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Improved Design of Indigenous Grain Stores

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Improving the Efficiency of Traditional Grain Stores in sub-Saharan Africa

Brice, J R[1] and Chigariro, J[2]

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[1] Natural Resources Institute, University of Greenwich, Central Avenue, Chatham Maritime, Kent ME4 4TB, UK

[2] Institute of Agricultural Engineering, PO Box BW 330, Borrowdale, Harare, Zimbabwe

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SUMMARY

This project examined building elements used in traditional grain store designs commonly found throughout sub-Saharan Africa. Specifically, the project set out to improve traditional designs to meet the need to minimize depletion of hardwood resources used in their construction and to reduce pest attack to the store and its contents.

- A common traditional on-farm structure, for storage of maize or sorghum, comprises a timber-based storage container on a simple wooden platform, which is supported on stones or timber.

- Termite damage to the store structure is the principal constraint identified by farmers. Termite damage leads to more frequent replacement of the timber supports, placing increased strain on hardwood resources (farmers have to travel further to locate timber supplies or purchase timber at increasing cost).

- Traditional stores built on stone legs do not prevent access to termites as they are able to traverse the short distance between the ground and the store platform, unseen. Prevention of rodent access to such stores is not practical.

- Replacement of the traditional timber supports with plastic pipes filled with concrete, dramatically reduced termite damage.

- In addition, the design prevented rodent access to the store contents, resulting in minimal grain loss due to rodent damage and, presumably (since this was not actually measured), minimal contamination with rodent urine and faeces.

- The suitability of the design change to a particular area depends on the availability of mature hardwood trees, the degree of termite activity and the farmers' access to funds to purchase the components. Of the three areas examined during the project, the design was more relevant and affordable in Mutoko than in Buhera or Binga.

Separate trials in Namibia examined the problem of farm store infestations of pearl millet with the moth *Corcyra cephalonica*. It was found that infestations were not due to a carry-over of insects in old stores (as had been thought), but that they were brought into the store with the grain. Large numbers of larvae and moths and large quantities of webbing were observed on the surface of the grain bulk, presumably due to migration of the larvae from within the bulk. Farmers and researchers discussed possible control measures and agreed that we should investigate the control provided by a layer of wood ash, placed near the top of the grain bulk to intercept migrating larvae. Two additional treatments, an inert dust and a synthetic chemical insecticide, will also be tested.

Contents

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BACKGROUND

Traditional grain store designs have evolved over hundreds, possibly thousands, of years to combine sound practical and social features. However, as conditions change, external pressures give rise to deficiencies in the economic and technical value of the grain stores.

Rural households use mature hardwood trees to construct most of the buildings in their compounds. The need to replace buildings on a fairly regular basis due to termite damage and, more specifically, the demand for new store construction imposed by poor access to markets, places unsustainable pressure on hardwood resources.

Eighteen specific areas of constraint to the post-harvest systems of communal farmers in Zimbabwe were identified by Donaldson *et al.,* (1996). The results of the study were discussed at a Research Steering Committee attended by representatives of the Department of Research and Specialist Services (DR&SS), the Institute of Agricultural Engineering (IAE) and the University of Zimbabwe (UZ). The Committee concluded that a shortage of wood suitable for grain store construction was becoming a widespread problem in Zimbabwe's rural areas (confirming Tshuma, 1989). Attempts to use other wood (such as eucalyptus) have failed because of termite damage (pers. comm., Prof. D. Giga, University of Zimbabwe).

Of the various traditional designs of storage structure found throughout sub-Saharan Africa, most are constructed from timber, and share common design features. This project set out to determine whether timber uprights, used to support the storage platform, could be replaced with a more sustainable material, and whether other improvements could be made to the basic structure.

PROJECT PURPOSE AND OUTPUTS

The Project Purpose was to:

develop strategies, which improve food security of poor households through increased availability and improved quality of cereal and pulse foods and better access to markets.

The Project Outputs were to provide:

- an illustrated account of traditional on-farm storage structures identifying the extent of hardwood use in store construction;
- a modified store design, minimizing the depletion of hardwood resources, for adoption by farmers;
- a review of losses due to rodents and termites in household grain stores;
- an evaluation of modified store construction by farmers in two Districts of Zimbabwe and one District in Zambia;
- modifications to household storage of threshed millet in Namibia;
- practical guidelines on improved store construction for extension workers (and local community leaders) in Zimbabwe and Zambia; and
- material for a training programme for extension staff in Zimbabwe and Zambia.

