A SURVEY OF MATERIALS WASTE ON BUILDING SITES

A Case study of Gaborone

Joseph Samman

1999

A SURVEY OF MATERIALS WASTE ON BUILDING SITES

A case study of Gaborone

By

Joseph Samman

This dissertation is submitted in fulfilment of the requirements for the award of a Master of Science Degree in Building.

FEBRUARY 1999

UNIVERSITY OF THE WITWATERSRAND

DEPARTMENT OF BUILDING AND QUANTITY SURVEYING

FACULTY OF ARCHITECTURE

ABSTRACT

The study aims to investigate materials waste on building sites in the Gaborone area with the view of making practical recommendations on ways and means of reducing it to the minimum. A literature search was undertaken in order to review the work already done on this subject. A site survey and a questionnaire survey were used to gather data for the study. Additional information was obtained by conducting interviews with site workers. Findings of the survey support the view that building sites generate large amount of materials waste. The study concludes that the solution to the problem of materials waste is through the adoption of effective materials control procedures on site. Suggestions are provided for those considering further research on the subject and finally recommendations are made to the Government, curriculum planners and professional bodies in the building industry on how they should assist in tackling the problem of materials waste in the building industry.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to my project supervisor Professor R. I. Schlos who guided me through this dissertation. My sincere gratitude also goes to Professor John Morris, who offered many useful suggestions during the preparation of this dissertation. My thanks go to the Chartered Institute of Building for providing me with articles on materials waste and management. Finally, my thanks go to the site agents/supervisors who freely and kindly allowed studies into waste on their sites.

CONTENTS

CHAPTER 1

INTRODUCTION

SYNOPSIS

This chapter discusses past research and related literature on materials waste. It states the problem to be researched. It also states the limitations of the research and the method used in carrying out the research. Finally, the chapter identifies the various sources from which the materials for the research were obtained.

1.1 Literature review

In 1963 the Building Research Station (now Building Research Establishment, BRE) discovered that contractors in UK were wasting more materials than they estimated for in their tenders (Skoyles and Skoyles 1987 p 14). Until then contractors were not aware of the large amount of materials waste occurring on their sites because of the insensitivity of their accounting methods. Studies carried out in other countries notably Holland, West Germany, Finland (Skoyles and Skoyles 1987 p 16), the Netherlands, Brazil (Bossink and Brouwers 1996), South Africa (Lampert 1990), Nigeria (Olomolaiye 1991), and Israel (Enshassi 1996) have also revealed that materials waste on building sites is considerable.

1.1.1 The definition of waste

The Concise Oxford Dictionary of Current English gives a number of definitions for waste. Those, which are appropriate to materials wastage, are stated below:

(a) *Superfluous - no longer serving a purpose.*

(b) *Left over after use.*

(c) *Bringing into a bad condition by neglect.*

(d) *Expend to no purpose or for an inadequate result.*

(e) *Use extravagantly.*

(f) *Useless.*

A number of writers have also defined waste. Arnold (1991 p 217) gives a general definition of waste as follows: "Adding cost is waste. Anything in the product cycle that does not add value to the product is waste."

Stein (1993 p 758) defines waste as "construction material that is additional to the actual quantity required in the work, as indicated in the contract documents, but that is, nevertheless, required by or used in performing the work".

Chandler (1980 p 7) defines waste as "the extravagant use or squandering of materials".

Illingworth and Thain (1987 p 2) define waste as " anything which results in money being lost".

Wyatt (1978 p 9) also defines waste as "the total loss of building material, materials or components arising from avoidable or unavoidable materials waste however caused".

CIOB Site Control guide (1979), however, gives a quantitative definition of waste:

Waste is *"the difference between the value of those materials delivered and accepted at the site and those properly used as specified and accurately measured in the work, after deducting the cost saving of substituted materials and those transferred elsewhere."*

1.1.2 Sources of waste

Waste associated with a building site can occur in a number of ways. It can occur when materials are being transported to the site or moved around the site. Waste can also occur when materials are carelessly unloaded or poorly stored or stacked. Using defective materials can also generate waste. The work will have to be re-done when rejected by the engineer/architect. This will cause delay and delay adds to cost. There is also the additional cost of replacing the defective materials and labour to re-fix the work. Delay in the supply of materials can also result in waste because operatives will have no productive work to do. Over-production of materials (e.g. wet materials such as concrete, mortar and plaster) can create waste. Waste can also occur at the work place due to cutting, rejection and mishandling of materials. Using materials for purposes other than those specified or in excess of what is required also causes waste - there is monetary loss to the contractor because he will not be paid for the extra costs involved. Waste can occur when finished work is damaged by succeeding trades.

Waste can also occur during learning periods when new entrants to the industry are being trained. Criminal activities such as pilfering, theft and vandalism can also result in waste.

1.1.3 Classification of waste

Waste associated with a building site can be categorised into two principal types: *direct waste* (total loss of materials) and *indirect waste* (where materials are used either for purposes other than those specified or in excess of the measured quantities). According to Skoyles and Skoyles (1987 p 22) "indirect waste is distinguished from direct waste by the fact that usually the materials are not lost physically, but only payment for the whole or part of the value". Direct waste can occur in various forms. They can be identified as: *delivery waste* (all losses in transit to the site, unloading and placing into the initial storage); *site storage and internal site transit waste* (losses due to bad stacking and initial storage, including movement and unloading around the site, to stack at the work place or placing into position); *conversion waste* (losses due to cutting uneconomical shapes, e.g. timber, sheeted goods, etc.); *fixing waste* (materials dropped, spoiled, or discarded during the fixing operation); *cutting waste* (losses caused by cutting materials to size, bond and to irregular shapes); *application waste* (materials in containers or cans such as mortar for brickwork, plaster and paint spilled or dropped. Similarly, materials left in containers or cans, which are not resealed. Mixed materials like mortar and plaster left to harden at the end of the working day); *waste due to the uneconomic use of plant* (this covers plant left running when not in use, or not employed to its optimum use); *management waste* (losses arising from an incorrect decision or from an indecision and not related to anything other than poor organisation or lack of supervision); *waste caused by other trades* (losses arising from events like "borrowing" by trades for purposes other than the work, and not returning the plant or material or damage by succeeding trades); *criminal waste* (this covers pilfering, theft from sites and vandalism); *waste due to wrong use* (when the wrong type or quality of materials are used); *waste stemming from materials wrongly specified* (waste due to errors, particularly in the bills of quantities and specification); and *learning waste* (usually by apprentices, unskilled "tradesmen", and tradesmen on new operations).

Indirect waste can occur in four forms: *substitution* (where materials are used for purposes other than those specified); *production waste* (where materials are used in excess of those indicated or not clearly defined in contract documents, for example, additional concrete in trenches which are dug wider than designed because no appropriate sized digger bucket is available); *operational waste* (where materials are used for temporary site work for which no quantity or other allowances have been made in the items in the contract documentation, for example, tower-crane bases, site paths, temporary protection, etc.); and *negligence waste* (where materials are used in addition to the amount required by the contract owing to the builder's own negligence).

Waste of materials may sometimes produce additional costs in areas that appear to be unrelated. Take for example, the delay caused by the shortage of materials or caused by rectifying damaged work. There will be additional costs of re-ordering replacement materials. The delay may also cause longer hire time of plant and labour and uneconomic use of plant and labour all resulting in increased costs to the contract. Such additional costs are collectively termed *consequential waste*.

1.1.4 The measurement of waste

The measurement of waste is an essential element of waste control. This view is supported by Illingworth and Thain (1987 p 4): "Some form of accounting is needed if the use of materials is to be monitored on a regular basis and loss and waste kept under control". Skoyles and Skoyles (1987 p 28) also note the importance of measuring waste: "A detailed knowledge of the incidence of waste is essential, particularly for the manager, site worker and student, in understanding the problem of waste prevention in practice". BRE has devised a system of waste accounting (*"Site accounting for waste of materials", BRE Current Paper CP 5/79,* *1978*), which enables site personnel to be sensitive to the occurrence of waste during the construction process. Skoyles and Skoyles (1987 p 157) list three forms of data required for the calculation of materials waste:

(i) A statement of the total delivery of materials to site.

(ii) A statement of the stock of the material.

(iii) A measure of work completed.

They suggest procedures for measuring direct waste. These are shown diagrammatically in Fig. 1.1. The procedures are also summarised as follows:

(i) Measure materials delivered to site. Adjust for transfers and credits and assemble the data.

(ii) Measure stock of materials on site. Adjust for any frozen stock and assemble the data.

(iii) Measure work executed. Adjust for any indirect waste. Measure the materials placed in the work as specified and assemble the data.

(iv) Complete the calculation of materials waste.

Harris and McCaffer (1977 p 75) have generated a formula for calculating materials waste:

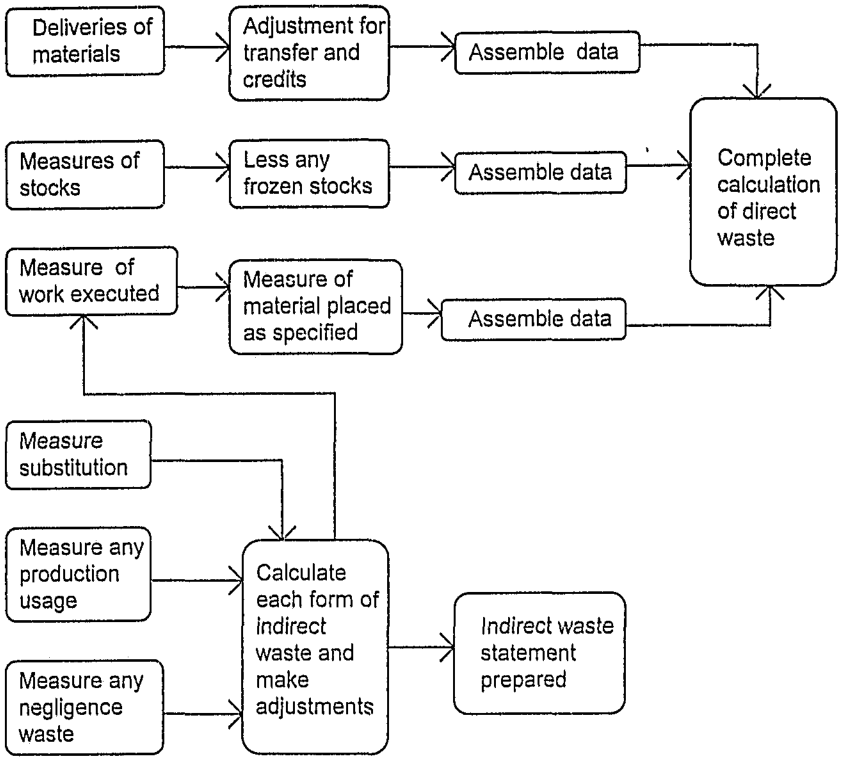
	£
Materials represented in measured work to the end of last peroid	a
Materials in measured work in this period	b
Therefore, materials value to date	$c = a + b$
Materials used to end of last period	d
Materials delivered in this period	e
Therefore, total cost of materials purchased to date	$f = d + e$
Materials currently on site	g
Therefore, materials used to date	$h = f - g$
Materials waste	$j = c - h$

BRE Digest 259 (1982 p 4) recommends that accounting should be undertaken at monthly intervals for the principal materials. It also recommends that accounting should begin as soon as sufficient materials are on site to justify a check. It further recommends that the waste levels should be based on deliveries because it represents the true loss. According to BRE Digest 259 "some firms prefer to calculate the waste level as a percentage of measures but over about ten per cent of this can give distorted figures".

1.1.5 Past research findings

In his paper titled *"Wastage of Building Materials"* Skoyles (1975 pp 191-192) identifies a number of reasons which give rise to waste on building sites. According to him the foremost reason for waste is the lack of appreciation of the

Fig. 1.1 Procedures for measuring waste



Source: Skoyles and Skoyles (1987 p 163)

value of materials. He says: "Anyone dropping money on the site would certainly never walk over it and trample it into the mud, but would stop to pick it up. Every day members of the building team, be they designers, managers, craftsmen or labourers, walk over cashable value of money in terms of someone's materials with no further thought". Another reason for waste he says is the fact that usually the proper procedures for controlling materials are ignored: "Many firms have rules for handling materials, guidance notes on stacking, rules for booking them in and checking their proper use. It has been found that these are generally 'not worked to' and waste plays a minor role both in business and craft training". He thinks that the biggest reason for waste is the general attitude to it. He says: "Apathy and an untidy site breeds waste because this creates a lack of respect for what is on the site - whether plant or materials". He advises that education can do much to cure it. He gives other reasons which also contribute to waste on site. These include mishandling and carelessness in the use of materials, bad stacking of materials, theft and vandalism. With regard to vandalism he reports that BRE noted that this was due primarily to disgruntled workmen. He also notes that "sites which are partially occupied, where children tend to play with goods (e.g. boxes of nails) left around by the men also encourage vandalism ".

The BRE studies on materials waste showed that the incidence of waste was, in general higher than that allowed for by contractors in their tenders. In one of the studies involving 230 sites BRE found that the actual materials waste on UK sites exceeds the amounts allowed by contractors in their tender prices by as much as 100 per cent (BRE Digest 247 1981 p 1). The results of the study are shown in Table 1.1. Table 1.1 shows that there is a wide variation in waste between different materials. The minimum waste of 1.25% was recorded for common bricks and the maximum waste of 37.5% was recorded for internal plumbing. The Table also shows that there is a wide variation in waste between sites for the same material. For example, the waste range for common bricks is 1.25 - 15.5%; the waste range for concrete is 2 - 5%; and the waste range for internal plumbing is 4 - 37.5%.

Table 1.1 also shows that the average waste of materials on UK sites varies between 3.5 - 18.8%.

