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Solid waste management strategy in Botswana: The reduction of construction waste

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Various waste streams are growing in volume and complexity as the economies of developing countries expand. To this end, the control of the environmental impacts associated with construction waste is of increasing concern. While the implementation of environmental management has a direct contribution to environmental protection, it involves the allocation and investment of resources, thus presenting a profit-making challenge, particularly to contractors in the construction industry. This paper investigates construction waste in the Francistown area of Botswana as a case study. The study considers waste from typical construction sites in the Francistown area, which includes sand, cement, concrete stone, concrete, steel, timber and general debris. The data was gathered from a survey and interviews with project managers, contractors, site workers and waste management service providers. The survey shows that construction sites generate large amounts of materials waste. and Poor waste management leads to direct financial losses, poses a danger to the environment, and hampers the national waste management efforts of Botswana. Opportunities are identified to reduce material waste in the developing country context through the adoption of effective materials control and waste management procedures on site.

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INTRODUCTION

Waste, in solid or other forms, is generated during industrial activities in which economically valuable products are supplied to end-customers. Waste reduction can be achieved by introducing cleaner production mechanisms at the generation stage (Australian Department of the Environment and Heritage 2001). Solid waste can further be separated so that some items are then treated before final disposal of the various components to minimise the impacts on the environment. All these processes constitute integrated waste management practices and they are well defined in developed countries.

In 1993 the government of the Republic of Botswana established a waste management project to address the growing waste dilemma in the country, which is attributable to the expanding economy and the increasing urban population (GTZ 1997). The project developed a waste management strategy, launched landfill guidelines, and was responsible for the promulgation of the Waste Management Act in 1998. The waste management hierarchy, as identified by the project, is shown in figure 1 (GTZ 1997).

The waste management strategy in Botswana

The hierarchy strategy (of figure 1) addresses waste management in a broad perspective and embeds the key principles of waste prevention, payment by the polluter, and cooperation among all the parties involved in the waste lifecycle. These points are the foundation on which all other waste management tools are built. The waste management process should be based on the current conditions as a starting point, and thereafter strive for progressive improvement of the situation in terms of (ILO-OSH 2001):

- Minimising and reducing wastes in industry, commerce and households;
- Maximising waste reuse and recycling, and
- Promoting waste collection, treatment and disposal.

Through the national waste management project and strategy, a number of studies were commissioned from 1996 onwards to evaluate the current waste situation in various sectors and to develop guidelines for improving the status quo. The waste streams that have been addressed include scrap metal, oil containing wastes, medical waste, packaging wastes, industrial wastes, and tyre and battery wastes.

Objectives of this study

International research has shown that construction sites generate large amounts of material waste (Building Research Establishment 1981; Lampert 1990; Olomolaiye 1991; Enshassi 1996; Bossink & Brouwers 1996), often attributable to the lack of on-site materials control. Many contractors

Table 1 Forms in which indirect and direct waste can occur in the construction industry

Principal types	Forms of the principal types
Indirect waste	■ 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, eg additional concrete in trenches, which are dug wider than was designed, because no appropriately 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 contract documentation, eg tower-crane bases, site paths, temporary protection ■ Negligent waste, where materials are used in addition to the amount required by the contract owing to the construction contractor's own negligence
Direct waste	■ Deliveries waste comprises all losses in transit to the site, unloading and placing into the initial storage ■ Site storage and internal site transit waste comprise 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 comprises losses due to cutting uneconomical shapes, eg timber, sheeted goods ■ Fixing waste comprises materials dropped, spoiled, or discarded during the fixing operation ■ Cutting waste includes losses caused by cutting materials to size and to irregular shapes ■ Application waste includes materials such as mortar for brickwork, paint spilled or dropped during application 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 includes losses arising from an incorrect decision or from indecision and not related to anything other than poor organisation or lack of supervision ■ Waste caused by other trades. This includes 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 covers pilfering, theft from sites and vandalism ■ Waste due to the incorrect type or quality of materials. This includes waste stemming from materials wrongly specified, waste due to errors, particularly in the bills of quantities and specification ■ Learning waste that is usually caused by apprentices, unskilled 'tradesmen', and tradesmen on new operations

