DESIGN OF FUMIGABLE STORES IN THE TROPICS

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ABSTRACT

The design of grain storage buildings is related to function, location and available resources. Whilst resources in developed countries are relatively unlimited leading to high standards of design and construction, many developing countries lack both material resources and experience of design and construction. Basic design requirements for fumigable stores in the tropics are considered, together with standards for assessing quality and workmanship. Standards attainable are discussed in relation to who pays for, constructs and supervises the building. The difficulty of achieving acceptable standards is emphasised. Some difficulties are caused by non-availability of materials, but local materials have been successfully used as substitutes. It is concluded that caution is needed in laying down precise design criteria for fumigable stores when resources are limited. However the design of such stores needs urgent attention because of reports of total store fumigation in unsuitable buildings causing resistance to fumigation by phosphine by a variety of pest species.

INTRODUCTION

There are three important aspects to be considered in the design of buildings for the storage of grain. First, it is necessary to decide on the precise requirements of the building in terms of its function and the operations to be carried out within it. Second, whether the location of the building is likely to cause problems including the possible effects of climate on the design. Third, the availability of resources to construct and operate the buildings must be assessed, with special reference to materials, capital and the managerial and technical resources needed both for construction and operation.

It is particularly important that the resources available for construction and the subsequent operation and maintenance of stores be taken into account when buildings are designed. It is clearly quite impractical to provide design specifications which, for one reason or another, are unlikely to be met and, for this reason some designs would not be appropriate for many developing countries of the tropics. For example, the design proposed by O'Neil (1983) at this Conference is clearly based on a situation where resources are relatively unlimited and the major constraint is technical development.

In a large number of tropical countries the grain storage system is for

bags. Bulk systems are often confined to port or mill installations where they form part of a complex that frequently can afford experienced and skilled management. Many of these port or mill units are linked to imported grain, whereas the main food grains produced and stored in the tropical zone are rice and maize, both of which are handled throughout the marketing chain in bags. Because of this, bag warehouses are ubiquitous throughout the tropics and likely to remain so for some time. However, it may be advisable to maintain a design that is flexible enough to handle both bagged and bulk grains. In these cases the problems of sealing entry doors, ventilation openings and grain handling systems are both more numerous and complex than in the case of large scale single grain type bulk stores.

A further factor is the significantly lower space utilisation of bagged commodities compared with the flat bulk stores or vertical silos. The designer of the fumigable stores for the tropics is therefore caught in a situation where the building volume per tonne of commodity is considerable larger than those current, for example, in Australia for wheat. Essential, but unused, space for passage ways, limitations on stack heights and general unsuitability of peaked bag stacks, result in increased building costs and a greater number of entry points. These factors alone indicate that a simple rescaling of storage designs based on those developed in Western Australia would be an unsuitable base for the tropical situation. To meet the basic design requirements it is advantageous to start at the first principles of a store design for bagged commodities in a developing country in the tropics.

Design Parameters for a Bagged Produce Store

(a) It will be used for in-sack storage. There is no clear justisfication in most developing countries to convert from bagged grain handling to bulk grain handling except in very special circumstances, which require individual consideration, but dual purpose bag/bulk stores may be an advantageous investment to cover future requirements.

(b) It will either be a primary or a secondary collecting point, therefore the delivery into the store will be slow, it may also be in an isolated situation.

(c) In order to effect adequate control of infestation, and possibly for other reasons, the size should be as small as economically practical. Economies of scale in store construction depend upon circumstances and generally extend up to 4,000 to 8,000 tonnes capacity. Therefore, there should be a tendency to build smaller units to achieve the desired flexibility.

(d) The store may be located in an urban area and used for seasonal or long term storage to maintain reserves for the urban population.

(e) It may operate as a transit store or a long term store wherever its location according to the seasonal supply from home grown production and from imported grains.

The most demanding requirements are for a transit store and these are:

(a) A length:width ratio of not less than 1:2.

(b) Doors to be provided one per 15m of wall length, preferably on each long wall of the building.

(c) Monolithic concrete floor with a vapour proof barrier.

(d) Ventilators in humid areas, or aeration where long term storage, with high moisture content grain, is contemplated. Ventilators should be at the eaves and the gables.

(e) Insulation should be provided by an eaves overhang, an orientation East-West and the outside painted white (the important part is to keep the outside white; therefore expensive, durable finishes which rapidly become stained or marked with dust, are less likely to be effective than simple whitewashing which can easily and cheaply be renewed as the reflective surface deteriorates).

(f) Masonry, concrete block or brick walls.

Where there are no constraints on the resources available, design parameters should be to the highest standards of engineering and building design and practice. Under these circumstances, the design of a fumigable store would be essentially the same wherever it was built. However, where resources are severely constrained, the design must take account of the limited facilities and resources that are available. However, there is no typical developing country; there is instead a range of conditions from those akin to industrialised countries where all the required resources are available in a descending progression to the very poorest country where few, if any, essential resources are available.