Table 1.1 Direct waste of principal materials on UK sites (BRE Studies)

Material	No. of sites studied	Waste range %	Overall waste average %	Normal allowance in tender %
Concrete	230	2 - 5	3.5	2.5
Common bricks	230	1.25 - 15.5	8.5	4.0
Facing bricks	230	3.5 - 19.75	12.5	5.5
Clinker blocks	230	8 - 11.25	10.5	5.5
Lightweight blocks	230	3.5 - 20.75	10	5.5
First fix - softwood	230	5.5 - 16.75	10.5	5.5
Boarding - softwood	230	12.75 - 22.75	15	5.5
Internal plumbing	230	4 - 37.5	11.5	3
Drylining	230	4.5 - 24.25	18.8	5.5

Source: Adapted from BRE digest 247, p 3

According to Skoyles and Skoyles (1987 p 14, p 15) BRE reached the following conclusions:

(i) That all those involved in the building process contributed to waste: those who design materials, plan and build, those who specify and communicate, like the quantity surveyor and head office staff; and particularly the site manager and site operative.

(ii) That waste was not necessarily related to the type of construction, although this did have an influence on certain areas like cutting, etc.

(iii) That waste was not related to the building company but to the site and the people engaged on it.

(iv) That waste is significant at specific stages for certain materials.

(v) That waste varies considerably between sites in the same firm and between projects of the same size and having a similar construction and materials usage.

(vi) That some companies had remarkably low overall waste levels, although within the same organisation some management faced high levels without any apparent reasons.

(vii) That the present measurement conventions, represented by traditional bills of quantities, while being geared to financial control for contracts, take little account of production and material control.

Due to lack of resources and sponsorship, BRE studies did not cover all forms of financial loss arising from waste, especially loss resulting from *consequential waste*. Therefore, in 1980 Skoyles and Skoyles (1987 p 15) investigated this type of waste. Their studies covered 27 sites in the Greater London and Home Counties area. The results showed that *consequential waste* amounts to between 1% - 2% of the contract sum on 75% of the sites studied. This excluded items for which the contractor obtained payment through the normal variation order procedure. They explained that this form of waste could not be quantified as a percentage of materials used because "it varies from site to site and is related in terms of cost."

The studies carried out in Holland, Germany, Finland and Sweden also gave similar results to those of BRE, namely, that waste is considerable and that this is usually related to the nature of the sites, type of materials and their methods of packaging (Skoyles and Skoyles 1987 p 16).

In his paper titled *"Wastage of Building Materials"* Mudd (1975 p 208) also expresses concern about wastage of materials in the industry. He advocates that the industry should be educated in waste and its cost. He stresses the importance of materials control. He says that without control "there arrives on the site either insufficient material resulting in delays (wasted time) or an excessive quantity, resulting in overstocked, hazardous sites creating waste and safety problems". He says further that the lack of appreciation by the supervisory staff of the ultimate destination of materials results in deliveries being effected to incorrect locations resulting once again in multiple handling, breakage risk, security and so on all adding up to waste as before.

Wyatt (1978 p 7) also expresses concern about waste on building sites. He calls for the re-examination of company policy, systems of purchasing, estimating and scheduling, checking procedures, material storage, handling and distribution, the care of and protection of materials in use, the control at site level and overall use of feedback and company training programmes. He emphasises that such a study requires among other things "a detailed understanding of material management, particularly what is meant by materials wastage and how it arises". He identifies a number of factors which contribute to the high level of materials wastage on UK sites (p 13, p 14, p 15), namely:

(i) Inadequate monitoring or administration, or poor housekeeping.

(ii) Inadequate material scheduling, administrative shortcomings in the ordering, delivery, checking and off-loading of materials and components on site.

(iii) More materials than required are delivered or taken to the working area.

(iv) Poor materials handling and placing, particularly at ground level. For example, deliveries tend to be off-loaded alongside access routes or within the working area.

(v) Inadequate care and protection for materials. For example, many materials are brought into direct contact with the ground, exposed to wetting/drying cycles, and damaged as a result of the presence of moisture or water, stored without adequate ventilation and exposed directly to the sun.

Writing under the title *"An approach to reducing materials waste on site"*, Skoyles (1984 p 1) notes that site managers are often unaware of the opportunities of cutting waste. According to him "many believe that it cannot be effectively controlled and that it is more efficient to allow losses to occur than to involve the use of extra resources in reducing or preventing waste". He believes that preventing waste can be cost effective. He maintains that waste prevention can be achieved "by stimulating an awareness of the waste problem rather than by identifying the particular means of achieving lower waste levels". He warns that materials waste has an adverse effect on profitability and must therefore be given serious attention by building management, particularly site managers. He reports of CIOB sponsored studies covering some selected sites in the London area. According to him the results of the studies showed that waste for the major materials is about twice that assumed. He notes that the waste accounting system suggested by BRE is inadequate. According to him the system "will provide results only after the loss has occurred". He thinks that, "what is needed is a system that warns the site manager before wastage is likely to occur". One such solution according to him is "the judgement of the site's waste problems, or potential problems, by another pair of eyes". This, he says "would allow site management an opportunity to relate problems of waste control to someone independent of the running of the site but with an awareness of its site problems in the same way that the services of safety officers are used".

In a paper titled *"Materials management - is it worth it?"* Illingworth and Thain (1988 p 1) express concern about the low priority given to materials management by many established managers. According to them materials management is seen by management as "a complicated and separate process, rather than as a fundamental part of construction". They assert that "mismanagement of materials invariably creates waste". They estimate that about 10% of the tender value can be lost on high and low rise housing as a result of wasted materials. They report on the following waste rates:

(i) A reconciliation on concrete usage on completion of a factory floor showed a wastage of 14%, entirely due to a poorly prepared sub-base.

(ii) In casing steel in a warehouse, the waste of concrete was 10% against the 4% estimated.

(iii) On one major housing site, bricks wasted above the normal allowance in the tender were equivalent to about ten extra houses. Or, at that time, enough nationally to build a further 15,000 houses.

They express concern about the low priority given to site security by many builders. They report that approximately 360 million Pounds of materials are stolen or damaged on building sites each year. They cite E. R. Skoyles (1981) as saying that if every construction firm in UK "were able to reduce its waste of common traditional materials by only 10% of present levels, about 70 million Pounds could be saved on the cost of materials alone".

In his study titled *"Productivity in the construction industry in the Republic of South Africa"*, Lampert (1990 Chap 17 p 5) observes that excessive wastage of materials occurs on South African sites. He reports that the building industry in South Africa lost about R350 million through materials losses during 1984. He notes that there is "a serious lack of awareness and caring amongst management and supervisory staff regarding the utilisation of materials and equipment" (Chap 9 p 12). He cites concrete spillage, broken bricks, excess mortar and poor housekeeping of equipment as evidence of this shortcoming. He notes also that "the purchasing function is one of the few elements in the total materials management spectrum which is effectively implemented. The lack of attention to the other elements such as scheduling, packaging and transportation, accounting and storage was found to lead to unnecessary losses" (Chap 9 p 15). He notes that in practice deliveries are seldom checked (Chap 9 p 7). According to him the latter is prevalent in the case of stone and sand deliveries. He gives some examples of materials wastage as observed in his study (Chap 9 p 12):

(i) None of the sites visited had suitable nor sufficient storage bins for small but costly items such as clamps, wedges and connectors. This resulted in equipment lost in construction dirt, and in backfill.

(ii) Frequent transportation damage was observed when wheelbarrows were used to transport face bricks. There seemed to be a complete lack of appreciation of the unit cost of a brick by the worker transporting them (and that also often applied to site supervision), since the bricks were thrown into the barrow with resultant chipping of the edges.

(iii) Mortar supplied in silos over a period of four months was found to be 118 cubic metres short supplied. This shortfall was valued at R7 080.

(iv) One million bricks were short supplied to a large housing contract. It was found that the truck drivers were removing the top layer of bricks en route from the yard to the site.

In his survey of materials waste on Nigerian sites Olomolaiye (1991 p 42) measured the incidence of waste on eight prominent materials: hollow sandcrete blocks, cement, sand, aggregates, timber, corrugated asbestos cement roofing sheets, reinforcement bars and glass sheets on fourteen construction sites. He found that the waste levels in all but one material (i.e. aggregates) were above the normal estimators' allowances (See Table 1.2). Table 1.2 shows that the overall waste of the principal materials varies between 2.3% and 13.14%; the lowest wastage occurring in gravel and the highest occurring in hollow sandcrete blocks. His study also revealed "a marked absence of structured planning in materials useage on Nigerian construction sites". He notes with concern that of the fourteen firms studied only three had a schedule of materials. Also, he observes that Nigerian contractors do not carry out comprehensive cost-conscious market surveys before purchasing materials. Regarding on-site materials control, he observed that even though the storage spaces were generally adequate and there was no difficulty in storing materials before usage, the materials were not carefully delivered from the lorries or carefully and sequentially put in position in the storage areas. He urges Nigerian contractors to be more efficient in managing their materials on site. He advises that Nigerian contractors should be made aware that so much of the materials is being wasted.

Kaekane (1994) did a study on materials management on construction sites in the Gaborone area. One of the problems he investigated was materials waste. He observed that there was "an alarming rate of materials wastage" on Gaborone sites. He notes: "there were all sorts of broken items, debris, etc. lying around the work area, indicating that there was indiscriminate throwing around of materials".

Table 1.2 Direct waste of principal materials on Nigerian sites

Material	No. of sites studied	Overall waste average %	Normal allowance in tender %
Hollow sandcrete blocks	11	13.14	5
Cement	11	4.68	2.5
Sand	11	4.27	2.5
Gravel	11	2.3	2.5
Timber	11	12.68	-
Asbestos-cement roofing sheets	7	3.21	2.5
Reinforcement bars	14	7.5	2.5
Glass sheets	-	11.4	5

Source: Adapted from P. Olomolaiye (1991 pp 40-42)

He cites concrete, mortar, reinforcement and sand as the most affected materials. He observes that "lack of proper supervision and attitude of both operatives and site management are responsible for high uncontrolled wastage".

Enshassi (1996) has also surveyed materials waste on a number of housing projects in the Gaza Strip, Israel. The sample consisted of 86 projects distributed in several locations in the Gaza Strip. The works ranged in value from about $1M to over $2M. His study shows that contractors in the Gaza Strip waste more materials than they assume in their tenders (See Table 1.3). Table 1.3 shows that materials waste generated on sites in the Gaza Strip is about twice that assumed by contractors in their tenders. Table 1.3 also shows that direct waste accounts for more waste than indirect waste.

Table 1.3 Materials loss resulting from direct and indirect waste on Israeli sites (Gaza Strip)

Material	No. of sites studied	Direct waste %	Indirect waste %	Overall waste %	Normal allowance %
Common bricks	86	3.2	2	5.2	2
Facing bricks	86	4.9	2.2	7.1	3
Steel bars	86	2.1	1.5	3.6	2
Shuttering	86	6.9	4.1	11	4.5

Source: Adnan Enshassi (1996 p 34)

Bossink and Brouwers (1996 p 57) report on a survey of materials waste carried out on a number of building sites in the Netherlands. The research carried out between April 1993 and June 1994 involved five housing projects. According to them the research revealed that 9% of the total purchased materials end up as waste (by weight). Tables 1.4 and 1.5 show the statistics of the individual

Table 1.4 Construction waste as percentage of purchased amount of specific construction material on Dutch sites

Application of construction material	Construction waste (by weight) (%)
Stone tablets	9
Piles	5
Concrete	3
Sand-lime elements	1
Roof-tiles	10
Mortar	10
Packing	Not applicable
Sand-lime bricks	6
Remainder (mainly small fractions of metal and wood)	-

Source: Bossink and Brouwers (1996 p 57)

materials. Table 1.4 shows waste as a percentage of the purchased amount of specific materials. In Table 1.4 the amount of materials waste lies between 1% and 10% of the amount purchased. Table 1.5 shows waste of each material as a percentage of the total amount of waste. In Table 1.5 the largest source of waste is

Table 1.5 Construction waste as percentage of total amount of construction waste on Dutch sites

Application of construction material	Construction waste (by weight) (%)
Stone tablets	29
Piles	17
Concrete	13
Sand-lime elements	11
Roof-tiles	10
Mortar	8
Packing	7
Sand-lime bricks	3
Remainder (mainly small fractions of metal and wood)	2

Source: Bossink and Brouwers (1996 p 57)

the use of stone tablets (*facing bricks*) [29%] followed by the use of piles (17%), concrete (13%), sand-lime elements (11%) and roof tiles (10%). Mortar, packing and sand-lime bricks account for 8%, 7%, 3% of the total waste respectively. Metal and wood account for the remaining 2%. They report also on studies conducted in Brazil to determine the waste rates for construction materials on site. In one of the studies the waste rate was found to be between 20 - 30% of the weight of total materials on site [cited in Pinto and Agopayan (1994)].

Another study conducted in the south region of Brazil also estimated the waste rate as 25% of all materials delivered to site [cited in Hamassaki and Neto (1994)]. Formoso et al (1994) [cited in Craven et al (1994)] also estimated that the waste rate was as much as 20% of all materials delivered to site. The data are shown in Table 1.6.

Table 1.6 Construction waste as a percentage of total amount of purchased construction material on Brazilian sites

Reference	Construction waste (by weight) (%)
Pinto and Agopayan (1994)	20 - 30
Hamassaki and Neto (1994)	25
Formoso et al (1993) [cited in Craven et al (1994)]	20

Source: Bossink and Brouwers (1996 p 56)

To gain an insight into the percentages of materials wasted on site for specific materials Bossink and Brouwers (1996) give results of three studies in Brazil (See Table 1.7). The table contains the results of a study by Pinto (1989, cited in Soiberman et al 1994), a synthesis of the results obtained in five construction sites researched by Soibelman et al (1994) and the results of experimental studies described by Pinto and Agopayan (1994). Table 1.7 shows that there is a wide variation in waste between different materials in a study. For example, Pinto's study (1989) shows a minimum waste of 1% for concrete and a maximum waste of 51% for mortar.