RESEARCH ACTIVITIES

The project activities were divided into the following seven components.

- Survey of grain store designs and practices in two Districts within the Zambezi valley.
- Development and field trials of the modified stores in Binga District.
- Assessment of farmer reaction to the modified store.
- Review of losses due to rodents and termites in household stores.
- Rapid assessment of the impact of the store design in other Districts.
- Production of extension material.
- Improved household storage practices for threshed millet.

SURVEY OF GRAIN STORE DESIGNS AND PRACTICES IN TWO DISTRICTS WITHIN THE ZAMBEZI VALLEY

The survey team consisted of storage and agricultural engineers, a termite specialist, and a socio-economist. The team examined store designs and practices in Binga and Kariba Districts within the Zambezi valley, in December 1996.

Participatory rural appraisal techniques were used in focus group meetings with male and female farmers, Chiefs, Headmen and extension staff. Twenty focus group meetings were held in the two Districts (Douglass *et al.*, 1997).

The principal types of storage container were identified and are illustrated in Appendix 1. Most grain stores are round or rectangular containers on a platform supported by rocks or posts – the heights of these platforms being approximately 0.3 m or 1.2 m above ground, respectively. The containers may be made from either a framework of small-section round timber, or from pliable split twigs woven into baskets – either type is occasionally plastered with mud (inside and/or outside). The stores are protected during the rainy season with a thatched roof, supported on posts rising from the ground or from the platform. Drying platforms, similar to the grain store platforms, are also used for (usually temporary) storage.

Termite damage was common in the structures – evidence being damage to the timber uprights, crossbeams and roofs, and earth runways on the structures. To combat the problem, termite-resistant timber is used wherever possible in construction. The most commonly used material, especially for the uprights and other structural elements, is mature *Colophospernum mopane.* The heartwood is reasonably resistant to attack and trees selected for use as uprights need to provide a heart of sufficient diameter to carry loads of up to three tonnes of grain. Farmers reported travelling up to 10 km to cut suitably sized timber.

Storage practices, including the responsibilities for both construction and day-to-day management of the stores, were also examined. Whilst men usually cut and transport the timber and then construct the main frame, the women are usually responsible for thatching and plastering the stores. Women then manage the stores (demonstrated during the interviews in that the men showed little interest in the subject). Estimates of grain losses (due to various factors) given by the focus groups were reasonably consistent at around 15 - 20%. Synthetic pesticides are not widely used and natural protectants, such as 'soswe' *(Maerua edulis)* are common. The threatened arrival of the larger grain borer (LGB), *Prostephanus truncatus*, in the area is a matter of concern to the farmers.

Various structural problems were identified.

- Lack of rodent control exemplified by the lack of rodent guards.
- Stores constructed on stone legs are too low to the ground and are difficult to protect against termites.
- Poor sealing of stores allowing easy access by insects to the grain.
- Poor construction detail, such as the movement of foot supports causing damage to the mud walling. Poor plastering and maintenance of plastered walls allowing insect access and harbourage.

Good storage practice in traditional store construction should include the following features.

- Where appropriate, all stores should be plastered, and damage quickly repaired, to minimize the areas that could harbour insects.
- Stores should be sealed to minimize access by insects, rodents and birds.
- Stores should be raised on platforms over one metre in height to prevent rodent access by jumping.

Alternative designs for store supports were suggested – either columns constructed from fired bricks, or concrete posts. The replacement of timber beams with concrete beams could also be considered. Five sites were identified for the trials, based on land tenure, affluence, and the support available from extension officers. Farmers were keen to participate in the design and running of the trials.

DEVELOPMENT AND FIELD TRIALS OF THE MODIFIED STORES IN BINGA DISTRICT

The effectiveness of fired brick supports at providing protection against termite attack has been examined by Koza *et al.* (1994), in the Institute of Agricultural Engineering, during the development of an improved brick-based storage structure. Whilst brick supports provide partial protection against termite damage, the design is not directly transferable, since it departs significantly from the traditional timber-based designs used in many parts of Zimbabwe. Brick pillars also provide little protection against rodent infestation. A modification to the timber-based structures is needed that requires minimal re-training of farmers and extension staff in store construction techniques.

