of achieving these included negotiation with transporters for good prices, supervision during loading and having their staff accompany the transport trucks. They also buy in bulk to minimize the transportation costs or benefit from "free" transport sometimes provided by the suppliers to those who buy in bulk.

For the informal sites only 9% indicated to having been involved in transportation and packaging of materials. Their way of involvement was similar to the formal sites (negotiation with transporters for good prices, supervision during loading and having their staff accompany the transport trucks). They also indicated having to buy from the nearest suppliers to minimize on transportation costs.

All the sites, formal and informal, indicated to having bought cement in the standard 50kg package. None bought in bulk for silo storage.

Transportation mode for the formal sites for ballast and sand was mainly by over 7 tones and over 14 tones lorries and for cement and steel was by pick ups and 7 tones and above lorries. 14 tones and above trucks were not commonly used for transportation of cement and steel for informal sites.

For the informal site, the transport mode for sand and ballast is also mainly over 7 tones and over 14 tones lorries, while cement and steel is by mainly pick up lorries/canters and over 7 tones lorries.

Only one site from the formal cluster indicated to be using ready mix concrete occasionally and the transportation method was transmixers.

4.2.7 Site materials management

Table 4.19 represents the outcome of the investigation on reasons that triggered the ordering of materials for both formal and informal sites.

Reasons for ordering materials	Site numbers and percentages					
	Formal		Informal		Combined	
	No.	%	No	%	No	%
Work schedule alone	2	9	1	5	3	7
Material shortage alone	3	14	2	10	5	12
Availability of funds	1	4	6	27	7	16
Shortage + work schedule	6	27	2	10	8	18
Shortage + funds	4	18	7	33	11	26
Work schedule + funds	3	14	1	5	4	9
Shortage + work schedule + funds	3	14	2	10	5	12
Total	22	100	21	100	43	100

Table 4.19: Reasons for ordering of materials for formal and informal

Source: Field survey, March 2005

Materials shortages seem to dominate the ordering of materials for formal sites with shortage alone, shortage plus work schedule, and shortage plus funds having a cumulative percentage of 59%.

For the informal sites, availability of funds dominate the ordering of materials with availability of funds and shortage plus funds giving a cumulative percentage of 60%.

Table 4.20 and 4.21 indicate the findings on storage of materials for both formal and informal sites respectively.

Storage of materials	Site numbers and percentages for materials							
	Ballast		Sand		Cement		Steel	
	No.	%	No	%	No	%	No	%
On site	20	91	20	91	22	100	22	100
Off site	2	9	2	9	0	0	0	0
Total	22	100	22	100	22	100	22	100

Table 4.20: Storage of materials for formal sites

Source: Field survey, March 2005

Storage of materials	Site numbers and percentages for materials							
	Ballast		Sand		Cement		Steel	
	No.	%	No	%	No	%	No	%
On site	21	100	21	100	21	100	21	100
Off site	0	0	0	0	0	0	0	0
Total	21	100	21	100	21	100	21	100

Table 4.21 Storage of materials for informal sites

Source: Field survey, March 2005

The study established that materials are mainly stored on site for both formal and informal with 91% of the formal sites storing most of the materials on site and 100% for the informal.

All the sites (both formal and informal) indicated to keeping some form of records for receiving and issuing of materials on site.

4.2.8 Quality management

Quality management is a component that should run through the entire materials management process. In this study the component was mainly examined under vendor selection, site management and site operations.

As already shown in table 4.11 under vendor selection, no site in both formal and informal was found to select its materials vendor (supplier) on the basis of the vendor having a quality control program.

Table 4.22 below shows the outcome on the investigation as to whether there was any written agreement on the quality standards of the materials purchased between the contractor/developer and the supplier/vendor.

Quality control	Site numbers and percentages					
	Formal		Informal		Combined	
	No.	%	No	%	No	%
Written standards on orders	7	32	0	0	7	16
No written standards	15	68	21	100	36	84
Total	22	100	21	100	43	100

Table 4.22: Quality control in purchasing
Source: Field survey, March 2005

Only 32% of the formal sites indicated to have some written standards/specifications for materials which are included or form part of the purchase order. However none of the informal sites included such standards in the purchasing of materials.

On whether they carried out any tests apart from physical examination on delivered materials to ensure that they are of the right quality, no site from both informal and formal clusters was found to carry out any examinations. Even for the water used for concreting there was no site found to carry out any test to ensure that the water was not contaminated.

Tables 4.23, 4.24, 4.25a and 4.25b indicate the outcome on investigation into methods of measuring the concrete ingredients, methods of mixing concrete and testing of concrete.

Measuring of ingredients	Site numbers and percentages					
	Formal		Informal		Combined	
	No.	%	No	%	No	%
Manual (wheelbarrows etc)	13	59	20	95	33	77
Batching boxes	8	36	1	5	9	20
Batching plant	1	5	0	0	1	3
Total	22	100	21	100	43	100

Table 4.23: Measuring of ingredients for concreting

Source: Field survey, March 2005

Mixing of concrete	Site numbers and percentages					
	Formal		Informal		Combined	
	No.	%	No	%	No	%
Manual (hand mixing)	0	0	3	14	3	7
Concrete mixers	21	95	18	86	39	90
Ready mix/transmixers	1	5	0	0	1	3
Total	22	100	21	100	43	100

Table 4.24: Mixing of concrete

Source: Field survey, March 2005

Testing for fresh concrete	Site numbers and percentages					
	Formal		Informal		Combined	
	No.	%	No	%	No	%
Slump test	3	14	0	0	3	7
No slump test	19	86	21	100	40	93
Total	22	100	21	100	43	100

Table 4.25a: Slump test for fresh concrete

Source: Field survey, March 2005

Testing for concrete	Site numbers and percentages					
	Formal		Informal		Combined	
	No.	%	No	%	No	%
Cube test	14	64	0	0	14	32
No cube test	8	36	21	100	29	68
Total	22	100	21	100	43	100

Table 4.25b: Cube test for concrete

Source: Field survey, March 2005

Measuring of concrete ingredients was mainly manual for both formal and informal sites at 59% and 95% respectively. However, 36% of the formal sites used batching boxes for measuring out. Mixing was mostly by concrete mixers with 95% for formal sites and 86% for informal. This could be attributed to the readily availability of concrete mixers for hire and the labour intensiveness that concreting requires. No testing of concrete, both slump test and cube test, was recorded for informal sites. However, only 14% of the formal sites indicated to carryout slump test compared to 64% for the cube test. The high percentage for cube test could be because this is sometimes a requirement in the formal contracts.

4.2.9 Wastage management

Tables 4.26a and 4.26b show findings on physical measurement of materials on delivery on site while table 4.27 shows the methods used in delivery of concrete in position both of which are indications of wastage control.