1.2 Statement of the problem

Research has shown that building sites generate large amount of materials waste (BRE Digest 247 1981, Lampert 1990, Olomolaiye 1991, Enshassi 1996, Bossink and Brouwers 1996). It has been realised that lack of on-site materials control contributes to the high level of materials waste on building sites. Many contractors fail to adopt proper procedures for controlling materials on site. They see materials control as an elaborate or expensive process (Illingworth and Thain 1987 p 1). Few contractors attempt to measure and monitor materials waste. Many contractors believe that waste cannot be effectively controlled and that it is more efficient to allow losses to occur than to involve the use of extra resources to control it (Skoyles 1984 p 1).

The consequences of misuse of materials on building sites cannot be overemphasised: it reduces a company's profitability, it increases future building costs, it reduces the availability of materials in the future and it contributes to low productivity in the building industry (Wyatt 1978 p7).

Table 1.7 Construction waste of specific materials as a percentage of total purchased amount of specific construction materials in Brazil (by weight)

Construction material	Pinto (1989)	Soibelman et al (1994)	Pinto and Agopa-yan (1994)
Steel	21%	16%	26%
Cement	25%	46%	33%
Concrete	1%	12%	2%
Sand	28%	31%	28%
Mortar	50%	48%	46%
Ceramic block	-	21%	-
Brick	11%	23%	12%
Timber	-	-	32%
Hydrated lime	-	-	51%
Wall ceramic tile	-	-	9%
Floor ceramic tile	-	-	7%

Source: Bossink and Brouwers (1996 p 56)

The control of materials waste on building sites is all the more important considering the fact that the cost of construction materials is escalating at a faster rate than labour (Chandler 1980 p 81, Briscoe 1991 p 149, Bernold and Treseler 1991 p 645) and that about 50% of the cost of a building project is in materials (BRE Digest 247 1981).

1.3 Objectives of the study

The objectives of this study are five-fold:

(i) To survey materials waste on building sites in the Gaborone area.

(ii) To identify the causes of materials waste on Gaborone sites.

(iii) To make suggestions on ways and means of reducing materials waste on building sites to the minimum.

(iv) To formulate a code of practice for waste reduction to guide contractors in the use of materials on building sites.

(v) To test the suggestions for reducing materials waste.

1.4 Limitations of the study

This study investigates the problems of materials waste on building sites in the Gaborone area. It concentrates mainly on wastes originating from the contractor's organisation. Waste originating from the designer, quantity surveyor, client and the suppliers of building materials are considered to be outside the scope of the study. The survey of materials waste is restricted to materials in the wet trades, namely, concrete, mortar in brickwork, mortar in plasterwork, cement, sand, stone, common bricks and facing bricks which form a large proportion of the builders' work. The study did not investigate indirect waste and consequential.

1.5 Research methodology

The research methodology involved the following steps (See Fig.1.1)

(i) Carry out a literature survey.

(ii) Develop a questionnaire.

(iii) Carry out site survey.

(iv) Collect data from questionnaire and site survey.

(v) Analyse the data collected.

(vi) Interpret the results

(vii) Make suggestions for waste reduction on building sites.

(viii) Test the suggestions for waste reduction.

(ix) Draw conclusions.

1.6 Sources of research data

The primary data were obtained from the following sources:

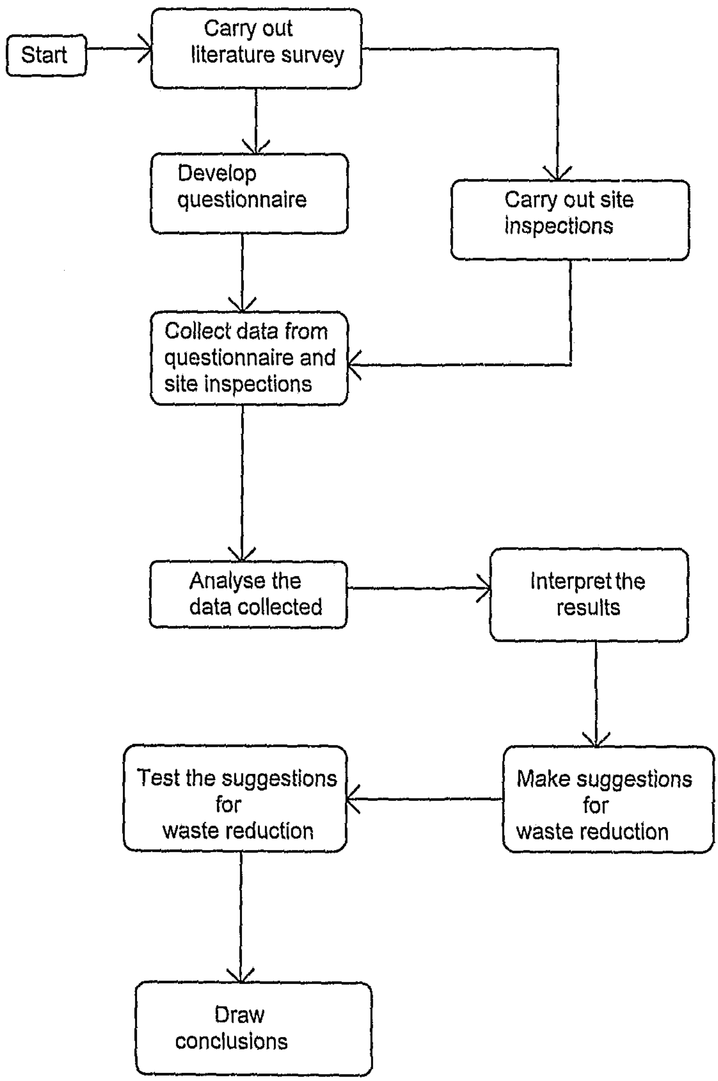
(i) Site observations from building sites in the Gaborone area (See Appendix 1).

(ii) Site measurements.

(iii) Contractors' records of delivery.

(iv) Contract drawings, specifications and bills of quantities.

Fig. 1.1 Methodology flow chart



The secondary data were obtained from the following sources:

(v) Books and periodicals from the libraries of the University of Botswana and the University of the Witwatersrand, Johannesburg (South Africa).

(vi) Periodicals from the Chartered Institute of Building (London).

CHAPTER 2

METHOD OF CARRYING OUT THE INVESTIGATION

SYNOPSIS

This chapter explains how the investigation was undertaken. It also explains how the data collected were analysed and presented.

2.1 Literature review

A literature survey was undertaken in order to review the work already done on the subject (See Chapter 1)

2.2 Selection of sites

Eleven building sites in the Gaborone area were selected after preliminary investigations. Two criteria were used in selecting the sites: the size of the project and the willingness of the contractor to co-operate with the investigation. Attempts were made to get sample sites from three groups of project sizes, namely: small size projects (projects under P1M in value), medium size projects (projects between P1M and P2M in value) and large size projects (projects over P2M in value). The projects selected ranged in value from P700,000 to P2.5M. At the time of undertaking the study there were few on-going projects in the Gaborone area.

Hence, the inability of the researcher to study a large sample of sites. All the projects were new construction. They consisted of housing projects, schools, offices/workshops, offices/warehouses and a filling station. Eight local contractors were studied. Four of them were categorised as small size contractors (employing up to 100 workers), three as medium size contractors (employing 100 – 500 workers) and one as a large size contractor (employing over 500 workers).

2.3 Site survey

Regular visits were made to the selected sites. On every visit the researcher toured the site to note examples of waste and their contributing factors. Actual site measurements of waste were also carried out during the progress of the site work. Details of the measurements are explained in Paragraph 2.5 hereunder.

2.4 Questionnaire survey/interviews

A questionnaire survey and interviews were conducted to augment the site survey. Copies of the questionnaire were given to site agents/supervisors administering the selected sites to complete. The questionnaire focussed on seven main areas of materials control, namely: planning of materials deliveries, inspection and checking of materials, documentation, planning of storage areas, planning of site transport routes, site security and monitoring of materials waste. Additional information was obtained through interviews with site workers, ˌcluding storekeepers/ materials checkers.

2.5 Measurement of waste

Wastes of the principal materials were measured in two forms, namely:

(i) daily waste,

(ii) overall waste.

(i) Daily waste

Direct measurements of waste in five principal materials, namely: concrete, mortar in brickwork, mortar in plasterwork, common bricks and facing bricks were made while work was in progress. Wastes in these materials were monitored continuously for a week on each of the sites. The procedures adopted for measuring the daily waste in concrete and mortar were as follows:

1. The volume of material produced in a particular day was assessed, say: a

2. At the end of the day the volume of material placed was measured, say: b

   Volume of concrete or mortar wasted $= a - b$

The following procedures were also adopted for measuring the daily wastage in bricks:

1. The number of bricks sent to the work place in a particular day was recorded, say: *a*.
2. The number of surplus bricks at the work place before work commenced on that day was also recorded, say: *b*.
3. The area of brickwall placed was measured at the end of the day. From the area of the wall the number of bricks placed was calculated, say: *c*.
4. Finally, the number of surplus bricks at the work place at the end of the day was recorded, say: *d*.

The number of bricks wasted at the work place was then calculated as follows:

$$\textit{No. of bricks wasted} = (a + b) - (c + d)$$

The amount of concrete, mortar or bricks wasted was then expressed as a percentage of deliveries:

$$\textit{Waste} = (\textit{Amount wasted} / \textit{Amount delivered}) \times 100\%$$

(ii) Overall waste

The overall waste in each of the five principal materials, namely: cement, sand, stone, common bricks and facing bricks were also assessed at the end of the contract. This was assessed by comparing the total amount of materials purchased with the materials in the completed work. The overall waste for each material was then calculated as follows:

Waste = (Total quantity of material delivered to site) - (Quantity used in measured completed work) - (Unused material on site)

The overall waste was then expressed as a percentage of deliveries:

Waste = (Total quantity wasted/Total quantity delivered to site) x 100%

It is worth noting that *Indirect waste* and *consequential waste* were excluded from the calculation of materials waste as these were difficult to assess.

2.6 Presentation and descriptions of the results

The data on the measurement of materials waste for the principal materials were analysed and presented in a tabular form. Three forms of analysis were presented: (i) daily waste of the materials, (ii) overall waste of the materials and (iii) waste of the materials according to project size. The sites were grouped into three project sizes, namely:

(a) small size projects (projects under P1M in value)

(b) medium size projects (projects between P1M and P2M in value)

(c) large size projects (projects over P2M in value).

Four projects were categorised under small size projects (Sites D, H, J and K), four under medium size projects (Sites A, B, F and G) and three under large size projects (Sites C, E and I) (See Appendix 1). Reasons were sought for the high waste rates recorded on the sites surveyed. Finally, the waste rates on Gaborone sites were compared with those on overseas sites. Results from the questionnaires were presented in two forms: (i) questionnaire results from the sites (See Appendix 3) and (ii) tallies of the questionnaire results (See Appendix 4). The researcher discussed his personal observations on the site regarding the level of materials control on the sites surveyed.

2.7 Suggestions for waste reduction

Based on the finding of the study, appropriate recommendations were made on ways and means of reducing materials waste on building sites to the minimum. A code of practice for waste reduction on building sites was also formulated to guide contractors on the control of materials on site.

2.8 Testing the suggestions for waste reduction

The researcher's suggestions for waste reduction were tested on a selected site (Site L – See Appendix 1) to determine if savings could be made in materials cost.

CHAPTER 3

PRESENTATION AND DESCRIPTIONS OF RESULTS

SYNOPSIS

This chapter discusses the results of the investigation. The waste rates of the principal materials are analysed and presented in a tabular form. Factors contributing to materials waste on Gaborone sites are discussed. Materials waste rates on Gaborone sites are compared with those on overseas sites. Results from the questionnaires are also discussed. Finally, the researcher's personal observations regarding on-site materials control on Gaborone sites are discussed.

3.1 Results from the site survey

Waste of eight principal materials namely: concrete, mortar in brickwork, mortar in plasterwork, cement, sand, stone, common bricks and facing bricks were investigated. The results of the investigations are now discussed.

(i) Waste of concrete (site mixed)

The waste rate of this material was monitored continuously for one week on each site. The analysis is shown in Table 3.1. Table 3.1 shows that the amount of waste of concrete lies between 2.3% and 7.8% of the amount produced.

Table 3.1 Waste of concrete as a percentage of total amount produced on Gaborone sites

Site	Daily waste on site (%)	Waste allowed in tender (%)
Site A	5.3	2
Site B	5.8	5
Site C	7.1	2.5
Site D	4.7	2
Site E	7.8	2.5
Site F	6.5	5
Site G	5.4	5
Site H	4.1	2.5
Site I	7.3	2.5
Site J	3.1	2
Site K	2.3	2
Total	59.4	33
Average	5.4	3

The highest amount of waste was recorded on Site E (7.8%) and the lowest on Site K (2.3%). The average amount of concrete wasted was 5.4%. This figure is above the normal waste rate of 3% allowed by contractors in their tenders.

Most of the waste of concrete was due to spillage. Spillage of the material occurred during transportation. Wheelbarrows and dumpers were often overfilled at the mixing point and as they travelled over bumpy grounds they spilled concrete. Sites A, F and G were the most affected sites. Undoubtedly, these sites recorded high waste rates as seen in Table 3.1. Wheelbarrow pushers and dumper drivers often failed to take adequate care in pouring the concrete into trenches and pits thus resulting in spillage. All the sites were guilty of this practice. Some sites, notably Sites H, J and K also lost concrete through spillage during the discharge from the batching plant. Mixer drivers on these sites overfilled transporting plant with concrete. The spilled concrete was not salvaged but left to harden at the mixing sites. Many sites, notably Sites C, E, F, G, H, I, J and K also lost concrete through overproduction. Labourers often did not know the quantity of concrete needed for the day because of poor planning. As a result they tended to mix more concrete than was needed. In many cases the excess concrete was left to harden on site. Some sites, notably Sites B, C, D, E and I mixed concrete on bare ground.