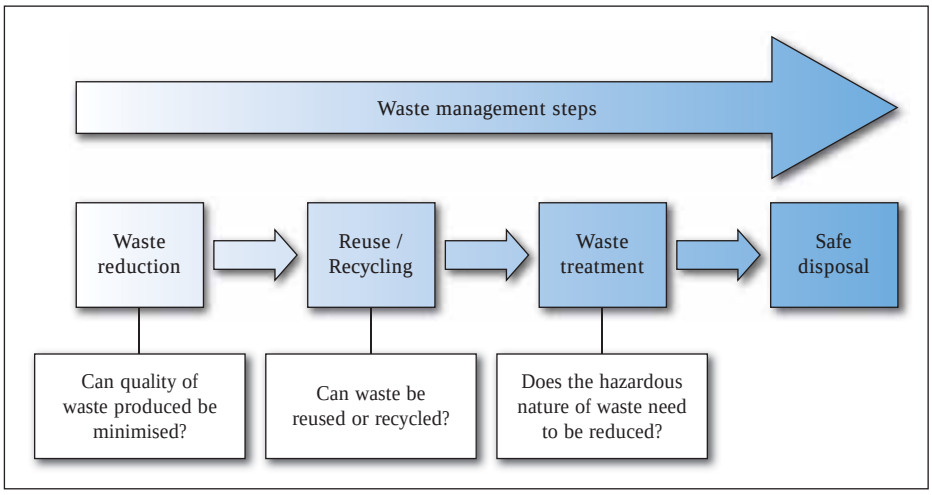

Figure 1 Hierarchy of waste management (adopted from GTZ 1997)

fail to adopt proper controlling procedures as they see these as elaborate or expensive processes (Illingworth & Thain 1987). The approach has been that it is more efficient to allow losses to occur than to involve the use of extra resources to control them, and material waste is subsequently seldom measured and monitored (Skoyles 1984). However, the consequences of mishandling of materials on building sites can lead to a decrease in project profitability and an increase in future building costs, that is, this contributes to low productivity in the construction industry (Wyatt 1978). Furthermore, in the long term, the generated material waste could lead to overburdened waste disposal facilities, since the disposal of residual waste to land is the ultimate end-point for any waste management system (WMS).

Following the previous Botswana studies of waste streams, this study investigated the waste dilemma on construction sites in the Francistown area. The main purpose was to identify the typical causes of material waste on construction sites in order to formulate a set of guidelines for reducing this waste stream.

EVALUATION OF WASTE IN THE CONSTRUCTION INDUSTRY

Classification of construction waste

The waste associated with a construction site has been categorised into two principal types (Skoyles & Skoyles 1987): direct waste or total loss of materials, and indirect waste. Indirect waste is distinguished from direct waste in that the materials are not usually lost physically, only the payment for part or the whole of the value. The various forms in which direct and indirect waste can occur are summarised in table 1.

Furthermore, waste of materials may additionally produce costs in areas that appear to be unrelated. For example, when delay is caused by the shortage of materials or by rectifying damaged work; there will be additional costs of re-ordering replacement materials. The delay may also cause an extended hiring time of plant and labour, and uneconomic use of plant and labour results in increased costs to the contract. Such additional costs are collectively termed consequential waste.

Measuring construction waste

The Building Research Establishment (BRE) has devised a system of waste accounting that enables site personnel to be sensitive to the occurrence of waste during the construction process (Skoyles 1979). Based on this procedure, formulae to calculate materials waste have been proposed (Harris & McCaffer 2001), which were applied in this study.

RESEARCH METHODS

Research data sources

The primary data sources for this research study were observations at building sites in the Francistown area, site measurements, contractors' records of delivery, contract and other project documentation, specifications and bills of quantities, and site record files (Urio 2004).

Selection of construction sites

Twelve building sites in the Francistown 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 cooperate with the investigation

Table 2 Overview of the twelve selected construction sites for the study

Site	Project description	Location	Value*
A	Construction of Francistown shopping mall	Francistown CBD	P 38 500 000
B	Construction of 109 houses for Botswana Housing Corporation	Gerald Estate, Francistown	P 15 000 000
C	Construction of judges' houses for Botswana Housing Corporation	Francistown Prison	P 6 000 000
D	Tati siding infrastructure development	Tati siding, Francistown	P 60 000 000
E	Construction of staff flats at Mater Spei College	Mater Spei College, Francistown	P 8 500 000
F	Construction of a Roman Catholic church building	Block 8, Francistown	P 1 500 000
G	Construction of residential flats for Silver Spar Hotel	Matsiloje, Francistown	P 800 000
H	Construction of RADS hostel	NWDC, Francistown	P 5 200 000
I	Construction of a new primary school at Tati siding	Tati siding, Francistown	P 2 500 000
J	Construction of a new primary school at Donga	Donga, Francistown	P 12 400 000
K	Construction of teachers' flats in China Town	China Town, Francistown	P 911 000
L	Construction of Francistown bus and taxi rank	Francistown CBD	P 970 000