Physical measurement	Site numbers and percentages for materials							
	Ballast		Sand		Cement		Steel	
	No.	%	No	%	No	%	No	%
Measured	6	27	8	36	22	100	20	91
Not measured	16	73	14	64	0	0	2	9
Total	22	100	22	100	22	100	22	100

Table 4.26a: Measurement of materials for formal sites

Source: Field survey, March 2005

Physical measurement	Site numbers and percentages for materials							
	Ballast		Sand		Cement		Steel	
	No.	%	No	%	No	%	No	%
Measured	1	5	1	5	21	100	20	95
Not measured	20	95	20	95	0	0	1	5
Total	21	100	21	100	21	100	21	100

Table 4.26b: Measurement of materials for informal sites

Source: Field survey, March 2005

Delivery of concrete	Site numbers and percentages					
	Formal		Informal		Combined	
	No.	%	No	%	No	%
Manual (wheelbarrows, trays)	5	23	14	67	19	45
Hoists and cranes	17	77	7	33	24	55
Total	22	100	21	100	43	100

Table 4.27: Delivery of concrete into position

Source: Field survey, March 2005

Apart from cement and steel where over 90% of both formal and informal sites physically verified the quantities on purchase and delivery, there was very little verification for ballast and sand averaging just 5% for informal sites and 31.5% for formal sites.

Majority of the informal sites (67%) delivered their concrete into position manually. However for the formal sites the majority (77%) used hoists and cranes.

The method of measuring of concrete ingredients shown in table 4.23 under quality control and which is predominantly manual at 59%for formal sites and 95% for informal site also has influence on wastage of materials.

4.2.10 Surplus management

Tables 4.28 and 4.29 respectively show the causes of surplus and the use of surplus materials respectively on the sites investigated.

Causes of surplus	**Site numbers and percentages**					
	Formal		**Informal**		**Combined**	
	No.	%	No	%	No	%
Deliberate over ordering	9	41	4	19	13	30
Overestimating	9	41	7	33	16	37
Changes in design and specs	3	14	0	0	3	7
No surplus (shortage)	1	4	10	48	11	26
Total	22	100	21	100	22	100

Table 4.28: Causes of surplus

Source: Field survey, March 2005

Uses of surplus	Site numbers and percentages					
	Formal		Informal		Combined	
	No.	%	No	%	No	%
Used on alternative tasks/jobs	19	86	8	38	17	62
Returned to supplier	0	0	0	0	0	0
Sold to third party	0	0	2	9	2	5
Donated to others	2	9	1	5	3	7
No surplus (shortage)	1	5	10	48	11	26
Total	22	100	21	100	43	100

Table 4.29: Uses of surplus

Source: Field survey, March 2005

96% of all the formal sites and 52% of the informal sites experienced considerable surplus of materials during concreting. The causes of surplus were mainly deliberate ordering at 41% and 19% respectively for formal and informal sites; and overestimation at 41% and 33% respectively for formal and informal sites. The surplus materials were mainly used on alternative tasks/jobs at 86% for formal and 38% for informal sites.

4.3 Findings and analysis of dependent variable

The questionnaire also set out to establish the extent/level of materials attributes on all the sites studied. The findings and analysis are presented in this section.

4.3.1 Availability of materials

Materials availability was investigated in terms of the sites having right quantities of materials at any given time without having storage problems or work being delayed, suspended, stopped or work time extended due to shortage of materials or emergency purchases of materials. The findings are presented in tables 4.30a, 4.30b, 4.30c and 4.30d.

Storage problems	Number of sites and percentages					
	Formal sites		Informal sites		Combined	
	NO.	%	NO.	%	NO.	%
Storage problems	14	64	17	81	31	72
No storage problems	8	36	4	19	12	28
Total	22	100	21	100	43	100

Table 4.30a: Materials storage problems

Source: Field survey, March 2005

Material shortages	Number of sites and percentages					
	Formal sites		Informal sites		Combined	
	NO.	%	NO.	%	NO.	%
Shortages experienced	2	9	10	48	12	28
No shortage problems	20	91	11	52	31	72
Total	22	100	21	100	43	100

Table 4.30b: Stoppage or delay in work due to material shortages

Source: Field survey, March 2005

Emergency purchases	Number of sites and percentages					
	Formal sites		Informal sites		Combined	
	NO.	%	NO.	%	NO.	%
Emergency purchase	7	32	14	67	21	49
No emergency purchase	15	68	7	33	22	51
Total	22	100	21	100	43	100

Table 4.30c: Emergency purchases of materials

Source: Field survey, March 2005

Extended working hours	Number of sites and percentages					
	Formal sites		Informal sites		Combined	
	NO.	%	NO.	%	NO.	%
Extended	12	55	13	62	25	58
Finished on time	10	45	8	38	18	42
Total	22	100	21	100	43	100

Table 4.30d: Extended working hours during concreting

Source: Field survey, March 2005

Most of the sites experienced some form of storage problems for the materials with 64% and 81% for the formal and informal sites respectively. Materials shortages were experienced mostly on the informal sites at 48% and only 9% for the formal sites. However, both formal and formal sites were involved in emergency purchases at considerably high rates of 32% and 67% respectively. Extended working hours for concreting works was prevalent on both formal and informal sites at 55% and 62% respectively.

4.3.2 Wastage of materials

The study investigated wastage of materials by establishing the occurrence of theft of materials, damage and deterioration of materials on sites. The results are shown in tables 4.31a and 4.31b.

Theft of materials	Number of sites and percentages					
	Formal sites		Informal sites		Combined	
	NO.	%	NO.	%	NO.	%
Theft experienced	5	23	9	43	14	33
No theft experienced	17	77	12	57	29	67
Total	22	100	21	100	43	100

Table 4.31a: Theft of materials on sites

Source: Field survey, March 2005

Damage and deterioration	Number of sites and percentages					
	Formal sites		Informal sites		Combined	
	NO.	%	NO.	%	NO.	%
Experienced	4	18	5	24	9	21
Not experienced	18	82	16	76	34	79
Total	22	100	21	100	43	100

Table 4.31b: Damage of materials on site

Source: Field survey, March 2005

Theft of materials was fairly high on informal sites at 43% compared to 23% for the formal while damage and deterioration was fairly low at 24% and 18% for the informal and formal sites respectively. The method of measuring of concrete ingredients, the method of placement of concrete and controls in transportation were also considered to have contributed to wastage of materials on site though they have been discussed elsewhere in the study.

Wrongful purchase of materials (including wrongful purchase due to discrepancy and changes in specifications) and condemnation of materials and works (leading to repeat works and repurchasing of materials) also were considered to contribute to wastage of materials. However, they are discussed under quality of materials.

4.3.3 Quality of materials

Issues of quality of materials were investigated and discussed extensively under quality management (section 4.1.8). The absence of a quality management system on any site inferred that the site had a likelihood of not having quality materials. Wrongful purchase of materials and condemnation of materials and works though contributing heavily to wastage, are considered under quality of materials (tables 4.32a and4.32b).