Some concrete got contaminated with earth and was rejected because it was not suitable for use.

(ii) Waste of mortar (site mixed)

The waste rate in this material was also monitored continuously for a week on each site. Mortar in brickwork and mortar in plasterwork were investigated separately. Table 3.2 shows the waste rate of the material in brickwork and Table 3.3 the waste rate in plastering. Table 3.2 shows a waste range of 3.7% and 10.5%. The highest amount of waste was recorded on Site I (10.5%) and the lowest on Site K (3.7%). The average waste rate of mortar in brickwork is 7.1%, which is above the normal waste rate of 2.8% allowed by contractors in their tenders. Table 3.3 also shows a waste range of 8.3% and 14.8%. The highest amount of waste occurred on Site E (14.8%) and the lowest on Site K (8.3%). The average waste rate of mortar in plasterwork is 11.7% which is again higher than the normal waste rate of 6.1% allowed by contractors in their tenders.

Spillage was identified as one of the major causes of waste in mortar. During bricklaying and plastering mortar droppings were not salvaged but instead left to harden. Many sites lost mortar through spillage during transportation. As explained

Table 3.2 Waste of mortar in brickwork as a percentage of total amount produced on Gaborone sites

Site	Daily waste on site (%)	Waste allowed in tender (%)
Site A	7.3	2
Site B	5.4	2
Site C	9.5	2
Site D	5.1	2
Site E	10.1	2
Site F	8.5	5
Site G	7.8	5
Site H	6.4	5
Site I	10.5	2
Site J	4.2	2
Site K	3.7	2
Total	78.5	31
Average	7.1	2.8

Table 3.3 Waste of mortar in plasterwork as a percentage of total amount produced on Gaborone sites

Site	Daily waste on site (%)	Waste allowed in tender (%)
Site A	13.5	2
Site B	10.6	5
Site C	14.3	5
Site D	10.4	5
Site E	14.8	5
Site F	11.2	10
Site G	10.8	10
Site H	11.9	10
Site I	13.8	5
Site J	9.3	5
Site K	8.3	5
Total	128.9	67
Average	11.7	6.1

in the case of concrete, wheelbarrows and dumpers were often overfilled and they spilled mortar as they moved over bumpy grounds. Some sites (Sites F, G and H) lost mortar at the mixing point as mixer drivers sometimes overfilled the transporting plant thereby causing spillage. The spilled mortar was often left to harden at the mixing point. Some sites lost mortar through overproduction of the material. As was the case of concrete, labourers often did not know the quantity of mortar needed for the day because of poor planning. As a result they tended to mix more mortar than was needed. Some sites, notably Sites B, C, D, E and I mixed mortar on bare ground. As in the case of concrete, some mortar got contaminated with earth and was rejected because it was not suitable for use.

(iii) Waste of bricks

Tables 3.4 shows the waste rates of common bricks as a percentage of the total purchased amount. Table 3.4 shows a minimum daily waste rate of 3.3% and a maximum daily waste rate of 10.2% in common bricks, the minimum waste rate occurring on Site K (3.3%) and the maximum on Site I (10.2%). The average daily waste rate in this material is 7.0%, this being higher than that allowed by contractors in their tenders (4.0%). Table 3.4 also shows an overall waste range of 7.8% and 15.1% in common bricks. The minimum waste rate was recorded on Site D (7.8%) and the maximum on Site E (15.1%). The average waste rate for this material was 10.9%, this being higher than that allowed by contractors in their tenders (4.0%).

Table 3.5 shows the waste rates of facing bricks as a percentage of the total purchased amount. Table 3.5 shows a daily waste range of 2.5% and 9.2% of facing bricks. The highest daily waste was recorded on Site I (9.2%) and the lowest on Site K (2.5%). The average daily waste rate of the material was 5.7% which is again higher than that allowed by contractors in their tenders (4.1%). Table 3.5 also shows an overall waste range of 7.5% and 12.5% of facing bricks, the minimum waste rate occurring on Site K and the maximum on Site G. The average waste rate in this material is 9.6%, this again being higher than that allowed by contractors in their tenders (4.1%).

Most of the waste of bricks was due to cutting waste. Loss occurred because a lot of cutting was needed to reduce bricks to size. Most of the cutting waste in common bricks was due to the use of wrong tool to cut the bricks. On all the sites bricklayers were seen cutting common bricks with a trowel instead of a bolster (brick chisel) or brick saw. For example, when a bricklayer needed a half-bat common brick he would use his trowel to chip off one end repeatedly until he was left with a half bat. A bolster (brick chisel) or brick-saw could have been

Table 3.4 Waste of common bricks as a percentage of total purchased amount on Gaborone sites

Site	Daily waste on site (%)	Overall waste On site (%)	Waste allowed in tender (%)
Site A	8.3	10.5	5
Site B	6.8	11.4	5
Site C	9.4	10.1	2.5
Site D	4.5	7.8	2
Site E	9.7	15.1	5
Site F	5.8	10.8	5
Site G	8.6	13.6	5
Site H	7.1	9.3	5
Site I	10.2	13	5
Site J	3.8	8.8	2
Site K	3.3	9.5	2
Total	77.5	119.9	43.5
Average	7.0	10.9	4.0

Table 3.5 Waste of facing bricks as a percentage of total purchased amount on Gaborone sites

Site	Daily waste on site (%)	Overall waste on site (%)	Waste allowed in tender (%)
Site A	6.1	9.3	5
Site B *	-	-	-
Site C *	-	-	-
Site D *	-	-	-
Site E	8.3	10.5	5
Site F	4.3	8.1	5
Site G	6.5	12.5	5
Site H *	-	-	-
Site I	9.2	11.4	5
Site J	3.3	8.2	2
Site K	2.5	7.5	2
Total	40.2	67.5	29
Average	5.7	9.6	4.1

* Facing bricks were not used on these sites.

conveniently used to cut the brick in half thereby avoiding waste. Some brick losses also occurred due to the rejection of pieces of cut bricks. Bricklayers would often cut half bats from full bricks instead of using already cut pieces to minimise waste in bricks. The high waste rate of bricks was also due to poor handling at the stacks. Many bricks got broken at the stacks because labourers did not take adequate care in removing them from the stacks. For example, labourers would often remove bricks from the middle part of the stacks because they could not reach the top. The top bricks would then fall down resulting in breakage or chipping of the edges. On Site H a labourer was seen 'knocking down' the top bricks from a stack with a rod because he could not reach the top.

Frequent transportation damage was observed when wheelbarrows and dumpers were used to transport facing bricks. For example, on five sites (Sites A, E, F, G and H) labourers were seen throwing facing bricks into wheelbarrows and dumpers during loading. On the same sites it was also observed that labourers were dumping facing bricks from wheelbarrows and dumpers during off-loading. A number of these bricks had their edges chipped off and were rejected by bricklayers. On three sites (Sites E, F and I) labourers were seen throwing bricks from person to person until they reached the point of use. This resulted in many bricks falling and consequently breaking and chipping. A mobile crane or a simple pulley system could have been conveniently used.

(iv) Waste of cement (bagged)

Table 3.6 shows the overall waste of cement as a percentage of total purchased amount on Gaborone sites. Table 3.6 shows a waste range of 4.5% and 18.5%, the minimum waste rate occurring on Site K and the maximum on Site C. The average waste rate in this material is 9.5%, this being higher than that allowed by contractors in their tenders (3.4%).

Poor storage and pilferage were the major causes of waste of cement. Labourers did not take adequate care in putting bagged cement in storage and as a result some of the bags got broken thus spilling their contents. On a number of sites labourers were seen dropping bagged cement from a height during storage. Some bags got broken and the contents spilled over. Security on most of the sites was found to be very poor. For example, many sites did not have fences; there was no provision for lighting during the night; during the working hours many sites left their stores open when not being used. All these shortcomings no doubt increased the risk of theft and pilferage. The site agents on three sites (Sites C, D and G) reported cement thefts on a number of occasions on their sites. However, they were unable to give

Table 3.6 Waste of cement as a percentage of total purchased amount on Gaborone sites

Site	Overall waste on site (%)	Waste allowed in tender (%)
Site A	10.1	5
Site B	10.3	2.5
Site C	18.5	5
Site D	8.8	2.5
Site E	12.3	5
Site F	9.5	2.5
Site G	7.5	2.5
Site H	6.5	2.5
Site I	11.4	5
Site J	5.3	2.5
Site K	4.5	2.5
Total	104.7	37.5
Average	9.5	3.4

figures because of poor documentation on their sites. It would seem therefore that theft and pilferage contributed to the high waste rates of cement on a number of sites, particularly Site C (18.5%), Site E (12.3%), Site I (11.4%), Site B (10.3%), Site A (10.1%) and Site F (9.5%).

(v) Waste of sand and stone

Tables 3.7 and 3.8 show the overall waste in sand and stone as a percentage of the total purchased amount on Gaborone sites. Table 3.7 shows a waste range of 8.1% and 16.8% of sand. The minimum waste rate was recorded on Site J (8.1%) and the maximum on Site C (16.8%). The average waste rate in this material was 12.9%, this being higher than that allowed by contractors in their tenders (8.2%). Table 3.8 also shows a waste range of 7.3% and 15.8% in stone. The minimum waste rate was recorded on Site J (7.3%) and the maximum on Site C (15.8%). The average waste rate in this material was 11.2%, which is again higher than that allowed by contractors in their tenders (5.9%).

Poor storage was one of the major causes of waste in sand and stone. The materials were always stored on bare ground. Losses occurred because some of the materials often sank into the ground and got contaminated with earth. Also, none of the sites provided adequate enclosures to prevent the materials from spreading. Again, losses occurred because the materials weathered and spread over a larger area than

Table 3.7 Waste of sand as a percentage of total purchased amount on Gaborone sites

Site	Overall waste on site (%)	Waste allowed in tender (%)
Site A	14.3	10
Site B	10.1	5
Site C	16.8	10
Site D	11.3	5
Site E	14.1	10
Site F	15.5	10
Site G	13.4	10
Site H	12.5	10
Site I	16.2	10
Site J	8.1	5
Site K	9.5	5
Total	141.8	90
Average	12.9	8.2

Table 3.8 Waste of stone as a percentage of total purchased amount on Gaborone sites

Site	Overall waste on site (%)	Waste allowed in tender (%)
Site A	11.5	10
Site B	11.6	5
Site C	15.8	2.5
Site D	10	2.5
Site E	11.9	10
Site F	12.5	5
Site G	13.2	5
Site H	8.2	5
Site I	12.8	10
Site J	7.3	5
Site K	8.5	5
Total	123.3	65
Average	11.2	5.9

the original dump occupied. Multiple storage was another source of waste, the most affected sites being Sites C, D, E, I, J and K. Those sites stored sand and stone in several locations on site. This factor undoubtedly contributed to the high waste rates of sand and stone on those sites, particularly Site C, which recorded 16.8% for sand and 15.8% for stone.

(vi) Waste of principal materials according to project size

The overall waste rates of the principal materials were analysed in terms of project size. The projects were divided into three groups: small size projects (projects under P1M in value), medium size projects (projects between P1M and P2M in value) and large size projects (projects over P2M in value). The results of the analysis are shown in Table 3.9. Table 3.9 shows that waste in a specific material increases as the size of the project increases. For example, the waste rate of cement is 6.3% for small size projects and increases to 9.4% for medium size projects and 14.1% for large size projects. Similarly, the waste rate in stone for small size projects is 8.5% and increases to 12.2% for medium size projects and 13.5% for large size projects. The same trend occurs in the other materials.

Table 3.9 Materials waste according to project size on Gaborone sites

Material	Overall waste on site (average) (%)		
	Small size projects	Medium size projects	Large size Projects
Cement (bagged)	6.3	9.4	14.1
Sand	10.4	13.3	15.7
Stone	8.5	12.2	13.5
Common bricks	8.9	11.6	12.7
Facing bricks	7.9	10.0	11.0
Concrete (site mixed)	3.6*	5.8*	7.4*
Mortar in brickwork (site mixed)	4.9*	7.3*	10.0*
Mortar in plaster-work (site mixed)	10.0*	11.5*	14.3*

* These figures are daily waste rates.

(vii) Comparison of materials waste on Gaborone sites with those on overseas sites

Table 3.10 shows the comparison of materials waste on Gaborone sites with those on overseas sites. Comparing the waste rates on Gaborone sites with those on Nigerian sites, it can be seen that Gaborone sites waste more cement, sand and stone than Nigerian sites. Regarding UK sites, it can also be seen that Gaborone sites waste more bricks and concrete than UK sites. Gaborone sites waste more bricks and concrete than Dutch sites. Comparing the waste rates on Gaborone sites with those on Israeli sites it can also be seen that Gaborone sites waste more bricks than Israeli sites. It can also be seen that Brazilian sites waste more cement, sand, bricks and mortar than Gaborone sites. Judging from the waste patterns in Table 3.10 it would seem that Gaborone sites generate more materials waste than Nigerian, UK, Dutch or Israeli sites.

(viii) The variability of materials waste

Table 3.11 shows the direct waste of the principal materials on Gaborone sites. Table 3.11 (Column 3) shows that waste vary considerably between different materials. The minimum waste rate was recorded for concrete (5.4%) and the highest for sand (12.9%). It can also be seen from Table 3.11 (Column 2) that there is a wide variation in waste between sites for the same material. For example, the waste range for cement is 4.5 - 18.5%; the waste range for stone is 7.3 – 15.6%; and the waste range for mortar in brickwork is 3.7 – 10.5%.