* 1 pula was approximately equal to US$0,2 (as at the beginning of 2004)

Table 3 Sources and causes of construction waste at the selected sites (Urio 2004)

Group	Source and cause factors	Examples
Design	■ Poor coordination of all parties during the design stage of a project ■ Lack of attention to the standard sizes of specified products ■ Error in contract documentation ■ Design changes	■ Demolition of work due to a change in the design at an advanced stage of the project
Procurement	■ Material delivery procedures ■ Order errors ■ Material storage and internal transport ■ Supplier errors	■ Procurement of incorrect sizes and poor storage on site
Material handling	■ During transportation to the site ■ During transportation on the site ■ Inappropriate storage	■ Chipping of face-brick due to bad handling on site
Operation	■ Errors by tradesmen ■ Equipment problems ■ Inclement weather ■ Damage by subsequent trade ■ Use of incorrect material ■ Accidents ■ Poor site management and supervision ■ Lack of coordination of responsibilities between main contractor and subcontractors ■ Lack of influence of contractors ■ Lack of knowledge about construction during design activities	■ Errors by tradesman such as wrong measurements, alignment and material use ■ Damage by another tradesperson whose work comes after major work have been completed
Residual	■ Waste from uneconomical shape ■ Offcuts ■ Overmixing of material ■ Waste from the application process	■ Waste such as bricks, mortar and concrete
Others	■ Criminal waste due to damage and theft ■ Lack of on site material control and waste management plans	■ Inefficient material schedules and waste reconciliation plans

Attempts were made to obtain sample sites of different project sizes. The projects selected ranged in value from P800 000 to P60 000 000, that is between approximately US$160 000 and US$12 000 000 (as at the beginning of 2004). The selected sites consisted of housing projects, schools, offices and a church building and are summarised in table 2. For the purpose of this study the sites are grouped into three project sizes, with four sites in each group:

- Small-size projects (projects under P2 500 000 in value)
- Medium-size projects (projects from P2 500 000 to P 8500 000 in value)
- Large-size projects (projects over P8 500 000 in value)

RESULTS AND DISCUSSION

Causes of direct material waste at construction sites in Francistown

The records from the sites indicated a number of sources and causes of construction waste. These causes have been categorised into six major groups, which are described in table 3. The grouping has been done according to the stage of the project at which the waste originated.

Variability of direct material waste at construction sites in Francistown

Table 4 summarises the direct wastage of the principal materials at the selected Francistown sites. Column 3 in the table highlights that waste does vary considerably between materials. The lowest waste rate was recorded for concrete (average of 5,7%) and the highest for sand (average of 13%). It can also be seen from column 2 that there is a wide variation in waste between sites for the same material.

Ranking of the causes of direct material waste on construction sites

Site participants of the survey were asked to rank the factors of table 3 on a scale of 1 to 10 in order of their significance to the specific site. Table 5 summarises the ranking values of the causes of construction waste generation by project managers, contractors, site representatives and waste management supervisors (Urio 2004).

Table 4 Direct wastes of principal materials on the selected Francistown sites

Construction material	No of sites	Waste range (%)	Waste average (%)	Tender allowance (%)
Cement (bagged)	12	4,5 – 18,5	10,3	3,3
Sand	12	8,5 – 17,0	13,0	7,9
Stone	12	7,8 – 14,8	11,0	6,9
Common bricks	12	4,1 – 10,2	7,4	3,8
Face bricks	8	2,5 – 9,2	6,9	3,9
Concrete (site mixed)	12	2,3 – 7,8	5,7	2,9
Mortar in brickwork (site mixed)	12	3,5 – 10,7	7,2	2,8
Mortar in plasterwork (site mixed)	12	8,0 – 14,4	11,0	6,4

Table 5 Ranking of the causes of construction waste on the selected sites (Urio 2004)

Causes of construction waste	Overall ranking
Lack of on site waste management plan (WMP)	1
Waste from application process, eg during plastering	2
Overmixing of material due to the lack of knowledge of requirements	3
Error by tradesperson or labourer	4
Cutting uneconomical shapes / length	5
Damage caused by subsequent trades	6
Change to design	7
Use of incorrect material	8
Damage during transportation on site	9
Inclement weather	10
Order error	11
Contract document incomplete at time of construction commencement	12
Error in contract document	13
Over-ordering	14
Inappropriate storage on site	15
Damage during transportation to site	16
Accident	17
Supplier error	18
Criminal waste due to damage or theft	19
Equipment malfunction	20