Wrongful purchase	Number of sites and percentages					
	Formal sites		Informal sites		Combined	
	NO.	%	NO.	%	NO.	%
Experienced	6	27	6	29	12	28
Not experienced	16	73	15	71	31	72
Total	22	100	21	100	43	100

Table 4.32a: Wrongful purchase of materials

Source: Field survey, March 2005

Condemnation	Number of sites and percentages					
	Formal sites		Informal sites		Combined	
	NO.	%	NO.	%	NO.	%
Experienced	8	36	0	0	8	18
Not experienced	14	64	21	100	35	82
Total	22	100	21	100	43	100

Table 4.32b: Condemnation of materials and works

Source: Field survey, March 2005

27% of the formal and 29% of the informal sites were found to have experienced some form of wrongful purchase of materials while 36% of the formal sites indicated to have experienced condemnation of materials and works either by themselves (through wrongful supply) or by the consultants. No informal site indicated to have experienced any condemnation, though this could me attributed to lack of quality control and absence of formalized supervision and consultants on informal sites.

4.3.4 Surplus materials

The study investigated the existence of surplus materials particularly from the concreting process, table 4.33.

Surplus of materials	Number of sites and percentages					
	Formal sites		Informal sites		Combined	
	NO.	%	NO.	%	NO.	%
Surplus	20	91	11	52	31	72
No surplus	2	9	10	48	12	28
Total	22	100	21	100	43	100

Table 4.33: Surplus materials

Source: Field survey, March 2005

Surplus of materials was mainly experienced on formal sites at 91% while on informal sites it was 52%.

4.3.5 Cost of materials

The investigation and measurement of this component of the dependent variable was fairly subjective and was based on the findings of various aspects of the study including the processes of vendor section and occurrence of emergency purchases of materials.

4.4 Measurement of variables

Each of the components of the variables (ten components for the independent variable and five components for the dependent variable) was measured on an ordinal scale. Thus based on the responses and analysis of the questionnaire, every site was given a score of either zero (0) or one (1) for each of the components to indicate its performance in that aspect. The cumulative score for each variable was assumed to form an interval scale and hence a measure of the performance of each site in that variable.

Therefore a site that was excellent in all aspects of materials management would score a total of ten (10) in the independent variable (extent of management) while the poorest would score zero (0) in this variable. Likewise an excellent site in all aspects of the dependent variable (extent of materials attributes) would score five (5) the poorest would score zero (0) in this attribute. The outcome is shown in tables 4.34a and 4.34b.

Component of variable	**Number of sites and percentages with score of one (1)**					
	Formal sites		**Informal sites**		**Combined**	
	NO.	%	NO.	%	NO.	%
Planning, organizing & staffing	10	45	6	28	16	36
Materials take off	4	18	4	19	8	18
Vendor selection	12	54	9	43	21	48
Purchasing	9	41	6	28	15	34
Expediting	16	72	10	48	26	60
Transportation	10	45	5	24	15	34
Site management	10	45	10	48	20	45
Quality management	10	45	10	48	20	46
Wastage management	11	50	9	42	20	46
Surplus management	9	40	13	62	22	51

Table 4.34a: Scoring for independent variable

Source: Field survey, March 2005

Component of variable	**Number of sites and percentages with score of one (1)**					
	Formal sites		**Informal sites**		**Combined**	
	NO.	%	NO.	%	NO.	%
Availability	14	64	8	38	22	51
Minimal wastage	8	36	6	28	14	32
Right quality	7	32	5	24	13	28
Minimal surplus	9	40	10	48	19	44
Right cost	7	32	5	24	12	28

Table 4.34b: Scoring for dependent variable

Source: Field survey, March 2005

According to the summary of site scoring expediting was ranked as the task that was well managed will 60% of the sites studied excelling (scoring one) in this aspect of management. It was followed by surplus management at 51%. The worst performed management component was materials take off with only 18% of the sites studied excelling in this aspect. It was followed by purchasing at 34%.

In terms of attributes, availability of materials was the most observed/recorded with 51% of the sites studied excelling in this component. The attributes that were least observed/recorded, were right quality and right cost where only 28% of the sites studied excelled in these attributes respectively.

4.5 Statistical analysis and hypothesis testing

Table 4.35 below is a summary of the scorings for both level of materials management and materials attributes for all the 43 sites studied. These scorings were then used for various inferential statistical analysis and hypothesis testing.

Site number	Level of materials management	Level of materials attributes
1	2	1
2	4	1
3	3	1
4	5	2
5	7	3
6	5	2
7	5	2
8	3	1
9	7	3
10	5	2
11	6	2
12	5	2
13	8	3
14	5	2
15	3	1
16	5	2
17	6	2
18	3	1
19	5	2
20	8	3
21	9	3
22	6	2
23	7	2
24	8	3
25	3	1
26	5	2
27	4	1
28	3	1
29	5	2
30	4	1
31	2	1
32	5	3
33	6	2
34	3	1
35	5	2
36	6	2
37	6	2
38	2	1
39	5	2
40	7	2
41	3	1
42	5	1
43	4	1

Table 4.35: Summary of scorings for all the sites

Source: Field survey, March 2005

As outlined elsewhere in this study, each of the sites was ranked on a scale of ten for level of materials management and on scale five for materials attributes. Scores for each of the sites are as indicated in table 4.35. Table 4.36 below shows the mean, median, mode and standard deviation for both variables (level of materials management and level of materials attributes).

		Level of materials management	Level of materials attributes
N	Valid	43	43
	Missing	0	0
Mean		4.95	1.79
Median		5.00	2.00
Mode		5	2
Std. Deviation		1.75	.71
Sum		213	77
Percentiles	25	3.00	1.00
	50	5.00	2.00
	75	6.00	2.00

Table 4.36: Descriptive statistics

Source: Field survey, March 2005

The mean score for materials management was 4.95 (out of ten) while that for materials attributes was 1.79 (out of five). The median score was 5 and 2 respectively for materials management and materials attributes respectively. These were the same scores for the mode respectively.

Frequency tables

Tables 4.37a and 4.37b are frequency tables for the scorings for the sites for the two variables under study.

	Score	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	3	7.0	7.0	7.0
	3	8	18.6	18.6	25.6
	4	4	9.3	9.3	34.9
	5	14	32.6	32.6	67.4
	6	6	14.0	14.0	81.4
	7	4	9.3	9.3	90.7
	8	3	7.0	7.0	97.7
	9	1	2.3	2.3	100.0
	Total	43	100.0	100.0	

Table 4.37a: Frequency table for level of materials management

Source: Field survey, March 2005

	Score	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	16	37.2	37.2	37.2
	2	20	46.5	46.5	83.7
	3	7	16.3	16.3	100.0
	Total	43	100.0	100.0	

Table 4.37b: Frequency table for level of materials attributes

Source: Field survey, March 2005

Frequencies provide statistics that are useful for describing variables. For a frequency report, distinct values are arranged in ascending order or categories ordered by their frequencies. From these tables it can be deduced that majority of the sites, 67.4% scored 5 and below in materials management, while only 32.6% scored 6 and above in materials management. No site scored 10, the maximum score in management while only one site scored 9 in management representing only 2.3% of the sites.