Table 3.10 Comparison of materials waste on Gaborone sites with those on overseas sites

Material	Overall waste (%)					
	Gaborone Sites (1)	Nigerian Sites (2)	UK Sites (3)	Dutch Sites (4)	Brazilian Sites (5)	Israeli Sites (6)
Cement (bagged)	9.5	4.68	-	-	39.5	-
Sand	12.9	4.27	-	-	29.5	-
Stone	11.2	2.3	-	-	-	-
Common bricks	10.9	-	8.5	6	17.5	5.2
Facing bricks	9.6	-	12.5	9	17.5	7.1
Concrete (site mixed)	5.4*	-	3.5	3	5	-
Mortar (site Mixed)	9.4*	-	-	10	48	-

(5) These are average wastes calculated from figures given by Soibelman et al (1994), Pinto (1989) and Pinto and Agopayan (1994) all cited in Bossink and Brouwers (1996) (See Table 1.7, Page 25).

* These figures are daily waste rates.

\- Figures not available.

Table 3.11 Direct waste of principal materials on Gaborone sites

Material	No. of Sites (1)	Waste range (%) (2)	Overall waste average (%) (3)	Normal allowance in tender (%) (4)
Cement (bagged)	11	4.5 - 18.5	9.5	3.4
Sand	11	8.1 - 16.8	12.9	8.2
Stone	11	7.3 - 15.6	11.2	5.9
Common bricks	11	7.8 - 15.1	10.9	4.0
Facing bricks	7	7.5 - 12.5	9.6	4.1
Concrete (site-mixed)	11	2.3 - 7.8*	5.4*	3
Mortar in brickwork (site-mixed)	11	3.7- 10.5*	7.1*	2.8
Mortar in plasterwork (site-mixed)	11	8.3 - 14.8*	11.7*	6.1

* These figures are daily waste rates.

3.2 Results from the questionnaire

Results from the questionnaire are summarised in Appendices 3 and 4. Appendix 3 shows questionnaire results from the sites. Appendix 4 shows tallies of the questionnaire results. The questionnaire results showed that none of the firms planned their materials to a time schedule. In fact, none of the firms could produce a schedule of materials. None of the sites pre-planned their storage areas and transport routes. All the sites checked the quality and quantity of materials delivered to site. Only four out of eleven sites recorded the materials delivered to site. None of the sites recorded materials issued to operatives. Only four sites recorded materials transferred to other sites. Regarding the checking of stocks, the survey showed that only two sites carried out frequent checks. None of the sites monitored materials waste. On enquiring why their firms failed to prepare materials schedules, plans of materials storage areas and site transport routes, all the site supervisors but one (agent on site D) cited time constraint as the militating factor. The agent on Site D indicated that his firm being a small size firm, did not have the expertise to prepare such documents. Regarding checks on quality and quantity of materials delivered to site, my investigations revealed that on many occasions some site supervisors were absent from sites when materials arrived. In the circumstance therefore, other site workers who were not qualified were asked to perform the checking duties. My investigations further showed that only two sites had qualified materials checkers who could make proper checks on materials in the absence of their site supervisors. On the question of why their firms did not monitor materials waste, many site supervisors indicated that it was time consuming and expensive to carry out such an exercise. Some of the supervisors also said that their firms did not have the needed expertise to carry out such an exercise. One agent indicated that his firm would normally take the monitoring of materials waste seriously when working on a large project.

3.3 Personal observations

Security on most of the sites were found to be very poor. Six sites (Sites A, B, C, D, F and H) did not have fences. The absence of adequate fences on these sites made it difficult to monitor the movement of people and vehicles into and out of the sites. This situation increased the risk of theft on those sites. No checks were carried out on vehicles going out of the sites. This means that there was no way of knowing if stolen materials were being taking away. It was also observed that all the sites failed to make adequate provision for the lighting up of their sites during the night thus exposing the sites to theft and vandalism. Little attention was paid to the pre-planning of stores, storage areas and site transport routes. Regarding storage of materials, three major problems were noted: inadequate storage spaces, multiple storage and poor location of stores and compounds. For example, Sites A, B and D had to store bagged cement in the open because of insufficient space in the storeroom, Sites C, D, E, I, J and K stored sand and stone in several locations (multiple storage) due to bad planning and all the sites except Sites B, E and I located their stores and compounds close to the site perimeter which increased the risk of theft and pilfering. It was also noted that there was no control over the supply of materials to the sites with the results that large amount of materials were brought to the site prematurely. The most affected materials were cement, bricks, sand and stone. It was noted that during the working hours six sites left their stores open when not being used - a dangerous practice! It was also noted that none of the sites had well defined transport routes. Dumper drivers and wheelbarrow pushers used routes of their choice. Some often chose long routes. Also, most of the routes used by dumpers and wheelbarrow pushers were in a bad state. For example, on Sites A, B, C, F, G and H the transport routes were found to be bumpy with the result that dumper drivers and wheelbarrow pushers spilled concrete and mortar as they moved along these routes.

CHAPTER 4

SUGGESTIONS FOR REDUCING MATERIALS WASTE ON SITE

SYNOPSIS

This chapter makes suggestions on ways and means of reducing materials waste on building sites to the minimum. It is suggested that materials deliveries should be properly planned. It is also suggested that adequate care should be taken in storing materials and storage areas and site transport routes should be properly planned. A number of security precautions are also recommended for minimising the risk of theft and pilferage. Care and proper handling in the use of materials and proper checking and regular accounting of materials are also recommended. The need for materials control policy is emphasised. It is also stressed that both head office personnel and site personnel should be educated on waste prevention. Finally, it is suggested that firms should draw up *codes of practice for waste reduction* to guide site personnel in the use of materials on site. It is worth noting that the suggestions made in this chapter are directed at the contractor.

4.1 Delivery of materials

It was noted in the survey that materials were not planned to a time schedule. Poor planning of materials deliveries or the lack of it could create a number of problems on site. For example, materials will not arrive on the site on schedule and in sufficient quantity thus creating shortage or materials will arrive too early which may lead to the deterioration of the materials or the depletion of the materials by pilferage or cause access problems around the site. It is therefore recommended that:

(i) Standard schedule of materials should always be prepared for every contract irrespective of size (See Appendix 4).

(ii) Materials should be referenced or coded to facilitate their control on site.

(iii) A copy of the schedule should be kept on site to assist site management in the control of materials.

The survey also revealed that many contractors failed to keep proper records of materials deliveries to the site. The contractor should ensure that proper records are kept of materials deliveries. It is therefore recommended that *materials delivery sheet* (See Appendix 6) should be used to record materials delivered to site and materials transferred to other sites. Checks on the accuracy of deliveries of materials should be made regularly by the site staff (materials checker or foreman) to reduce the risk of 'short deliveries' by the suppliers of materials. Site management should ensure that there is always somebody (materials checker or the foreman) on hand to check the quantity and quality of materials delivered to the site. A weigh-bridge may be introduced in a large project or group of projects to help keep account of the correct amount of materials (especially loose materials such as sand and stone) brought to the site. Any discrepancies observed during checking should be noted on all copies of the delivery note.

Delivery drivers should be properly supervised. If there is a lack of supervision, delivery drivers would simply unload the materials in any vacant place they find convenient. This usually leads to waste of materials through double handling. In the case of aggregates, larger amounts of them may be lost into the ground if they are unloaded on soft ground, or they may not be fully utilised if they are not unloaded near to the mixing plant.

4.2 Storage and internal transport

The survey revealed a number of shortcomings in the storage and protection for materials on site. Many sites stored bagged cement on bare floor. If the floor is damp, cement will solidify before it is used. The material should therefore be prevented from coming into contact with the bare floor. It should be stacked on a raised platform to prevent any contact with moisture from the ground. Site inspections also revealed that stacking heights of bagged cement were excessive, usually more than 2 metres. Stacking heights of materials especially cement and bricks should not be more than 2 metres high and 1.5 metres wide. If materials are stacked too high they may either fall over and get damaged or the bottom part may be damaged due to excessive pressures. The practice of dropping bags of cement from a height should be discouraged. Instead, bags of cement should be lowered gentle onto the stacks. It was noted that contractors stored sand and stone on the bare ground. This practice should be discouraged. If the materials are dumped on bare ground they sink into the ground and become contaminated. Sand and stone should therefore be prevented from coming into contact with the bare ground. The materials should be stored on hard standings or timber boards. The materials should also be protected from weathering and spreading by enclosing them with retaining boards.

It was also noted that contractors failed to pre-plan storage areas for materials. In fact, none of the sites surveyed had its storage areas pre-planned. Pre-planning of storage areas enhances effectiveness of materials handling and hence materials control. For example, it ensures that materials are stored close to their point of use to eliminate double or multiple handling. It also ensures that adequate storage areas are allocated to materials thus preventing the frequent movement of stacks which inevitably increases the risk of waste. It is therefore recommended that the contractor should always pre-plan storage areas before the commencement of work on site. Location of storage areas on site should always be planned by reference to the construction programme. To ensure proper planning of storage areas the contractor should seriously consider the following factors:

(i) Proper locations of the storage areas. Storage areas should be as close as possible to the place of work in order to avoid double or multiple handling.

(ii) Adequacy of storage areas. The contractor should ensure that the area allocated has sufficient space to accommodate both the materials to be stored and to allow for movement by the delivery vehicles and handling equipment. There should also be free access to withdraw materials as needed.

It was also noted that contractors hardly pre-plan site transport routes. The lack of or inadequate transport routes on site will prevent free and ready access of plant or other vehicles to and from storage and working areas. In such a situation it is inevitable that materials will be damaged. It is therefore recommended that the contractor should always pre-plan his site transport routes. The following factors should be given serious consideration during the pre-planning stage:

(i) The routes should be laid in such a way that they will provide easy access to materials, equipment and working areas.

(ii) The routes should be as short as possible to minimise materials movement. The use of string diagrams will help determine the shortest transport routes.

(iii) The widths of transport routes should be adequate to accommodate vehicles in order to prevent vehicles from damaging stacked materials.

(iv) Transport routes should as far as possible be level and should be well maintained.

4.3 Security on site

Security on most of the sites surveyed was poor. It is therefore recommended that the contractor should take the following security precautions to prevent materials from being lost or damaged by theft and vandalism.

(i) The site should be adequately fenced. Fences should be high enough to prevent intruders from scaling them. Fences should not be less than 2 metres high. Fences should also be provided with strong gates and well secured padlocks.

(ii) Storage compounds and stores should be sited well away from the site perimeter or road to minimise the risk of theft and pilfering.

(iii) Adequate lighting should be provided during the night to deter potential thieves.

(iv) Security guards/watchmen should be employed to keep watch over the site, especially during non-working hours.

(v) Stores should not be located in inaccessible positions where visual control is obscured or difficult.

(vi) Stores should always be locked when not in use.

(vii) Locks should be changed periodically.

4.4 Handling and use of materials

The survey showed lack of care among site operatives regarding the use of materials on site. It is therefore recommended that site operatives should be properly supervised during site operations. Labourers should be instructed to handle materials with care during transportation. For example, bricks should not be dumped from wheelbarrows during off-loading. This practice often results in breakage or chipping of the edges of the bricks. Wheelbarrows and dumpers should not be overfilled with concrete or mortar as this, results in loss of materials through spillage. Site management should ensure that labourers mix concrete and mortar on suitable mixing boards. The practice of mixing concrete and mortar on bare ground should be discouraged. Instead, the materials should be mixed on a timber platform or hard surface. Labourers should be made to mix the right amount of concrete or mortar. Should excess concrete or mortar be produced site management should ensure that it is profitably used somewhere else rather than dumping it on site only to be wasted. Careless cutting of materials such as bricks, plasterboard sheets, timber and roofing sheets by tradesmen should be discouraged. Tradesmen should be advised to take adequate care in cutting. Efforts should be made to salvage bricks left behind by bricklayers and those hidden under debris. Efforts should also be made to salvage broken bricks for re-use. The broken bricks can be used as bats to avoid the cutting of full lengths of bricks as bats.

4.5 Site accounting

The survey revealed that contractors hardly account for materials waste both during and after construction. The importance of site accounting cannot be over emphasised. Without proper site accounting the contractor will not know or cannot control his waste performance. It is therefore recommended that the contractor should carry out waste reconciliation regularly, possibly on a monthly basis, to warn site management of the likely occurrence of waste on site. In this regard, the contractor is advised to adopt the procedures given in BRE Current Paper CP 5/79,1978 ("Site Accounting for Waste of Materials"). Materials issued to and returned by site operatives should be properly recorded. This will assist in materials reconciliation. Site management should ensure that stocks are taken regularly to determine any shortages that might occur during the process of construction.

4.6 Education

There is the need to educate both technical staff and site operatives on waste prevention. Workers in the contractor's firm should be made aware that so much is being wasted. Posters should be placed at strategic points on the site to remind workers about the importance of waste prevention. Management should organise periodic in-company training in materials management and control for the technical staff. Management should also organise site training for site operatives.

4.7 Materials control policy (MCP)

None of the firms surveyed had waste control policy. This shortcoming adversely affected their waste control performances on site the result of which was the high levels of material waste recorded in the survey. Management has an important role to play in the control of waste on site. The formulation of sound materials control policy (MCP) will go a long way in reducing on site materials waste to the minimum. It is therefore recommended that every firm irrespective of size should have a sound MCP. In this regard a waste prevention committee should be formed to formulate this policy. The policy should cover areas such as purchasing, estimating and scheduling, materials checking and recording, care and protection of materials, materials handling and distribution, waste accounting and feedback and training programmes. It is also recommended that management should employ a waste control officer (Dand 1973 p 20, Skoyles 1984 p 3).