Table 6 Conclusions on the reasons for high waste rates of five principal materials

Principal material	Conclusions on high waste rate
Waste of concrete	Three main factors were identified: ■ Spillage, during transportation and placing; ■ Overproduction; and ■ Loss resulting from mixing the material on bare ground
Waste of mortar	
Waste of bricks	A number of factors were identified as being responsible for the high waste rate of bricks: ■ Cutting; ■ Poor handling at the stacks; ■ Irresponsible loading and offloading; and ■ Inappropriate lifting equipment
Waste of cement	Two main factors were identified as being the cause of wastage of cement: ■ Spillage; and ■ Theft and pilferage
Waste of sand and stone	Poor storage was the major cause of the high waste rates in sand and stone

CONCLUSIONS

Project managers of construction sites have to give serious attention to material waste control. The requirement of material waste control has been highlighted by the results of this study, which showed a high level of direct wastage of materials on typical construction sites in the Francistown area. The waste rates of concrete, mortar, bricks, cement, sand and stone were all found to be high for the case studies. The reasons for the waste rates are summarised in table 6. Furthermore, the investigation showed that construction waste contributes a high percentage of waste received at the formal disposal sites in Francistown. Therefore, specifically in the developing country context, there is a call for change in attitude towards material waste control and disposal of the unavoidable waste.

The execution of a construction project can be a complex and difficult process. It is often compounded by constraints on time, resources and performance, and is frequently exacerbated by conflicting objectives of the parties involved. This makes the construction project a fertile ground for various uncertainties that bring about waste. The link between success on site and strong management teams identifies the need for effective site management and supervision by contractors. This, in turn, calls for the design and implementation of proper training programmes for contractors to enhance their knowledge and skills, specifically in waste management.

Recommendations for waste prevention

Based on the findings of this study, a number of recommendations can be made to reduce material waste on construction sites to a minimum. The recommendations are stipulated in table 7, but the following are specifically noted:

- Materials deliveries should be properly planned.
- Adequate care should be taken in storing materials. 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 is essential. Proper control and regular accounting of materials are also recommended.

The need for materials control policies is thereby emphasised. It is proposed that firms should draw up working procedures for waste reduction to guide site personnel in the use of materials on site. It is also stressed that both head office personnel and site personnel should be educated on waste prevention.

Finally, in view of the importance of waste prevention to the national economy of Botswana, the following general recommendations are made:

Table 7 Recommendations of waste prevention from the Francistown case studies

Recommendation	Description
Delivery of materials	Deliveries should be properly planned. Contractors should have and use the approved standard schedules of materials throughout the lifecycle of the project. Copies of the schedules should be kept on site to assist site management in the control of materials
Storage and internal transportation	For better storage and internal transportation, site management should consider: ■ The location of the storage area to avoid double handling and travelling long distances to the workplace ■ Sufficient space at storage areas to accommodate the materials to be stored and to allow for movement by the delivery vehicles and handling equipment
Security on site	The following recommendations should improve security and prevent material being lost or damaged by theft and vandalism: ■ The site should be adequately fenced ■ Storage areas should be strategically located and well secured to minimise the risk of theft and pilfering ■ There should be adequate lighting at night ■ Security guards / watchmen should be on duty, especially during non-working hours
Handling and use of materials	■ Proper site supervision should be instituted at all construction sites ■ Efforts should be made to salvage and reuse bricks left behind by bricklayers ■ Workers should be encouraged to mix correct quantities of material using correct procedures ■ Workers should be encouraged to handle material with care during transportation on site
Site accounting	Regular waste reconciliation has to be done by the contractor to ascertain and control waste during and after construction. Material reconciliation and stocktaking should also be done regularly
Education	All people working on site should be educated on waste prevention. Workers should be made aware that the construction industry creates much waste. Periodic training and awareness campaigns can assist in building the necessary attitude towards waste and can have an effect on the project
Waste control policy	To reduce the amounts of construction waste being generated and disposed of, a sound waste control policy must be introduced and enforced as part of the requirements of a construction project. This should cover all activities related to construction material use on site

- Waste prevention clauses should be incorporated in the general conditions of contract for construction works.
- Materials management and waste control should be included in the construction education curricula in the country.
- Professional bodies in the construction industry should organise workshops and seminars to educate contractors and members of the construction design team on the importance of waste prevention in the industry and the national economy at large.

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