In the component materials attributes, 83.7% of the sites scored 2 and below while only 16.3% of the sites scored 3. None of the sites studied scored 4 or 5 (the maximum score).

Figures 4.1a and 4.1b below are graphical presentations of frequency tables for both materials management and materials attributes.

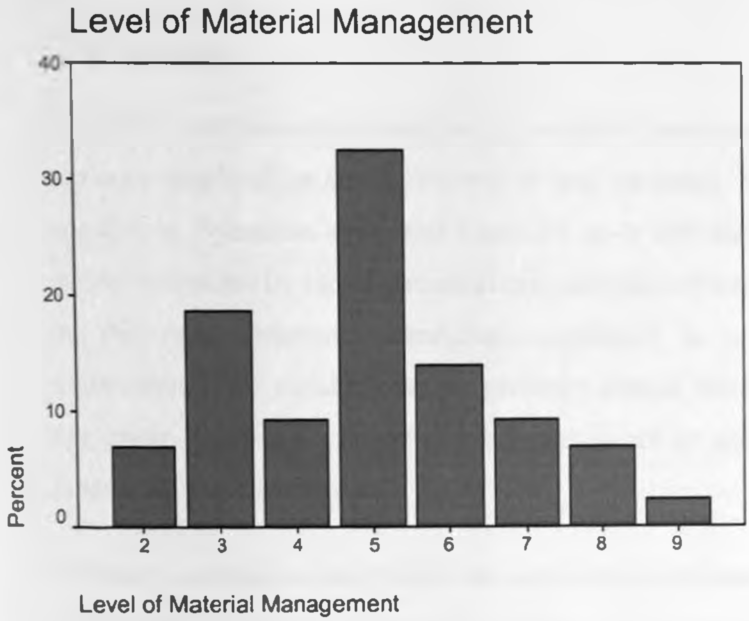


Figure 4.1a: Frequency graph for materials management

Source: Field survey, March 2005

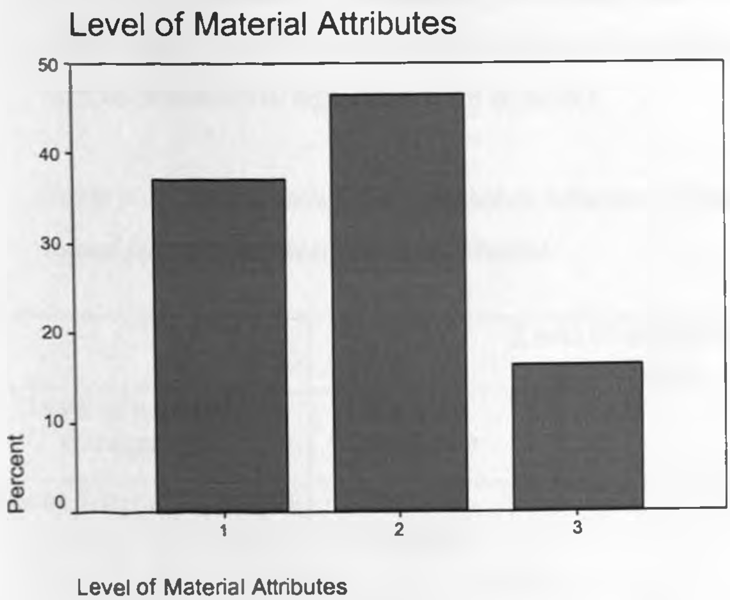


Figure 4.1b: Frequency graph for materials attributes

Source: Field survey, March 2005

The frequency graphs for both materials management and materials attributes tend towards normal distribution curves.

Correlations

Regression and correlation analysis (also called "least squares" analysis) helps examine relationships among interval or ratio variables. Pearson's correlation coefficient, Spearman's rho, and Kendall's tau-b with their significance levels can be computed by use of statistical data analysis software such as SPSS used in this case. Pearson's correlation coefficient is a measure of linear association. Two variables can be perfectly related, but if the relationship is not linear, Pearson's correlation coefficient is not an appropriate statistic for measuring their association.

Pearson's correlation coefficient was computed in this case basing on the fact that the data is not badly skewed. If the data were ordinal or badly skewed, the Kendall's tau-b or the Spearman,s coefficients would be computed instead. To predict the direction of the relationships in questions (with variables expected to be positively or negatively correlated) the "Two-tailed for Test of significance" is used. (Note: Since the data was for population rather than sample, measures of significance are ignored.)

Table 4.38 below shows the correlation between materials management and materials attributes from the data collected.

		Level of materials management	Level of materials attributes
Level of materials management	Pearson Correlation	1.000	.877
Level of materials attributes	Pearson Correlation	.877	1.000

Table 4.38: Correlation between materials management and materials attributes

Source: Field survey, March 2005

The level of materials attributes has a very strong correlation (0.877) with the level of materials management, which is statistically significant at the 0.01 level (that is, it would occur by change less than one time in a hundred).

Thus the hypothesis of the influence of level of materials management with level of materials attributes is supported.

Regression and regression lines

Linear regression estimates the coefficients of the linear equation involving one or more independent variables that best predict the value of the dependent variable. Tables 4.39a and 4.39b are regression tables generated from statistical operations on the data while figure 4.2 is the regression in graphical form (regression line).

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	16.244	1	16.244	136.676	.000
	Residual	4.873	41	.119		
	Total	21.116	42			