4.8 Code of practice for waste reduction

The need for a *code of practice for waste reduction* in the contractor's organisation cannot be overemphasised. The following paragraphs outline the details of such a code.

(a) Organisation and planning

(i) Develop a system of materials control before the commencement of work on site. Arrange for the necessary forms and procedures.

(ii) Consider the following factors: site layout, methods of site transport, hoisting, handling and storage. These factors should be considered well in advance before the procurement of materials commences as these will affect the type of materials to be ordered, their quantity, their packaging and their rate of delivery.

(b) Purchasing

(i) List materials required by analysing the bills of quantities and then determine suitable sources of supply.

(ii) Send out enquiries to suppliers. Specify precisely the quality and quantity of materials, the timing and method of delivery and the method of packaging.

(iii) Select from the quotations received and place an order. Consider the following factors before selecting a supplier: whether the price is reasonable; whether his specification complies with the firm's own; whether the terms and conditions of sale are favourable; whether he can supply the material as and when required; and whether his payment terms are favourable.

(c) Estimating and scheduling

(i) Take-off material quantities from the drawings. Relate wastage allowances to the site, type and quality of materials and their method of packaging, and method of storing and handling on site.

(ii) Determine when the materials are required and their delivery periods with the help of the master programme. Prepare a materials schedule (See Appendix 5).

(iii) Expedite deliveries by telephone, letter, or visit the manufacturer.

(d) Materials checking and recording

(i) Ensure that storage areas are prepared for the reception of the materials.

(ii) Check quality of materials at works and on site.

(iii) Arrange for testing of materials where necessary.

(iv) Check quantity of materials delivered. Note any poor quality materials, shortages and/or damages during delivery and record them on all copies of the delivery notes. Enter details of materials received onto a *material delivery sheet* (See Appendix 6).

(e) Care and protection of materials

(i) Ensure that materials are properly stacked: check that materials are not stacked too high (height must not be more than 2 metres); check that stacking is on a firm surface or provided with a firm base; check that materials are not in direct contact with the bare ground.

(iii) Ensure that materials are adequately covered to prevent damage due to rain and solar energy: materials such as timber and reinforcement are to be covered with polythene sheets or stored under a covered shed where necessary.

(iii) Ensure that loose materials (e.g. sand and stone) are stored on hard standings or timber boards to prevent them from coming into contact with the bare ground.

(iv) Ensure that loose materials (e.g. sand and stone) are prevented from weathering and spreading by enclosing them with retaining boards.

(iv) Ensure that sufficient security precautions are taken to prevent materials from being lost or damaged by theft and vandalism. That is, ensure that:

1. the site is adequately fenced,
2. storage compounds are sited well away from the site perimeter or road,
3. the site is provided with adequate lighting during the night,
4. the site is provided with security guards during non-working hours,
5. stores are located in accessible positions where visual control is made easy,
6. stores are always locked when not in use.

(f) Materials handling, distribution and placement

(i) Plan in advance adequate storage space in the correct position to ensure security, safety, and protection.

(ii) Plan in advance site transport routes to facilitate easy access to and from storage areas and working areas.

(iii) Ensure that handling equipment is compatible with handling methods.

(iv) Ensure that transport routes are clear of obstructions and that they are well maintained.

(v) Assess in advance the amount of wet materials (e.g. concrete, mortar, and plaster) required for the day – over mixing of wet materials can lead to considerable waste.

(vi) Site operatives must be given adequate instructions regarding the proper handling and use of materials.

(g) Waste accounting and feedback

(i) Waste reconciliation must be carried out regularly (preferably every month) to assess waste levels.

(ii) A waste controller must carry out periodic inspections on site to spot actions that are likely to generate waste and to notify site management accordingly.

(h) Training programmes

(i) Draw up comprehensive training programme for the firm.

(ii) Arrange for specialised courses on materials management and control for the technical staff.

(iii) Organise periodic in-company training in materials management and control for the technical staff. Participants must include the following people: managers, contract managers, at least one quantity surveyor and one estimator, buyer, and the plant manager. The organisers must focus on the following: how waste occurs and how it varies, how it can be identified, and the good practice needed to gain the optimum levels.

(iv) Organise site training for site operatives. The role of the operatives in waste prevention on site must be spelt out to them. Films and videos must be used to complement the lectures.

CHAPTER 5

TESTING THE SUGGESTIONS FOR WASTE REDUCTION ON A SELECTED SITE

SYNOPSIS

This chapter discusses the application of the suggestions and guidelines proposed for the reduction of materials waste on site. The waste prevention methods adopted on the test-site (Site L - See Appendix 1) are discussed. Results of the investigation are also discussed. Factors contributing to the reduction in waste on the selected site are also discussed.

5.1 Waste prevention methods

The following waste prevention methods were adopted on the test-site (Site L).

(i) Awareness

It was necessary to raise an awareness of waste among the site workers. The site agent therefore summoned a meeting of all the site workers. He alerted them of the high level of materials waste on the company's sites. He informed them on the need to minimise waste on site. He outlined the causes of waste on site and how it could be prevented. He implored every worker to assist in minimising materials waste.

(ii) Delivery of materials

The site agent appointed a materials-checker to record and supervise the delivery of materials. He was instructed to make checks on the accuracy of materials deliveries in order to reduce the risk of 'short deliveries'. The materials checker was also asked to supervise delivery drivers to ensure that materials were delivered to the right location to avoid double handling.

(iii) Storage and internal transport

A plan showing the locations of the storage areas of materials was prepared (See Appendix 7). This was to ensure that materials were stored close to their point of use to eliminate double handling. Special routes were designated for wheelbarrow pushers, dumpers and trucks to ensure free and ready access to and from storage and working areas. The storage and protection of materials were also given special attention. Bagged cement was stacked on a raised platform to prevent the material from being damaged by moisture from the ground. Consideration was also given to the stacking height of cement and bricks. The stacking height of these materials were limited to 2 metres to ensure that they would not fall over and get damaged or the materials at the bottom would not be damaged due to excessive pressures. To minimise waste of cement, labourers were instructed not to drop bags of cement from a height during storage but instead they should lower them gently. Attempts were also made to minimise waste of sand and stone due to multiple storage. Delivery drivers were therefore instructed to unload the materials in one location. Attempts were also made to further minimise waste of sand and stone. The materials were therefore provided with timber retaining boards to prevent them from weathering and spreading. The storing of sand and stone was a problem. The contractor stored the materials on the bare ground He argued that the cost of providing timber platform or hard-standing would far outweigh the savings resulting there of.

(iv) **Security on site**

The site was adequately fenced and provided with two strong gates and well-secured padlocks. A security guard was employed to monitor the movements of traffic into and out of the site. He was asked to search all vehicles going out of the site. A watchman was also employed to keep watch over the site during the non-working hours. The storage compound and stores were sited well away from the site perimeter to minimise the risk of theft or pilferage (See Appendix 7). The materials checker was asked to take control of the stores. He was asked to monitor the movements of people into and out of the stores. He was to ensure that the stores were always locked when they were not being used.

(v) Handling and use of materials

Attempts were made to minimise concrete and mortar spillage. To minimise spillage due to overfilling of wheelbarrows, mixer drivers were instructed as to the level to which wheelbarrows and dumpers were to be filled with concrete and mortar. At the mixing area polythene sheet was spread on the ground to salvage over-spilled concrete and mortar from wheelbarrows and dumpers. Labourers were also instructed to carefully pour concrete into foundations so as to avoid spillage. Attempts were also made to minimise mortar waste during plastering. Timber boards were therefore placed at the foot of scaffolding to collect fallen mortar for re-use. To avoid over-mixing of concrete and mortar, the site agent was asked to calculate the amount of materials required per day and the labourers made to mix as specified. Attempts were also made to minimise waste of bricks. Labourers were therefore instructed to carefully:

(a) remove bricks from stacks,

(b) load bricks into wheelbarrows instead of throwing them,

(c) unload bricks instead of dumping them on the ground.

Bricklayers were also instructed to cut bricks with care to minimise waste. They were also encouraged to use cut-bricks as bats. In addition, the site agent appointed two labourers to salvage bricks. They were asked to tour the site each day to pick unused bricks left behind by bricklayers. They were also asked to search for unused bricks hidden under debris. Also, they were asked to collect broken bricks for re-use as bats.

5.2 Results from the investigations

There was an appreciable decrease in the level of waste of the principal materials investigated on the test-site (Site L). The results of the investigations are now discussed.

(i) Waste of concrete (site mixed)

Table 5.1 shows a waste reduction of 7.4% of concrete on Site L (test-site). There was little spillage of concrete on Site L as labourers took care in transporting and pouring the material in trenches. Spillage due to overfilling of wheelbarrows and dumpers was also minimised as mixer drivers took great care in pouring concrete from the mixing drum. Also, spilled concrete at the mixing area was salvaged by the use of polythene sheeting spread on the ground. The frequent over-mixing of

Table 5.1 Comparison of materials waste rates on Site L (test-site) with materials waste rates on Sites J and K

Material	Overall waste on site (%)					Waste allowed in tender
	Site J	Site K	Avg. waste on Sites J and K	Site L (Test-site)	Re-duction in waste on Site L (test-site)	
Cement (bagged)	5.3	4.5	4.9	4.8	2.0	2.5
Sand	8.1	9.5	8.8	8.6	2.3	5
Stone	7.3	8.5	7.9	7.6	3.8	5
Common bricks	8.8	9.5	9.2	8.5	7.6	2
Facing bricks	8.2	7.5	7.9	7.2	8.9	2
Concrete (site mixed)	3.1*	2.3*	2.7*	2.3*	7.4*	2
Mortar in brickwork (site mixed)	4.2*	3.7*	4.0*	3.6*	10*	2
Mortar in plasterwork (site mixed)	9.3*	8.3*	8.8*	8.0*	9.1*	5

*These figures are daily waste rates.

concrete were reduced as labourers knew how much concrete to mix in any particular day.

(ii) Waste of mortar (site mixed)

Table 5.1 shows a waste reduction 10% of mortar in brickwork and 9.1% of mortar in plasterwork on the test-site (Site L). The amount of spillage in mortar during bricklaying and plastering was considerably reduced. Spilled mortar was salvaged from timber boards placed at the foot of the scaffolding. As in the case of concrete, spillage due to overfilling of wheelbarrows and dumpers was also minimised as mixer-drivers took great care in pouring mortar from the mixing drum. Spilled mortar at the mixing area was salvaged by using polythene-sheeting spread on the ground.

(iii) Waste of bricks

Table 5.1 shows a waste reduction of 7.6% of common bricks and 8.9% of facing bricks. The campaign to salvage broken bricks and bricks hidden under debris resulted in some savings in bricks. Damages were minimised as labourers took great care in removing bricks from the stacks. Transportation damages were also minimised as labourers handled facing bricks with care during loading and off-loading. Cutting waste was still considerable as bricklayers used trowel instead of the brick chisel (bolster) or brick-saw to cut bricks to size. However, some savings in bricks were obtained through the use of broken bricks as bats.

(iv) Waste of cement (bagged)

Table 5.1 shows a waste reduction of 2% of cement on Site L (test-site). There was no reported damage of cement as labourers took great care in putting it in storage. Also, there was no reported damage of bagged cement due to moisture as the material was stored on a raised platform. It would seem that the tight security on site did minimise the incidence of pilferage with consequent reduction in the waste rate of cement.

(v) Waste of sand and stone

Table 5.1 shows a waste reduction of 2.3% of sand and 3.8% of stone on Site L (test-site). Storage of sand and stone was still a problem on Site L. These materials were stored on bare ground. As mentioned earlier, the contractor refused to store them on timber platform or hard standing. The slight reduction in waste of sand and stone was therefore due to the use of timber retaining boards to prevent the materials from weathering and spreading and the avoidance of multiple storage of the materials.

(vi) Savings in the principal materials

The savings in the principal materials were estimated (See Table 5.2). The greatest savings occurred in common bricks (P9405.76) followed by facing bricks (P8479.48), stone (P466.74), cement (P384.22) and sand (P96.60). Table 5.2 further shows that the contractor made 7.39 % savings on the total amount of purchased materials.

5.3 General comments

The contractor was delighted to learn that his site had made some savings in materials cost, moreso when the savings were achieved without the use of extra resources. It must be noted that no additional personnel were employed neither were the site staff given additional remuneration for controlling waste on site. It was pointed out to the contractor that the site could have made more savings if the site staff had been given some form of monetary incentives. The contractor agreed with the researcher that the problem of wastage on site could be minimised through the adoption of effective materials control procedures on site. However, he echoed the often-held view among contractors that the measurement of waste is a tedious exercise.

Table 5.2 Savings in the principal materials

Material	Purchased Amount	Unit Price (P)	Total Purchase Price (P)	Reduction in waste (%)	Total Savings (P)
Cement (bagged)	1 290 No.	14.90	19 221.00	2.0	384.22
Sand	350 M3	12.00	4 200.00	2.3	96.60
Stone	170 M3	72.25	12 282.50	3.8	466.74
Common bricks	221 000 No.	0.56	123 760.00	7.6	9 405.76
Facing bricks	51 500 No.	1.85	95 275.00	8.9	8 479.48
Total			254 738.50		18 832.80

Savings as a percentage of the total amount of materials purchased:

(Total savings/ Total purchase price) x 100%

= (P18 832.80 /P254 738.50) x 100%

= 7.39 %

CHAPTER 6

CONCLUSIONS

6.1 Conclusions with respect to stated objectives

The building industry is wasteful in the use of materials. Studies in the UK, the Netherlands, Brazil, Israel, South Africa and Nigeria have all recorded high waste rates of materials on building sites. To make the industry more productive attempts must be made to reduce this wastage to the minimum.