The project specifically examined the use of plastic pipes filled with concrete as supports for grain stores (Chigariro, 1998). These experimental posts consisted of PVC pipes (110 mm diameter and 1.4 m long, with approximately 400 mm buried in the ground) filled with concrete. Two pieces of galvanized wire protruded from the top of each leg and were used to secure the platform to the leg.

Three modifications were made to the superstructure of the test stores. Poles which pass through the walls of the store, and used as a step to gain access, are not usually securely fixed, which leads to movement and subsequent damage to the wall structure. Reinforced steps were, therefore, incorporated into the modified store. A tightly-fitting door was added, to prevent the entry of pests. Walls were plastered to a smooth finish to minimize access by insects and remove cracks and crevices, which could provide harbourage.

Preliminary tests of termite activity on store support poles took place. *Eucalyptus* and mopane poles were placed in the ground alongside the experimental poles (24 of each type of pole) and termite activity was compared. Ease of access to the store by termites was assessed by examining surface damage and weight loss to the poles. All the *Eucalyptus* poles were damaged very rapidly by termites, sustaining more than twice the amount of surface damage of mopane, and approximately 3.5 times the weight loss of mopane poles (Table 1). Damage was so severe that the *Eucalyptus* had been eaten through, causing the poles to fall over. Mopane was clearly more resistant, although significant levels of damage were recorded. No termite activity was recorded on the experimental poles. These findings were reinforced by observations on whole stores, where termite damage to the superstructure of stores supported by the experimental poles was reduced significantly ($P<0.0001$). The principal termite genera identified as being the cause of damage were *Ancestrotermes*, *Macrotermes* and *Microtermes*.

Table 1. Termite damage to support poles and associated weight loss.(July 1997 to May 1998)

Pole	Mean % level of damage (±SE)	Mean % weight loss (±SE)
Eucalyptus spp.	71.9 ± 3.9	61.8 ± 3.4
Colophospernum mopane	35.2 ± 2.6	17.0 ± 0.8
Plastic pipe + concrete	0	0

Twelve modified and twelve unmodified stores were constructed at research sites in Binga District. Six stores were filled with threshed sorghum and six with unthreshed sorghum. Grain samples were taken every four weeks over a period of 6 months. Grain damage due to storage insects increased in all treatments over time. Weight losses are recorded in Table 2. Major insect species recorded were *Sitophilus oryzae*, *Sitotroga cerealella*, *Tribolium castaneum* and *Rhyzopertha dominica*. *Plodia interpunctella*, *Corcyra cephalonica* and *Cryptolestes* spp. were also present (Chigariro, 1998).

Table 2 Weight losses due to storage insects

	Weight Losses (%)	
	Unmodified stores	Modified stores
Threshed sorghum	3.6 ± 0.2	3.1 ± 0.7
Unthreshed sorghum	4.6 ± 0.6	3.8 ± 0.6

The modified legs (plastic pipes filled with concrete) were extremely effective at protecting the superstructure against termite attack. They had the added advantage of excluding rodents from the store, with the associated benefits of reducing losses and preventing contamination of foodstuffs from rodent urine and faeces. Storage platforms must be at least 1 m above ground to prevent rodents from jumping into the store.

The platforms and storage containers were built under close supervision, and clear instructions were left with farmers as to how they should construct the roofs. However, some farmers built roofs on wooden posts supported directly from the ground rather than from the platform (as had been requested). These designs provided termites and rodents with an easy route to by-pass the modified store supports. Greater effort will be needed to ensure store builders and users are fully aware of the reasons for changes in store design.

FARMER REACTION TO THE MODIFIED STORE

A participatory appraisal was carried out by Boyd and Chigariro (1998) to:

- assess the financial, economic, social and environmental impact of modified stores in Binga District;
- examine farmers' perceptions of the effectiveness, affordability and acceptability of the modifications;
- identify socio-economic constraints to store construction and management for both traditional and modified stores; and
- advise on future modifications that are affordable and acceptable to farmers.