a Predictors: (Constant), Level of materials management

b Dependent Variable: Level of materials attributes

Table 4.39a: Anova regression table

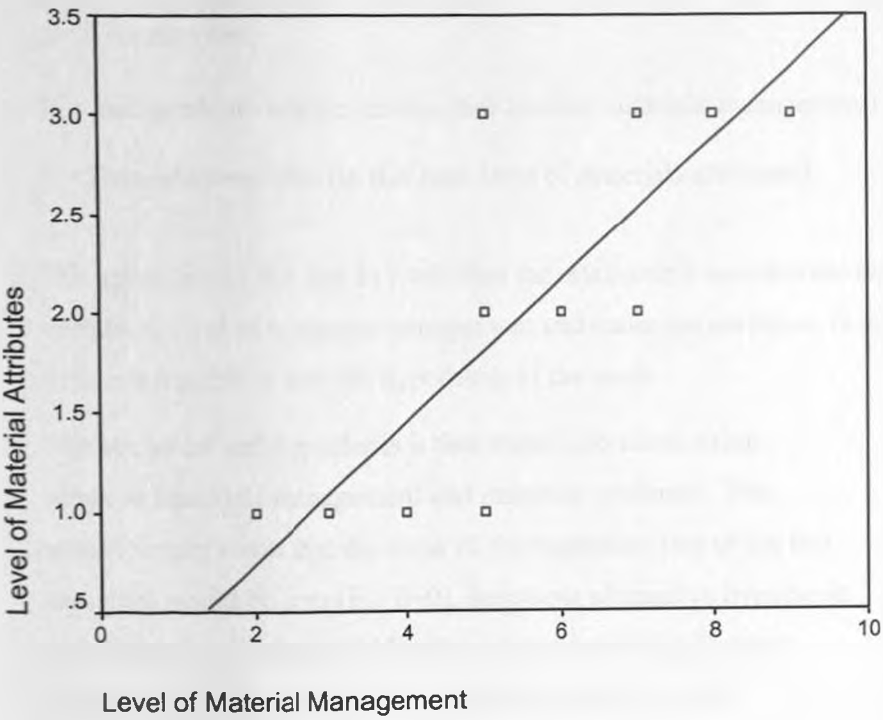
Source: Field survey, March 2005

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta		
1	(Constant)	2.545E-02	.160		.159	.874
	Level of Material Management	.356	.030	.877	11.6 91	.000

a Dependent Variable: Level of materials attributes

Table 4.39b: Coefficients of correlation

Source: Field survey, March 2005



REGRESSION LINE; Y=M0.356+2.545E-02

Figure 4.2: Regression on level of materials management and level of materials attributes
Source: Field survey, March 2005

For the regression line, most of the points fall fairly close to the line but a few do not. The vertical distance between the point and the line is called the residual, the difference between the actual value of the dependent variable and the value "predicted" by the least squares equation represented by the line. One may need to identify some of the "outliers" (cases with high residuals) and remove them but was not necessary in most of the cases.

More information about the regression line can be gotten by obtaining the equation of the line in form of Y =MX+C, where;

C=Constant (i.e., the Y intercept) = 2.545E-02 (can also be read from the coefficients table)

M=B (un standardized coefficient) = 0.356 (can also be read from coefficients table)

X = Independent variable (in this case level of materials management)

Y= Dependent variable (in this case level of materials attributes)

The reliability of this line in predicting the relationship between the two variables, level of materials management and materials attributes, is tested. This relationship is also the hypothesis of the study.

The statistical null hypothesis is that there is no relationship between materials management and materials attributes. This would simply mean that the slope of the regression line of the two variables would be zero (H_o: ß=0), hence our alternative hypothesis (the research hypothesis) is that there is a relationship between materials management and materials attributes (H_A: ß≠0).

We test this at 95% confidence level (α=0.05 and 41 degrees of freedom). The table value is 2.0452. When H_o is true the test statistic is distribute as student's t with n-2 degrees of freedom.

The null hypothesis is thus rejected if the computed value of t is either greater than or equal to 2.0452 or less than or equal to -2.0452 (obtained by interpolation).

The statistic is computed as $t = b - \beta_o / S_b$. The values of b and S_b are 0.356 and 0.030 respectively (also read from coefficients table).

Thus t=0.356/0.030=11.87

Thus Ho is rejected because 11.87 >2.0452

It can then be conclude that the slope of the true regression line is not zero and that there is a relationship between materials management and materials attributes which is statistically significant at the 0.01 level (that is, it would occur by change less than one time in a hundred {p<0.01}.

Comparison between formal and informal sites

Statistical comparison of formal and informal sites has been carried out as indicated in tables 4.40, 4.41a, 4.41b, 4.41c and 4.41d below.

		Materials Attributes Formal	Materials Attributes-Informal	Materials Manageme nt-Formal	Materials Manageme nt-Informal
N	Valid	22	21	22	21
	Missing	0	0	0	0
Mean		1.95	1.64	5.23	4.64
Std. Error of Mean		.15	.14	.39	.35
Median		2.00	2.00	5.00	5.00
Mode		2	1	5	5
Std. Deviation		.72	.66	1.82	1.62
Skewness		.069	.547	.251	.212
Std. Error of Skewness		.491	.491	.491	.491
Kurtosis		-.929	-.528	-.326	-.470
Std. Error of Kurtosis		.953	.953	.953	.953
Sum		43	36	115	102
Percentiles	25	1.00	1.00	3.75	3.00
	50	2.00	2.00	5.00	5.00
	75	2.25	2.00	6.25	6.00

Table 4.40: Comparative statistics between formal and informal sites

Source: Field survey, March 2005

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	4.5	4.5	4.5
	3	4	18.2	18.2	22.7
	4	1	4.5	4.5	27.3
	5	8	36.4	36.4	63.6
	6	3	13.6	13.6	77.3
	7	2	9.1	9.1	86.4
	8	2	9.1	9.1	95.5
	9	1	4.5	4.5	100.0
	Total	22	100.0	100.0	

Table 4.41a: Frequency table for level of materials management for formal sites

Source: Field survey, March 2005

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	2	9.5	9.5	9.5
	3	4	19.0	19.0	28.5
	4	3	14.3	14.3	42.8
	5	6	28.6	28.6	71.4
	6	3	14.3	14.3	85.7
	7	2	9.5	9.5	95.2
	8	1	4.8	4.8	100.0
	Total	21	100.0	100.0	

Table 4.41b: Frequency table for level of materials management for informal sites

Source: Field survey, March 2005

		Frequency	Percent	Valid Percen	Cumulative Percent
Valid	1	6	27.3	27.3	27.3
	2	11	50.0	50.0	77.3
	3	5	22.7	22.7	100.0
	Total	22	100.0	100.0	

Table 4.41c: Frequency table for materials attributes for formal sites

Source: Field survey, March 2005

		Frequency	Percent	Valid Percer	Cumulative Percent
Valid	1	10	47.6	47.6	47.6
	2	9	42.9	42.9	90.5
	3	2	9.5	9.5	100.0
	Total	21	100.0	100.0	

Table 4.41d: Frequency table for materials attributes for informal sites

Source: Field survey, March 2005

The mean score for level of materials management for the formal sites is 5.23 while that of informal sites is 4.64. The mean score for level of materials attributes is 1.95 and 1.64 for formal and informal sites respectively. The mode score for level of management is 5 for both formal and informal sites while the mode score for materials attributes is 2 and 1 for formal and informal sites respectively. 63.6% of all the formal sites studied scored 5 and below in level of materials management while 71.4% of all the informal sites studied scored 5 and below in level of materials management. Most of the sites studied scored 2 and below in level of materials attributes with 77.3% for the formal and 90.5% for the informal sites.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The aim of this study is to improve the level of materials management and materials attributes on construction sites and thus enhance general project performance. Inadequate materials management was hypothesized as the cause of apparent poor materials attributes on construction sites. Objectives were also set out at the beginning along which the research was to be carried out. The related literature has been reviewed and data collected from the field and analyzed.