The study attempted to investigate the wastage problem on building sites in the Gaborone area. The purpose was to identify the causes of materials waste on Gaborone sites in order that a set of guidelines for reducing materials waste on sites could be formulated. An investigation of materials waste on twelve building sites in the Gaborone area was therefore carried out. The investigation was carried out through site visits, a questionnaire survey and interviews. Actual site measurements of waste were also taken during the progress of work. The contractors' records of delivery were compared with the measurements of the finished work. The investigation showed a high level of waste of materials on Gaborone sites. The waste rates of concrete, mortar, bricks, cement, sand and stone were all found to be high.

(i) Waste of concrete

Three main factors were identified as contributing to the high waste rate of concrete on Gaborone sites: spillage, overproduction and loss resulting from mixing the material on bare ground. Spillage of the material occurred during transportation. Most often wheelbarrows and dumpers were overfilled and they spilled concrete as they travelled over bumpy grounds. Spillage of the material also occurred during placing. Labourers did not take adequate care in pouring concrete in foundations. Spillage also occurred at the mixing sites. Mixer drivers would often overfill transporting plant (wheelbarrows and dumpers). The spilled concrete was not salvaged but left to harden. Regarding overproduction, labourers often mixed more concrete than was needed because of poor planning. Loss of the concrete also occurred as a result of mixing the material on bare ground. Some concrete got contaminated with earth and was rejected because it was not suitable for use.

(ii) Waste of mortar

Spillage, overproduction and mixing the material on bare ground were identified as the major causes of waste of mortar. Regarding spillage, it was noted that during bricklaying and plastering mortar droppings were not salvaged but instead left to harden. Also, loss of the material occurred during transportation. As in the case of concrete, transporting plant (wheelbarrows and dumpers) were often overfilled and they spilled mortar as they moved over bumpy grounds. Loss of mortar also occurred at the mixing point as mixer drivers sometimes overfilled wheelbarrows and dumpers thereby causing spillage. The spilled mortar was left to harden at the mixing point. Regarding overproduction, labourers often did not know the quantity of mortar needed for the day and as a result they tended to over-mix mortar. Loss of the material also occurred as a result of mixing the material on bare ground. Some mortar got contaminated with earth and was rejected because it was not suitable for use.

(iii) Waste of bricks

A number of factors were identified as being responsible for the high waste rate of bricks. The major source of waste was cutting waste. A lot of cutting was needed to cut bricks to size. Some loss occurred in common bricks because bricklayers used the wrong tool (trowel) to cut the bricks. Loss of bricks also occurred because bricklayers would often cut bats from full bricks instead of using pieces of cut bricks as bats. Poor handling at the stacks also contributed to the high waste in bricks. Many bricks were broken at the stacks because labourers did not take adequate care in removing them from the stacks. Loss of the bricks also occurred because labourers did not take adequate care in loading the materials into the transporting plant (wheelbarrows and dumpers) and offloading from the same. The labourers often threw the bricks into the transporting plant when loading and also dumped the materials from the transporting plant during off-loading and as a result some bricks got broken and some had their edges chipped off. The failure to use the appropriate plant to lift bricks at higher levels also contributed to the high waste rate in bricks. On some of the sites labourers threw bricks from person to person until they reached the point of use. This practice resulted in many bricks falling and consequently breaking and chipping.

(iv) Waste of cement

Two main factors were identified as being the cause of wastage of cement on Gaborone sites, namely: spillage and theft and pilferage. Regarding spillage, it was noted that labourers did not take adequate care in putting bagged cement in storage and as a result some of them got broken thus spilling their contents. Also, some bagged cement got broken because of excessive stacking heights. Some sites lost cement through theft and pilferage.

(v) Waste of sand and stone

Poor storage was the major cause of the high waste rates in sand and stone. The materials were always stored on bare-ground and losses occurred because some of the materials often sank into the ground and got contaminated with earth. Also, the sites failed to provide adequate enclosures to prevent the materials from spreading. Some losses of the materials also occurred through multiple storage.

(vi) Variability of materials waste

The survey showed that waste varies considerably between different materials. The survey also showed that there is a wide variation in waste between sites for the same materials. The waste rates of the principal materials were analysed in terms of project size. The results showed that waste in a specific material increases as the size of the project increases. The waste rates on Gaborone sites were also compared with the waste rates on overseas sites. It was found that:

(a) Gaborone sites waste more cement, sand and stone than Nigerian sites.

(b) Gaborone sites waste more bricks, concrete and mortar than UK sites.

(c) Gaborone sites waste more bricks than Israeli sites.

(d) Brazilian sites waste more materials than Gaborone sites.

(vii) Results from the test-site

The proposals for waste reduction were tested on a selected site. There was an appreciable decrease in the level of materials waste. The test-site recorded low waste rates of concrete, mortar, bricks, cement, sand and stone. The reduction in waste rates of the materials was due to a number of waste control measures instituted on the test-site:

(a) The site agent ensured that the materials were properly stored and protected.

(b) Storage areas were properly planned.

(c) Theft and pilfering was minimised due to the adoption of a number of security precautions on site.

(d) Adequate instructions were given to site workers regarding the most effective methods of carrying out their respective tasks.

(viii) Recommendations

A numb' . of suggestions for minimising materials waste on site were made. It was recommended that:

(a) Every firm irrespective of size should have a sound materials control policy.

(b) Management should educate both technical staff and site operatives on waste prevention. Workers should be made aware that so much is being wasted and that something should be done about it.

(c) A waste controller should be employed to carry out periodic inspections on site to spot actions that are likely to generate waste and to notify site management accordingly.

(d) The contractor should adopt effective materials control procedures on site. The following recommendations were therefore made:

1. Materials deliveries should be properly planned to avoid delays or premature deliveries. Delays generate waste (consequential waste). Premature deliveries can lead to the deterioration of the materials or the depletion of the materials by pilferage or cause access problems around the site.

2. An organised method to ensure the proper receipt of materials and supervision of their placement on site should be adopted. Site management should ensure that there is always somebody (materials checker or foreman) on site to check the quantity and quality of materials delivered to site. Materials deliveries and issues should be properly documented to facilitate materials reconciliation. Delivery drivers should be properly supervised during deliveries. Unloading materials in the wrong place can create waste.

3. Proper precautions need to be taken to protect materials from damage. Materials that are susceptible to moisture should always be

prevented from coming into contact with the bare ground. Stacking heights of materials should not be excessive (not more than 2 metres). Adequate cover should be provided for materials (especially those which are susceptible to the weather) to protect them from solar radiation or rain. Loose materials such as sand and stone should be prevented from coming into contact with the bare ground. The materials should also be protected from weathering and spreading by enclosing them with retaining boards.

4. The contractor should take adequate security precautions to prevent materials from being lost or damaged through theft and vandalism. In this regard, the possibility of providing fencing and lighting should be considered. The gate should be manned by a security guard during the working hours. There is also the need to employ a watchman to guard the site during non-working hours. Consideration should be given to the location of stores and storage compounds. These facilities should be sited well away from the site perimeter or road to minimise the risk of theft or pilfering. Stores should not be located in inaccessible positions where visual control is obscured or

difficult. Stores should always be locked when not in use. Also, locks to these stores should be changed periodically.

5. The contractor should always pre-plan storage areas before the commencement of work on site. Pre-planning ensures that materials are stored close to their point of use thereby eliminating double or multiple handling. It also ensures that adequate storage areas are allocated to materials thus preventing the frequent movement of stacks which inevitably increases the risk of waste. Similarly, it is recommended that the contractor should pre-plan site transport routes to ensure free and ready access of plant or other vehicles to and from storage and working areas. The routes should be as short as possible to minimise materials movement.

6. Site operatives should be properly instructed on how to use materials on site. Labourers should be instructed to handle materials with care during transportation. Site management should ensure that labourers mix the right amount of concrete or mortar. The practice of mixing concrete or mortar on bare ground should be discouraged Instead the materials should be mixed on timber boards. Tradesmen should be

advised to take adequate care in cutting. Efforts should be made to salvage items such as broken bricks, short pieces of timber and cuttings of plasterboard sheets for re-use.

7. It is recommended that the contractor should carry out waste reconciliation regularly preferably every month to assess waste levels. The contractor is advised to adopt the procedures given in BRE Current Paper CP 5/79, 1978 ("Site Accounting for Waste of Materials").

Results from the survey have clearly indicated the excessive waste of materials on Gaborone sites. The survey has also shown that lack of on-site materials control is responsible for the high level of materials waste on building sites. The survey revealed many shortcomings in the areas of materials scheduling, materials reception and accounting, storage, handling and use. Regarding materials scheduling, the questionnaire survey showed that materials were not planned to a time-schedule. The effect of this shortcoming could clearly be seen on most of the sites visited. Large amounts of materials, especially cement, bricks, sand and stone were brought to the sites prematurely. The result was that a large amount of these materials were either misused or stolen from the sites. Regarding materials reception and accounting, the questionnaire survey showed that most sites did not document materials delivered to site, materials issued to operatives and materials transferred to other sites. These shortcomings made it difficult for the contractor to monitor the use of materials. Stocks were not taken regularly which often made it difficult for the contractor to assess shortages. There was also the problem of accounting for waste. It was noted that none of the sites monitored waste levels of materials on site. The lack of waste accounting procedures on site undoubtedly compounded the problem of materials waste on the sites because most of the contractors did not know that they were loosing so much materials and therefore could not control their waste performances. Regarding storage, it was noted that contractors failed to pre-plan storage areas for materials. The effects of this shortcoming were clearly seen on some of the sites. For example, six sites were seen to have stored sand and stone in several positions (multiple storage) due to lack of planning. As a consequence these sites recorded high waste rates in sand and stone. Again, three sites had to store bagged cement in the open because of insufficient space in the storeroom. This, again being the result of lack of planning! Yet another example of poor planning was the location of stores and compounds close to the site perimeter, a practice which increases the risk of theft and pilfering. Regarding the handling and use of materials, it was noted that contractors did not take adequate care in handling and placing materials on site. For example, in concreting, bricklaying and plastering losses of the materials occurred because labourers mixed concrete and mortar on bare ground, over mixed the materials, spilled the materials at the mixing sites by overfilling transporting plant and spilled the materials during transportation and placing. During bricklaying and plastering, bricklayers failed to salvage mortar droppings and allowed them to harden. Labourers carelessly removed bricks at the stacks, threw bricks into and dumped bricks from wheelbarrows and dumpers during loading and off-loading resulting in breakage and chipping. Bricklayers carelessly cut bricks resulting in considerable loss of materials.

6.2 General conclusions

The literature survey and the findings of the site survey have clearly indicated that the problem of materials waste on building sites can be reduced through the adoption of proper materials control procedures on site. Results from the test-site indicated that opportunities exist for reducing materials waste on building sites. As seen in Table 5.2 (page 84) the test-site recorded 7.39% savings on the total amount of purchased materials in cement, sand, stone and bricks. Management must develop effective procedures for the receipt and issue of materials within the site, plan in advance adequate storage places and on-site transport routes.

Adequate instructions should be given to site workers regarding the most effective methods of carrying out their respective tasks. Sufficient security precautions should be taken to ensure that materials are not lost or damage by theft or vandalism. Finally, a control system should be established so that budgeted waste and the actual measure of waste levels can be compared while work is in progress.

6.3 Suggested areas for further research

This study has concentrated on materials waste mainly in the Gaborone area. It was also limited to only twelve sites in the Gaborone area. There is therefore the need to investigate the subject of materials waste further by considering a large sample of sites in the Gaborone area. There is also the need to investigate materials waste on a national level to ascertain how much (in monetary terms) the country is loosing by way of materials waste on building sites. The study did not investigate indirect waste and consequential waste of materials. These areas also need further investigation. The researcher could get only one site to test his proposals for waste reduction of materials on site. Although the results from the test site indicated that opportunities exist for reducing materials waste on building sites, it is the view of the researcher that further research need to be undertaken to establish positively this fact. In this regard, it is recommended that as future study, the waste performances of the identified contractors should be monitored vis-à-vis their implementation of the study's recommendations.

6.4 General recommendations

In view of the importance of waste prevention in the National economy the following general recommendations are made:

(a) Waste prevention clauses should be incorporated in the local Standard Conditions of Contract for building works.

(b) Materials management and waste control should be included in the building education curricula in the country.

(c) Professional bodies in the construction industry should organise workshops and seminars to educate both contractors and members of the construction design team on the importance of waste prevention in the industry and the National economy at large.

REFERENCES

1. Arnold J. R. Tony : *Introduction to Materials Management* (Prentice Hall, 1991).

2. Bernold Leonhard E, et al : "Vendor Analysis for Best Buy in Construction" (*Journal of Construction Engineering and Management,* Vol.117, No. 4, December, 1991).

3. Bossink B. A. G., et al : "Construction Waste: Quantification and Source Evaluation" (*Journal of Construction Engineering and Management, March, 1996).*

4. Briscoe Geoffrey : *The Economics of the Construction Industry (Mitchell* Publishing Company Ltd., 1991).

5. *Building Research Establishment Digest 247:* "Waste of Building Materials" (Her Majesty's Stationery Office, UK, March, 1981).

6. *Building Research Establishment Digest 259*: "Materials Control to Avoid Waste" (Her Majesty's Stationery Office, UK, March, 1982).

7. Chandler Ian E : *Materials Management on Building Sites* (The Construction Press, Lancaster, UK,1980).

8. Enshassi Adnan: "Materials Control and Waste on Building Sites" (*Building Research and Information, Vol. 24, No. 1,* 1996).

9. Harris F., et al : *Modern Construction Management* (Granada Publishing Ltd., 1977).

10. Illingworth John, et al : "Materials Management – Is it Worth it?" (*Construction Industry Research and Information Association, Technical Information Service, No. 93*, 1988).

11. Illingworth John, et al : "The Control of Materials and Waste". (*The Institute of Building, Technical Information Service, No. 87*, 1987).