Data collection was based on a combination of:

- semi-structured interviews with trial farmers (men and women);
- group discussions based on causal diagrams of post-harvest constraints (one dominated by men, the other by women); and
- key informant interviews.

The survey team confirmed that the availability of suitable hardwoods for the construction of grain stores (and other traditional structures) varies from moderate to low in the areas surveyed. Farmers have to travel further to source construction materials, and hardwoods are becoming scarce near to areas of high population.

The rate of traditional store replacement is a key factor in determining the appropriateness of the new store design. Mean rate of replacement in Binga District was found to be at or below 10 years. Replacement rates increase in areas with high termite activity.

The cost of replacement is another key factor influencing adoption. Formal lending institutions, such as the Agricultural Finance Corporation, were not active in the study District and, even if they were, their terms are unlikely to appeal to resource-poor farmers. Considerable informal lending takes place, generally for small amounts over short periods to finance immediate consumption needs. The nature of the transaction depends on the degree of trust and various ties between the lender and borrower, and no standard interest rate applies. In group discussion, farmers said that larger amounts could be raised by borrowing from a number of different creditors. However, it was not possible to determine whether informal lending of larger amounts over longer periods, to finance small-scale investments, would be a reasonable option for resource-poor farmers.

The cost of capital also depends on the availability of alternative investments to farmers, and on consumption needs. In group discussion, farmers said that they usually construct stores in July or August. This is a period of fairly low cash expenditure, which starts to increase as food stocks run low in September, building to a peak in December and January. It is likely that a discontinuity exists between the cost of capital for cash-constrained and non-cash-constrained farmers because of imperfections in local capital markets. At current costs, and in the absence of credit arrangements, the technology would be attractive to households that are not cash-constrained and would normally expect to harvest enough grain to last well into the rainy season.

Mopane responds to coppicing. Improved management of woodland resources should take place alongside the reduction of timber harvesting achieved through the introduction of this alternative technology (ODA, 1996).

LOSSES DUE TO RODENTS AND TERMITES IN HOUSEHOLD STORES

A review of losses due to rodents revealed few references to small-scale storage (Taylor and Brice, 1997). For example, from 166 references to rodents on one database, only six were concerned with post-harvest losses, and only one of these related to small-scale storage. Texts on rodents tend to focus on pre-harvest losses, with post-harvest aspects focusing on large-scale centralized storage. Significant issues such as food contamination with faeces and urine are hardly considered. Losses based on dry weights before and after storage were reported, but these are difficult to assess and may be due to other factors such as household removal or spillage. Harris and Lindblad (1976) suggested that estimates of loss can be based on an assessment of the rodent population in an area, and their potential food intake. However, the authors concluded that if it could be confirmed that rodents are present (and damaging the grain), then this is sufficient justification for a rodent control programme.

The review raised the following important points.

- Have modifications, such as rodent guards, been taken-up elsewhere?

- Do rodents actively seek out grain or do they come across it by chance?
- Are rodents in stores true field species, seeking shelter and food after harvest, or are they species normally associated with human habitation?
- To what extent are rodent-borne diseases a problem?

These, and other, questions are being addressed by a second DFID funded project, *"Development of a methodology for assessing the impact of rodents on rural household food security"*, currently active in Mozambique.

Previous research into termite damage (ignoring the many entomological and ecological references) has tended to concentrate on the protection of modern housing and offices (Taylor and Brice, 1997). Termites favour timber structures, but they also thrive in mud-based structures where they can tunnel upwards within a mud wall to attack the thatch and the wooden roof structure (necessitating replacement of the thatch every one to two years). Pearce (1997) indicated that damage to grain due directly to termite feeding was low, but contamination with moulds as a consequence of their attack is frequent.

Much of the information on the life of storage structures was found to be anecdotal, ranging from two to ten years. The problem is that a combination of species of termites, levels of infestation, and varying designs of structure, makes comparison between different stores in different locations difficult to assess by discussion (GTZ, undated). Destruction of termite hills has been practised with varying degrees of success. Proper store management practices, such as removal of as much plant material as possible from the vicinity of the store, helps reduce termite activity. The incorporation of grass into mud mixtures should be avoided in mud-based structures (Pearce, 1997): however, this will have a detrimental effect on the strength of these materials.