This chapter therefore outlines the researcher's conclusions and recommendations based on the findings of the study.

However, it is worth noting that this research had several limitations as outlined in chapter one. The conclusions and recommendations should therefore be looked at in respect to the limitations.

5.2 Findings on study objectives

The main objective of this study was to establish the extent of materials management on construction sites (both formal and informal).
The extent of materials management was established by examining the performance of materials management activities on the construction sites studied. Ten functions of materials management that also formed the components of the independent variable were examined for every site.

From the findings of this study, fairly little effort is put towards planning, organizing and staffing for materials on construction sites. Only 45% of the formal sites and 28% of the informal sites studied were found to have what can be considered as reasonable materials organization, planning and staffing.

Though materials take off is vital in determining the volumes of the materials to be purchased throughout the construction process, only 18% of the formal sites and 19% of the informal sites studied were found to be sufficiently involved in this process. Most of the formal sites (86%) basically relied on the contract bills of quantities, which are not prepared by the contractor/developer. While for the informal sites, the majority of the sites (48%) did not have any organized way of estimating for the materials.

The study found that there is no systematic criterion for selecting materials suppliers on most of the sites. The criterion used to select the suppliers on most of the sites is not professional and in the opinion of the researcher, it does not give the contractors/developers value for their money. Only 54% of the formal sites and 43% of the informal sites were found to select their suppliers through a competitive process.

41% of the formal sites and 28% of the informal sites studied were found to have purchased their materials in a very casual manner, without any proper documentation or contracts. This can be a source of problems in trying to enforce the purchase contracts incase of disputes.

Though 72% of the formal sites and 48% of the informal sites were found to exercise some form of follow up on materials orders, this was mainly done when there was a problem or anticipated problem. Ideal expediting should be systematic and run through the entire process of materials procurement.

Minimal participation of contractors/developers in the materials transportation process was established. Only 45% of the formal sites and 24% of the informal sites studied were directly involved in managing the materials transportation process.

The study set criteria for examining sound site materials management, quality management, wastage management and surplus management. Based on the set criteria, 45% of the formal sites and 48% of the informal sites studied had good site management. 45% of the formal sites and 48% of the informal sites were considered to have good quality control practices. 50% of the formal sites and 42% of the informal sites studied practiced what could be considered as good surplus management, while 40% of the formal sites and 62% of the informal sites had good wastage management.

Though the various aspects of materials management were experienced with varying degrees from site to site, a systematic and integrated approach to all the management functions was missing. There was no site that had an integrated materials management plan. Computer software was not used in the management of materials on all the sites studied.

With all the ten aspects of materials management considered for all the sites studied, the mean score was found to be 4.95 out of a maximum of ten for the variable management. This comprised of a mean score of 5.23 out of ten for the formal sites and 4.64 out of ten for the informal sites. Of all the sites studied, 67.4% of the sites scored 5 and below in level of materials management which can be considered to be below average. Of all the formal sites studied, 63.6% scored 5 and below while 71.4% of the informal sites scored 5 and below.

The second objective of the study was to establish the extent of materials attributes on construction sites. Various aspects of materials attributes were considered.

Out of all the sites studied, 64% of the formal sites and 81% of the informal sites were found to have either experienced some storage problems for materials or increased costs associated with storage of materials. Shortage of materials when needed was experienced on 9% of the formal sites and 48% of the informal sites. 32% of the formal sites and 67% of the informal sites studied undertook some form of emergency purchases during the concreting process. The concreting process experienced extended working hours on 55% of the formal sites and 62% of the informal sites studied. There was rescheduling/stoppage of concreting on 9% of the formal sites and on 19% of the informal sites as a result of lack of materials. On average, materials were available when needed and in right quantities on 64% of the formal sites and 48% of the informal sites.

Wastage of materials through theft was experienced at 23% for the formal sites and 43% for the informal sites, while wastage through damage and deterioration was experienced on 18% of the formal sites and 24% of the informal sites. 59% of the formal sites and 95% of the informal sites were involved in poor working methods that could increase wastage of materials.

Quality problems were experienced on 32% of the formal sites and 24% of the informal sites. However, 27% of the formal sites and 29% of the informal sites experienced wrongful purchases of materials. 36% of the formal sites experienced condemnation of works and materials by consultants. Though no informal site experienced condemnation of materials and works by consultants, the same could be attributed to limited involvement of consultants on informal sites.

91% of the formal sites and 52% of the informal sites studied were established to have experienced what could be considered as unplanned surplus materials.

Based on the criteria established to examine whether materials were acquired at reasonable cost, 32% of the formal sites and 24% of the informal sites studied may not have acquired materials at what could be considered as reasonable cost.

The various aspects of materials attributes were grouped into five categories namely materials availability, minimal wastage, right quality, minimal surplus and reasonable cost. The five formed the components of the dependent variable. The mean score for all the sites studied was 1.79 out of five. The formal sites had a mean score of 1.95 out of five and the informal sites had a mean score of 1.64 out of five. Of all the sites studied, 83.7% of them scored 2 and below in the level of materials attributes. 77.3% of the formal sites scored 2 and below while 90.5% of the informal sites scored 2 and below.

The third and final objective of the study was to find out whether there existed a realistic relationship between the extent of materials management and materials attributes. This was also the study hypothesis. SPSS (Statistical Programme for Socio- Scientific Data Analysis) software was used to test the hypothesis. From the correlation and regression analysis, the relationship was found to exist and the hypothesis supported. The correlation between level of materials management and materials attributes was 0.877.

5.3 Conclusions

From the findings and analysis of this study, it can be concluded that the extent of materials management on construction sites is fairly poor. The situation is more severe on informal sites.

Again based on the findings and analysis of the study it can also be concluded that the extent of materials attributes on construction sites is poor. The attributes are relatively bad on the informal sites compared to the formal sites.

Based on correlation and regression analysis, and hence hypothesis testing inadequate materials management on construction sites can be said to be the cause of poor materials attributes on construction sites. The outcome of hypothesis testing confirmed that at 95% confidence level (α=0.05 and 41 degrees of freedom). The outcome is supported with strong correlation (0.877) between level of materials management and materials attributes. This is statistically significant at 0.01 level (that is it would occur by chance less than one in a hundred times). Therefore inadequate materials management results in poor materials attributes on construction sites. This outcome can now be generalized to the whole population and thus apply to all construction sites in Kenya.

The implication of the findings is that construction sites in Kenya will continue to experience poor materials attributes unless adequate materials management is enhanced.

The study concludes that proper project planning, use of qualified personnel with adequate training and enhanced site management is lacking on formal sites despite these aspects being very essential for effective materials management.