12. IOB Site Control Guide : "Try Reducing Building Waste" (*The Chartered Institute of Building's Site Management Practice Committee*, 1979).

13. Kaekane J. M. : "An Investigation into Materials Management in the Construction Industry – The Case of Gaborone" (B. Eng. Thesis, Department of Civil Engineering, University of Botswana, November, 1994).

14. Lampert Harry : "Productivity in the Construction Industry in the Republic of South Africa". (PhD Thesis, University of the Witwatersrand, Johannesburg, 1990).

15. Mud D. R. : "Wastage of Building Materials – Part 2" (*The Quantity Surveyor*, April, 1975).

16. Olomolaiye Paul : "Materials Management Practice and Waste on Nigerian Building Sites" (*Building Research and Information, Vol. 19, No. 1*, 1991).

17. Oxford University Press : *Concise Oxford Dictionary of Current English* (Oxford University Press).

18. Skoyles E. R. : "Wastage of Building Materials (Part 1)" (*The Quantity Surveyor*, March, 1975).

19. Skoyles E. R., et al : *Waste Prevention on Site* (The Mitchell Publishing Company Limited, 1987).

20. Skoyles John R.: "An Approach to Reducing Materials Waste on Site" (*Site Management, No. 34,* 1984).

21. Stein J. Stewart : *Construction Glossary, An Encyclopedic Reference and Manual* (John Wiley Sons, Inc.,1993).

22. Wyatt D. P. : "Materials Management - Part 1"(*The Institute of Building, Occasional Paper No.18*, 1978).

BIBLIOGRAPHY

1. Apple J. M. : *Plant Layout and Material Handling* (John Wiley and Sons, 1977).

2. Beirne J. M. : "How to avoid Waste on Building Sites" (*The Practice of Site Management, CIOB*)

3. Building Research Station Digest 122: "Security" (Her Majesty's Stationery Office, UK., October, 1970).

4. Burrell C. H., et al : "Cost Reduction on Site – Some new thoughts on an old Subject" (*The Royal Institute of Chartered Surveyors*, November, 1981).

5. Chartered Institute of Building, The : "Materials Control and Waste in Building" (*The Chartered Institute of Building*, October, 1980).

6. Christopher Gordon-Wilson, "When Boys in Blue are not Enough" (*Chartered Builder*, Vol.4, No.5, June, 1992 , The Chartered Institute of Building).

7. Dand R.: "Materials Management in the 1970's" (*Building Materials Jan/Feb 1973*).

8. Forster G. : *Construction Site Studies - Production, Administration and Personnel*(Longman Group Ltd.,1981).

9. Good K. R.: "Handling Materials on Site" (*The Chartered Institute of Building, Technical Information Service, TIS No. 68*, 1986).

10. Illingworth John, et al: "Handling of Materials on Site" (*Construction Industry Research and Information Association, Technical Information Service, No. 92*, 1988).

11. Mc Nutty A. P. : "Management of Small Construction Projects" (Mc Graw-Hill Book Company, 1982).

12. Pheng Low Sui, et al : "The Measurement of Just in time Wastage for a public Housing Project in Singapore" (*Building Research and Information, Vol. 25, No. 2*, 1997).

13. Skoyles E. R. : "Materials Wastage - a Misuse of Resources" (*International Council for Building Research, Studies and Documentation, Vol.4, No.4*, July/August 1976).

14. Upson Alan: "Financial Management for Contractors" (*BSP Professional Books*, 1987).

15. West African Technical Review: "Managing Resources on a Construction Site" (*West African Technical Review*, November, 1982).

16. Wyatt D. P. : "The Control of Materials on Housing Sites" (*Institute of Building, Site Management Information Service*, No. 75 Autumn, 1978).

17. Wyatt D. P. : "Materials Management - Part 2" (*The Institute of Building, Occasional Paper No.23*, 1983).

Appendix 1 List of building sites surveyed in the Gaborone area

Site	Project	Location	Contractor	Contract Value
A	Construction of a showroom for Arma Holding.	African Mall	LMF Construction	P1 200 000
B	Construction of 26 low cost houses for Botswana Housing Corporation.	Gaborone West	Mhago Construction	P1 059 172
C	Construction of 46 medium cost houses for Botswana Housing Corporation.	Gaborone West	Pame Construction	P4 000 000
D	Construction of 7 staff houses for Ministry of Education.	Gaborone West	Thebe Construction	P [illegible]08 647
E	Construction of 6 staff houses for Marang Junior Sec. School.	Broadhurst	Moramosi Construction	P2 500 000
F	Construction of office and workshop for Suncon Pty. Ltd.	Airport Road	Suncon Pty. Ltd.	P1 500 000
G	Construction of a warehouse and an office for Document Bank Botswana Microfilm Centre.	Gaborone West	Suncon Pty. Ltd.	P1 650 000
H	Construction of a filling for British Petroleum.	Tlokweng	Van & Truck Hire	P700 000
I	Construction of 6 staff houses and 4 classrooms for Maoka Junior Sec. School.	Partial	Moramosi Construction	P2 500 000
J	Construction of a dinning hall for Marulamantsi Junior Sec. School.	Gaborone West	Tswana Construction	P700 000
K	Construction of a dinning hall for Kgali Hill Junior Sec. School.	Kgali Hill	Tswana Construction	P700 000
L	Construction of 8 staff houses for Ministry of Education.	Block 6	Tswana Construction	P800 000

Appendix 2 Questionnaire

****

PLEASE tick ✓ relevant block.

****

Name of the firm ....

Address ....

Type of firm:

⬭ Public Company ⬭ Private Company

⬭ Partnership ⬭ Other (State) ....

Size of firm (Number of employees):

⬭ Small (Up to 100)	⬭ Medium (100-500)	⬭ Large (Over 500)

Name of the project ....

....

Location of the site ....

Contract Sum of the project: P

Appendix 2 Questionnaire (Cont'd)

Planning of materials deliveries

1. Did you plan your materials to a time schedule?

○ Yes ○ No

Inspection and checking of materials

2. Are materials checked for quality during delivery?

○ Yes ○ No

3. Are materials checked for quantity during delivery?

○ Yes ○ No

4. Are stocks checked frequently?

○ Yes ○ No

Documentation

5. Do you record the quantity of materials delivered to site?

○ Yes ○ No

6. Do you record the quantity of materials issued to operatives?

○ Yes ○ No

Appendix 2 Questionnaire (Cont'd)

7. Do you record the quantity of materials transferred to other sites?

⬭ Yes ⬭ No

Planning of storage areas

8. Did the firm prepare a layout plan of storage areas for the project?

⬭ Yes ⬭ No

Planning of site transport routes

9. Did the firm prepare a layout plan of transport routes for the project?

⬭ Yes ⬭ No

Site Security

10. Is there provision for night watchman on this project?

⬭ Yes ⬭ No

Monitoring of materials waste

11. Are waste levels of materials recorded ?

⬭ Yes ⬭ No

****

Appendix 3 Questionnaire results from the sites

QUESTIONS	SITE/ANSWERS										
	A	B	C	D	E	F	G	H	I	J	K
Planning of materials deliveries											
1. Did you plan your materials to a time schedule?	No	No	No	No	No	No	No	No	No	No	No
Inspection and checking of materials											
2. Are materials checked for quality during delivery?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3. Are materials checked for quantity during delivery?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4. Are stocks checked frequently?	No	No	No	No	No	Yes	No	Yes	No	No	No
Documentations											
5. Do you record the quantity of materials delivered to site?	No	No	No	No	Yes	Yes	Yes	No	Yes	No	No
6. Do you record the quantity of materials issued to operatives?	No	No	No	No	No	No	No	No	No	No	No
7. Do you record the quantity of materials transferred to other sites?	No	No	No	No	Yes	Yes	Yes	No	Yes	No	No
Planning of storage areas											
8. Did the firm prepare a layout plan of storage areas for the project?	No	No	No	No	No	No	No	No	No	No	No
Planning of site transport routes											
9. Did the firm prepare a layout plan of transport routes for the project?	No	No	No	No	No	No	No	No	No	No	No
Site security											
10. Is there provision for night watchman on this project?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Monitoring of materials waste											
11. Are waste levels of materials recorded?	No	No	No	No	No	No	No	No	No	No	No

Appendix 4 Tallies of the questionnaire results

QUESTIONS	NO. OF SITES/ ANSWERS	
	Yes	No
Planning of materials deliveries		
1. Did you plan your materials to a time schedule?	-	11
Inspection and checking of materials		
2. Are materials checked for quality during delivery?	11	-
3. Are materials checked for quantity during delivery?	11	-
4. Are stocks checked frequently?	2	9
Documentation		
5. Do you record the quantity of materials delivered to site?	4	7
6. Do you record the quantity of materials issued to operatives?	-	11
7. Do you record the quantity of materials transferred to other sites?	4	7
Planning of storage areas		
8. Did the firm prepare a layout plan of storage areas for the project?	-	11
Planning of site transport routes		
9. Did the firm prepare a layout plan of transport routes for the project?	-	11
Site security		
10. Is there provision for night watchman on this project?	11	-
Monitoring of materials waste		
11. Are waste levels of materials recorded?	-	11

Appendix 5 Materials schedule

MATERIALS SCHEDULE

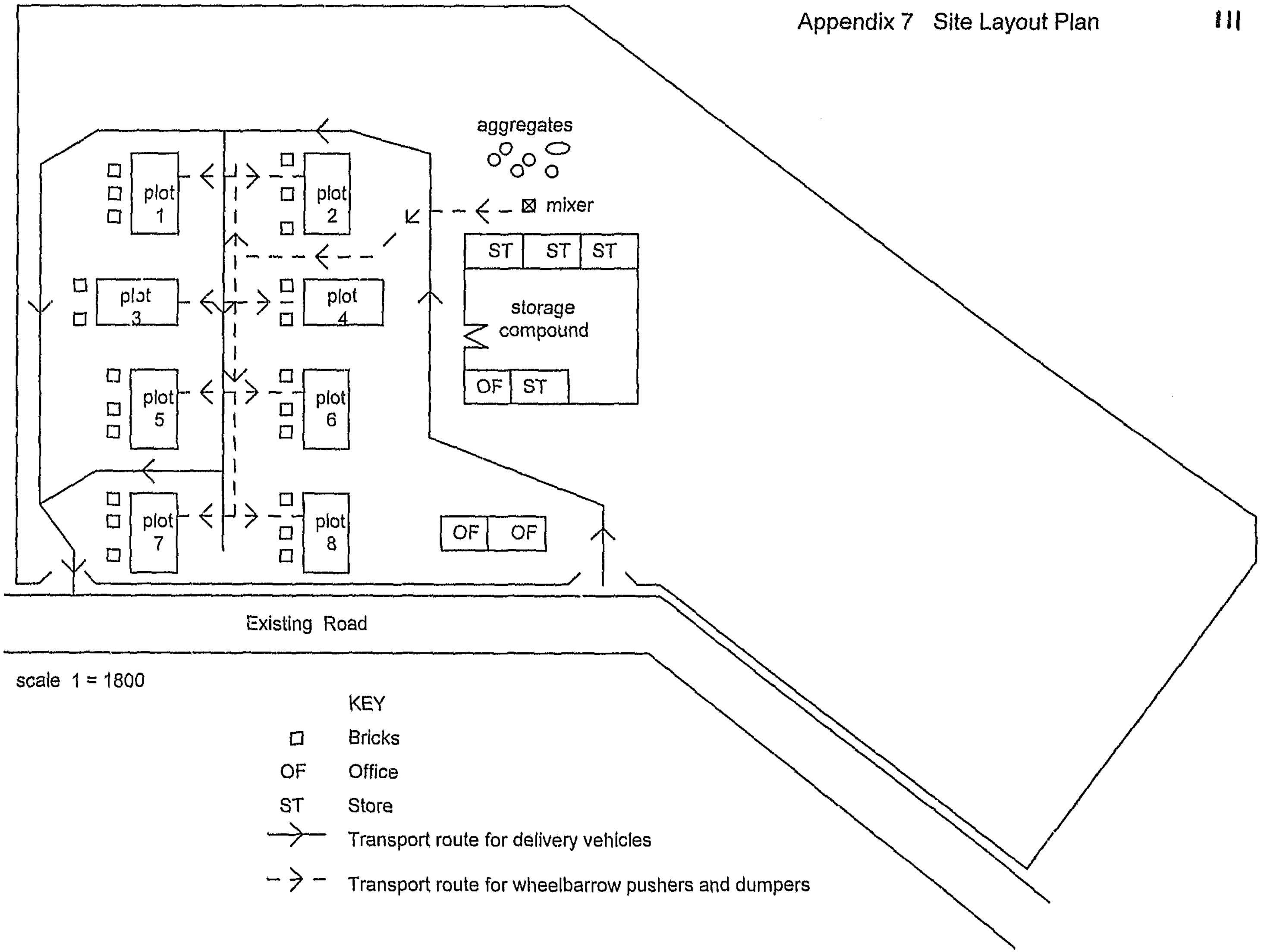
CONTRACT: SHEET NO.

DATE: PREPARED BY:

Ref.	Material Description	Supplier	Address/ Tel. No.	Order No.	Qty.	Bill Ref.	Date Ordered	Key Dates			Remarks
								Notice Reqd.	Date Reqd.	Date Recd	

Appendix 6 Materials delivery sheet

Deliveries			Deliveries			Transfers			Notes
Date	Reference	Quantity	Date	Reference	Quantity	Date	Reference	Quantity	
Material									


aggregates
mixer
plot 1
plot 2
plot 3
plot 4
plot 5
plot 6
plot 7
plot 8
ST
ST
ST
storage compound
OF
ST
OF
OF
Existing Road
scale 1 = 1800
KEY
Bricks
OF Office
ST Store
Transport route for delivery vehicles
Transport route for wheelbarrow pushers and dumpers