Control practices can be divided into chemical methods and physical barriers (Pearce, 1997):

> **Chemical methods** range from engine oil, crushed neem leaves and other plant materials, to the use of synthetic chemicals, in particular organochlorines. Soil treatments below stores, with chemicals such as chlorpyrifos, can provide protection for up to 5 years under tropical conditions (the period of effectiveness increases to 25 years under temperate conditions). The duration of protection given by treatments above ground depends on the degree of weathering.
>
> **Physical barriers** such as stones, concrete or metal sheets are used to exclude termites. Barriers such as wood ash, sand and gravel are also effective, damaging the cuticle, leading to dehydration. Groundnut shells placed under sacks of grain have been reported to reduce termite damage. Soil associated with termite nests can be used to construct stores. The soil is hardened by firing, waterproofed with bitumen and used for lining pits.

RAPID ASSESSMENT OF THE IMPACT OF THE MODIFIED STORE DESIGN IN OTHER DISTRICTS

Acting on suggestions from the participatory evaluation report (Boyd and Chigariro, 1998) that the modified store may be more suited to other Districts, demonstration stores were erected in Buhera and Mutoko. A rapid assessment was then performed to gauge farmers' perceptions of the improved design (Marsland, 1998). This assessment tested the following key propositions.

- The availability of mopane woodland per household is at or below the level estimated by Lynam (1996) to be necessary to meet household needs sustainably (i.e. about 7.5 ha/household).
- The mean rate of store replacement is at or below 10 years (probably correlated with the level of termite infestation).
- In the absence of significant cost reductions and/or credit arrangements the technology will be most relevant for those households that are not cash-constrained and that would normally expect to harvest enough grain to last well into the rainy season.

The activity: assessed the environmental case for extending the project into Buhera and Mutoko; attempted to ascertain woodland availability, average store life and the severity of termite problems at the site level; and attempted to gauge the appropriateness of the technology for households, covering a range of harvest size, cash and labour availability.

Farmers in both Buhera and Mutoko stated that the hardwood poles required for building grain stores and houses were becoming more difficult to source. Although the shortage of suitable poles was not yet critical, it was becoming an issue. Using a ranking exercise, termites were recorded as the most important factor causing storage problems, in both Buhera and Mutoko (Table 3).

Table 3 Ranking of factors causing storage problems (1 = most severe)

	Buhera	Mutoko
Weevils (in store)	-	4
Weevils (in field)	-	6
Weevils	2	-
Rodents (Rats)	4	3
Moisture (Rotting)	7	2
Termites	1	1
Chemicals (ineffective/misapplied)	-	4
Moths	3	-
Larvae	6	-
Poultry	7	-
Birds	7	-
Thieves	5	-

There was a mixed response to the question of the life of the traditional timber grain stores. It was provisionally concluded that: it is possible for stores to last for many years, but this is dependent on termite activity and the use of preventative measures; and there is a strong need for further research into why stores built of the same basic materials and of the same basic design appear to have such a wide range of longevity.

Case studies in the two areas indicated that those farmers who have seen the demonstration store in Buhera acknowledge that it would be effective against termites. At the current price of Z$600 (£10) the technology would not be affordable to cash-constrained households and many households headed by women (although not all). The relevance and affordability of the proposed design would probably be more applicable to farmers in the Mutoko site rather than those at Buhera.

PRODUCTION OF EXTENSION MATERIAL

To enable the extension of project findings, a training manual, video and training programme were developed at the end of the project. Since this is a research project, this material was produced for AGRITEX to train field staff at a later stage (the materials were not actually used during the project). Specifically:

A **manual** and a **video** (Chigariro, J.[1] and Chigariro, J.[2] respectively) illustrating the design and construction of stores have been produced in collaboration with IAE/AGRITEX. The emphasis (in the case of the manual) was on the pictorial account of the design and construction of improved stores. Both the video and the manual are targeted at training field staff. Vernacular copies are being prepared.

A **5-day training programme** has been developed, including course content, timetable and activities - the video and manual discussed previously obviously formed a large part of the prepared material.