For the informal sites, the study further concludes that materials management functions are carried out in a very rudimentary and subjective manner, without being considered as an essential aspect of the project. The personnel involved also lack the necessary training.

5.4 Recommendations

1). From the findings of the study, only 45% of the formal sites had some form of planning for materials. Only 14% of the formal sites had an integrated materials management plan. A systematic and integrated approach is therefore needed to manage materials and minimize the costs associated with poor materials management. All materials management functions should be well integrated and not performed in isolation since they are interrelated and their performance affects each other. It is therefore necessary to have an integrated materials management plan at the beginning of the project and the plan should span through out the project and be updated as the project progresses.

   Only 28% of the informal sites had some form of planning for materials. However, 48% of the informal sites experienced materials shortages and 67% of the informal sites were involved in emergency purchases of materials. Though a fully integrated materials management planning may not be viable for the informal sites, some form of forward planning for materials is necessary to avoid the costs associated with lack of it.

2). The study established that despite the advancement and widespread use of computer software globally in materials management, the same is not used in the local industry in materials management. On the formal sites only charts and tables were used (at 86%) and none of them was found to use computer software. The study recommends enhanced use of computers in management of materials since they can easily be used in the planning and monitoring of materials management. Codification of the materials should also be encouraged to make use of computers effective. However, given the costs associated with computer software, its use may not be viable for informal construction which are mainly of modest value and a one off affair (the developer may not have another project in a long time to reuse the software).

3). 72% of those involved with materials management on formal sites had formal training. However, only 36.4% of the formal sites were considered to have performed fairly well in materials management. Despite a great number of personnel involved in the management of materials having formal training, they lack specialized training in management of materials. Training should therefore be enhanced even if it is through focused seminars targeting materials managers or by developing a materials management handbook.

For the informal sites only 42% of those involved in materials management had formal training and mostly intermediate college training. Only 28.6% of the informal sites were considered to have performed fairly well in materials management. The study therefore recommends that the informal developers should be encouraged to use trained personnel on their sites in order to improve on materials management.

4). In formal construction, cost, time and quality are mainly used to measure performance of projects. By extension, this would also be an indicator of good materials management. The three parameters are mainly important for the client. However considering that on most of the contracts the client only pays for the net materials used, it may be important for contractors to be encouraged to use other indices like materials management to measure their performance.

5). This study established that most of the construction process for both formal and informal sites is carried out on site. This involves a lot of site handling of materials leading to challenges in materials management. Use of in time construction like precasting of concrete components off the site and use of ready mix concrete would minimize handling of materials on site. Subcontracting of various work components would also minimize the burden of materials management.

6). For both formal and informal sites, the study established that there was very little effort towards quality management of materials. Since materials contribute a lot to the overall quality of the projects, quality management for materials should be enhanced.

5.5 Suggested areas of further study

1. Development of materials management model appropriate for the Kenyan construction industry.
2. Appropriate materials management training for the industry.
3. Research in developing an appropriate materials management performance measurement index and other associated indices for the Kenyan construction industry.
4. Improvement in procurement and performance of informal construction.

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APPENDIX A

P.O. BOX 2379-00100
NAIROBI
14/02/05

Dear Respondent

The author of this letter and questionnaire is a graduate student in the department of building economics and management of the University of Nairobi, and is conducting a research on materials management on construction sites in Nairobi.

The research is part fulfillment for the award of the degree of Master of Arts in Construction Management.

The Objective of the research is to evaluate the level of materials management on construction sites in Nairobi.

Your site has been selected out of the accessible active sites to provide the information needed in this study. Your experience presents the experiences of many others participating in the construction process in Kenya.

Kindly provide the information required by helping complete the questionnaire.
The information will be used for research purposes only and will remain confidential as well as your identity.

Your assistance shall be highly appreciated.

Yours faithfully

Asienga J. Ebole

APPENDIX B

QUESTIONNAIRE FOR CONSTRUCTION SITES

BY

ASIENGA J. EBOLE

DEPARTMENT OF BUILDING ECONOMICS AND MANAGEMENT

UNIVERSITY OF NAIROBI

DECLARATION:

THE INFORMATION COLLECTED THROUGH THIS QUESTIONNAIRE SHALL BE TREATED AS CONFIDENTIAL.

Your assistance in the completion of this questionnaire will be highly appreciated

Questionnaire No...

Enumerator..

Date...

Location of Site ....

Description of Project...

INSTRUCTIONS

Please tick (√) the appropriate answer and give reasons or explanations where necessary. **<u>More than one answer may be ticked</u>** where applicable.

QUESTIONNAIRE

1. (i) Type of Construction Site
   - ☐ Formal (Contractor)
   - ☐ Informal (Self Build)

   (ii) Value of the construction in Kshs……………………………………………

2. (i) If formal, what type of contract is used?
   - ☐ Traditional (Design separate from construction)
   - ☐ Design and Build (contractor same as designer)
   - ☐ Build Operate and Transfer (BOT)
   - ☐ Labour Contract
   - ☐Others (specify)………………………………………………………….

   (ii) What is the class of the contractor? …………………………………………

3. (i) What is the title/position in the project/company is the person responsible for overall materials management functions?

   ……………………………………………………………………………………

   (ii) What is his/her level of training?
   - ☐ University Technical Degree
   - ☐ Polytechnic diploma
   - ☐ Technical College Certificate
   - ☐ No Technical Training
   - ☐ Others (specify) ………………………………………………

   (iii) Any specific training in materials management?

   ……………………………………………………………………………………

   (iv) What is the total number of staff involved in the management of materials on the project? ……………………………………………………

4. (i) Is there a materials Management plan for the project
   - ☐ Yes
   - ☐ No

   (ii) If Yes at what point was it formulated?
   - ☐ After completion of design and award of contract
   - ☐ Before completion of design and award of contract

   (iii) What does the plan contain? ……………………………………

   ……………………………………………………………………

   (iv) If No, how are the materials acquired? …………………………

   ……………………………………………………………………

5. (i) For the contractors, are all the materials management activities carried out from the site or both site and company office.
   - ☐ Site
   - ☐ Both Site and Company Office

   (ii) If both site and company office, then how is communication done between the site and the offices? ……………………………………

   ……………………………………………………………………………

6. (i) What is the title/position of the person responsible for the materials take off/estimation? ....
   (ii) What are his/her qualifications? ....
   (iii) At what point in the project was the materials take off done? ....
   ....

7. How was the supplier for each of the materials identified?

Identification of supplier	Ballast	Sand	Cement	Steel	Ready mix Conc.
Open tendering					
Introduction by third party					
Marketing by suppliers salesmen					
Contractor same as supplier (own supply)					
Others (specify)					

8. For each of the materials, how many suppliers were identified?

Material	No. of Vendors
Ballast	
Sand	
Cement	
Steel	
Ready mix concrete	

9. Which of the following was used in the selection of vendor/supplier for the materials?

Criteria for selection of supplier	Ballast	Sand	Cement	Steel	Ready mix concrete
Past Success with supplier					
Good Price					
Geographical location					
Credit offer					
Quality assurance programme					
Bargaining agreement					
Schedule adherence					

10. For each of the materials, how are the orders placed?

Placement of orders	Ballast	Sand	Cement	Steel	Ready mix conc.
Telephone					
Written order					
Verbally through agents					
Others (specify)					

11 (i) Are there any written agreements with the suppliers on quantity, quality, price, delivery time and place of delivery for the materials before they were supplied?

- ☐ Yes
- ☐ No

(iii) Is any testing of quality apart from physical examination carried out on materials on delivery?

- ☐ Yes
- ☐ No

(iv)Is there any physical measurement/counting of quantities of material at purchasing and delivery on site?

Physical measurement	**Ballast**	**Sand**	**Cement**	**Steel**	**Ready mix conc.**
Yes					
No					

(iv)If no, how do you ensure that the right quantity and quality of materials are supplied at the right time and place? ....
....

12 (i) Once the materials are ordered are any follow ups made with the suppliers to ensure that deliveries are made correctly?

- ☐ Yes
- ☐ No

(ii) If yes, what form of follow up ....
....

13 (i) Are there any disagreements with the suppliers from any of the sources outlined below for the respective materials?

Source of disagreement	**Ballast**	**Sand**	**Cement**	**Steel**	**Ready mix conc.**
Price					
Quality					
Quantity					
Time of delivery					
Damage of materials					
Others (specify)					

(ii) How are the disagreements settled? ....
....

14 What activates the ordering of the materials?

- ☐ Shortage
- ☐ Work Schedule
- ☐ Availability of funds
- ☐ Others, specify..

15 (i) Were you involved in the transportation of materials to site?

- ☐ Yes
- ☐ No

(ii) How do you ensure that you minimize transportation costs, damage, wastage and delay of materials associated with transportation? ....
....

16 (i) Are any special arrangements made for packaging of any of the materials?

- ☐ Yes
- ☐ No

(ii) How is cement delivered?

- ☐ 50 kg packs
- ☐ In bulk for silo storage

17. How are the materials delivered on site?

Method of delivery	**Ballast**	**Sand**	**Cement**	**Steel**	**Ready made concrete**
Pick up loads					
7 ton lorries and above					
14 ton lorries and above					
24 ton lorries and above					
Transmixers					
Others (specify)					

18. (i) How are the materials stored?

Storage	**Ballast**	**Sand**	**Cement**	**Steel**
Silos				
Stores				
Yards on site				
Central yard off site				
Others (specify)				

(ii) Were any storage problems (in adequate storage) experienced on site?

- ☐ Yes
- ☐ No

19. Are any recordings done for receiving, storing and issuing of materials for use?

- ☐ Yes
- ☐ No

20. (i) Was the latest/most recent major concreting work done as scheduled?

- ☐ Yes
- ☐ No

(ii) If no, what caused the delay..
....

(iii) Were there any emergency purchases of materials during concreting?

- ☐ Yes
- ☐ No

21. (i) How are the concrete ingredients measured out before mixing of concrete?

- ☐ Manual (wheelbarrows, spades, trays etc)
- ☐ Batching box
- ☐ Batching plant/equipment
- ☐ Ready mix concrete used
- ☐ Others (specify)...

(ii) How is the concrete mixed?

- ☐ Hand mixed
- ☐ Concrete mixers
- ☐ Batching plant/equipment
- ☐ Ready mix concrete used
- ☐ Others (specify)...

(iii) Is any testing for quality carried out on the freshly mixed concrete before pouring?

- ☐ Yes
- ☐ No

(iv) If Yes which test is carried out ....

(v) Which method is used to deliver the mixed concrete into position/formwork?

- ☐ Wheelbarrows and trays (manual)
- ☐ Pumps
- ☐ Hoists
- ☐ Cranes

22. (i)How much surplus was experienced for each of the following materials during the concreting? Express in quantities.

Material	Surplus
Cement	
Sand	
Ballast	
Steel	
Ready mix conc.	

(ii) Where there was surplus, what was the cause of surplus?

Cause of surplus	Ballast	Sand	Cement	Steel	Ready mix conc.
Deliberate over ordering					
Overestimation					
Changes in design					
Changes in specifications					
Others (specify)					

(iii) How was the surplus for each of the materials used?

Cause of surplus	Ballast	Sand	Cement	Steel	Ready mix conc.
Used on alternative jobs/tasks					
Returned to the supplier					
Sold to third party					
Others (specify)					

(iv) What measures are taken to minimize surplus of materials? ....
....

23. (i) What are the causes of material shortages on site?

- ☐ Theft
- ☐ Poor workmanship
- ☐ Underestimation
- ☐ Late ordering and/or delayed delivery
- ☐ Lack of finance
- ☐ Others (specify)...

(ii)How are the shortages dealt with? ....
....

24. (i) During and prior to the concreting, was there any wastage of materials due to any of the following?

Source of Wastage	Ballast	Sand	Cement	Steel	Ready mix conc.
Discrepancy in specifications					
Wrongful purchase					
Wastage in transportation					
Damage on site					
Deterioration					
Poor workmanship leading to repeat of works					
Others (specify)					

(ii) What measures were taken prior to and during concreting to minimize wastage? ....,...
....

25. (i)Which method is used in organizing materials for concrete works?

- ☐ Computerized package (software)
- ☐ Charts
- ☐ Tables
- ☐ Others (specify)...

(ii) What influenced the selection of the particular method?
....

(iv) Where computers are not used, what are the reasons?
....

26. (i) What is the source of water used for concreting?..

(ii) How is the water stored on site? ....

(iii)During mixing of concrete, how is the water for the mix measured out?

....

(iv)What measures are taken to ensure that the water used for concreting is of the right quality and is not contaminated? ....

....

APPENDIX C

Classification of general contractors

CATEGORY	VALUE LIMIT (KSHS)
A	Unlimited
B	Up to Kshs. 250,000,000
C	Up to Kshs. 150,000,000
D	Up to Kshs. 100,000,000
E	Up to Kshs. 50,000,000
F	Up to Kshs. 20,000,000
G	Up to Kshs. 10,000,000
H	Up to Kshs. 5,000,000

Classification of specialist contractors

CATEGORY	VALUE LIMIT (KSHS.)
A	Unlimited
B	Up to Ksh. 50,000,000
C	Up to Ksh 30,000,000
D	Up to Kshs. 20,000,000
E	Up to Kshs. 10,000,000
F	Up to Kshs. 4,000,000
G	Up to Kshs. 2,000,000
H	Up to Kshs. 1,000,000

Source: Ministry of Roads and Public Works (2005)