TRIALS IN NAMIBIA TO DEVELOP IMPROVED STORAGE PRACTICES

In Namibia's North-Central Division, there is an overwhelming need for improved on-farm storage of *mahangu* (pearl millet) to prevent attack by the moth *Corcyra cephalonica*, which may be causing physical losses in excess of 10% by weight, depending on how long farmers store the grain. Given the high price of storage baskets made from mopane wood, there is also a need for cheaper on-farm storage structures.

A programme of trials was conducted involving storage of *mahangu* in newly constructed traditional baskets, baskets lined with polythene, and modified metal water tanks. The hypothesis to be tested was that *C. cephalonica* infests the new crop from residues in the traditional basket and does not enter the bins as a low infestation in the harvested crop. However, on opening the bins after 9 months storage, *Corcyra* infestations were observed on the surface of the grain bulk in all treatments. The metal containers were insect-proofed by sealing all joints, so the appearance of larvae and cocoons on the surface of grain stored in the metal bins was a clear indication that the infestation was active on the grain before the bins were filled.

The bins were resealed and left for a further 12 months to observe the progress of the infestation.

The opening of the bins was attended by groups of farmers and extension workers from the surrounding villages, and discussions led to further suggestions for control of the pest. On opening one replicate of treatments and control, at each of the two research sites (Mahanene and Okashana), it was observed that infestations were not randomly distributed, but congregated on the surface of the grain bulks. Since we can assume that the infestation would not have been localised at the surface when the bins were filled, then it is safe to conclude that *C. cephalonica* larvae migrate vertically to the surface of the grain bulks to pupate. A layer of wood ash placed near the top of the grain bulk would intercept migrating larvae and could prevent pupation and emergence as sexually active adults. Wood ash is widely-used by small-scale farmers in southern Africa to protect stored produce against insect infestation. Such a treatment could be cheap and very effective, and is likely to be acceptable to farmers. Sieving and washing to remove ash residues from the grain are normal practice for households before the grain is pounded into a meal.

This suggestion will be incorporated into a second phase experiment, which will also include the use of an inert dust and a conventional synthetic insecticide.

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APPENDIX:

PRINCIPAL TYPES OF STORAGE CONTAINER

Figure A1.1 Rectangular grain store on a raised platform

Figure A1.2 'Bottle-shaped' grain store on a raised platform

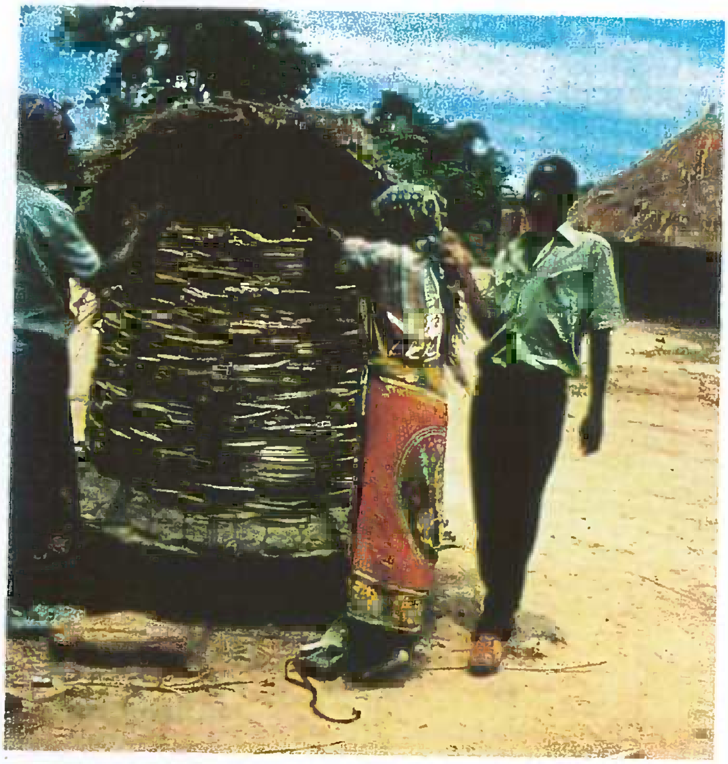

Figure A1.3 Simple woven basket

Figure A1.4 Brick-built rectangular store

Figure A1.5 Modified timber-based store incorporating PVC plastic legs filled with concrete