Generally the training of storekeepers and operators has been directed towards the use of phosphine for fumigation. If there is to be any

substitution with inert gases for controlled atmosphere storage, carbon dioxide is likely to be the most commonly available. Both gases require a treatment time of 4-10 days as a minimum and therefore this defines the sealing standard of a fumigable store. However this indication is not a practical measure for site inspection during construction and commissioning, or a suitable method for management to check the maintenance of the sealing standard, both of which require the addition of a simple test that has been verified against the leakage rates of the gases employed and infiltration of atmosheric oxygen. The pressure delay time has the advantage of simplicity but as Banks and Annis (1980) have noted, it is as yet incompletely verified. It is however likely to remain the most practical method for design and more important the standard of inspection and final acceptance of the building as well as a management tool to indicate a need for building maintenance.

During modifications required to a conventional building for grain storge, any particular aspects needed for fumigable stores could be incorporated simply and cheaply into the building at the design stage. Sealing design and materials should also be included in any package for the supply and erection of fumigable stores offered by donors. Caution, however, should be exercised in relation to specialised application machinery and techniques especially for construction at isolated sites. Adhesives and mastics, silicone rubbers with extra lap fastenings for wall and roof sheets should, as far as possible, be the norm. The temporary closure of doors and ventilators should be with PVC tape, butyl or epoxy mastics which, whilst unsuitable for long-term storage may well be quite satisfactory for short periods.

The attainable standard of construction often depends upon who pays for the building construction and for the operation; i.e. whether this is a donor agency or a local organisation. Most aid donors operate on the principle of tied aid in so far that a high percentage of materials and equipment shall come from the donor's own country. In this case, it is not difficult to arrange a supply of good quality steel frame type industrial buildings. Basically these are perfectly adequate and require only minor modifications to design to make them suitable for in-sack storage. Indeed, donors should be encouraged at all times to supply the highest quality buildings in order to reduce, as far as possible, local requirements and costs for maintenance, although care is needed to ensure that the main items needing maintenance and replacement are ones that are available locally, choice of cladding pattern is one such example. Some donors also pay for the building and provide supervision for construction. This does not necessarily mean the buildings will be constructed to the same requirement and standards as in the donor's own country, but at least their presence on site is conducive to a

higher standard of construction. Where a local building contractor is to construct the store then building standards can be extremely variable. Whilst there appears to be little difficulty in the construction of a Hilton Hotel or a convention centre, it is often very difficult to ensure the building of simple grain stores to basic construction standards.

Basic Requirements for Design of Fumigable Stores

Fumigable stores generally require most of the design features for general purpose stores. This means that in addition to providing adequate protection from rain and ambient humidity produce within the store must, as far as possible, be protected from fluctuations in temperature. These not only cause negative and positive pressures which will result in air being pumped into and out of the building, grain deterioration through high temperatures are related to the highest temperatures within a cycle, not to the median. If effective fumigations are to be carried out then losses of gas through ventilators, doors, the walls and roof must also be minimised so that adequate concentrations of fumigant gas can be maintained for sufficient periods of time. This is of particular importance for fumigations involving the use of phosphine where the duration of exposure is of more importance than the achievement of high concentrations (Bell *et al*, 1977).

Where the local organisation is responsible for the design and construction of buildings it becomes a major problem to maintain adequate building standards. Historical evidence in developing countries indicates that local design and construction often do not meet even the most basic of good building standards, both in quality of materials and in the placing and fixing of materials. In general this leads to a high and costly maintenance requirement. In the poorer countries where standards are lowest, planned maintenance and maintenance budgets for grain stores are an extremely rare occurrence. With inadequate maintenance, stores may deteriorate and still continue to be satisfactory for conventional storage but under this situation the ability to maintain adequate sealing for fumigation is extremely problematical and often not recognised by management. Under such circumstances, the danger of inadequate sealing become very real. Banks (1980) suggested that the success of sealing depends on the skill of the man doing it and his awareness of how the sealing system must be applied, rather than the particular method and materials used.

Some of the difficulties are due to the availability of supplies. Building material, including cement and reinforcing steel, are generally recognised as an economic necessity and, although sometimes difficult to obtain, are generally available. The requirement for particular sealing material may require a special import licence. Under present conditions where foreign exchange is desperately short in many developing countries, this is a very

major problem leading to delays which make the local builder obliged to use what ever materials are locally available. In such a case in Senegal, bitumen became a universal sealant being applied liberally to cracks and joints. The eaves joint between masonary wall and corrugated sheeted roof was filled with a rigid packing of concrete or plaster and the ensuing cracks filled also with bitumen. Walls were painted with bitumen mixed with gypsum powder to eliminate the stickiness and finally painted with emulsion paint to relieve the drab colour. The treatment in this particular store is considered to be adequate although as yet untested. It was arrived at after simple laboratory tests but unfortunately this example is not common and frequently unsuitable decisions are taken without adequate advice.

Webley and Harris (1979) found in Mali that the traditional "banco" stores built entirely of mud with a flat roof, also of mud support by palm trunks, could be satisfactorily fumigated providing that cracks on the inside and around doors and windows were effectively sealed with fresh mud. Purpose built stores for fumigation have been satisfactorily constructed. Cocoa stores at Ikeja in Nigeria were constructed in 1966 and were reported to be satisfactory in operation (Riley and Simmons, 1967). Semi-underground hermetic stores, the so-called Cyprus Bins, described by de Lima (1980) have been used satisfactorily for the long term storage of wheat and maize under hermetic and fumigated conditions. However, neither of these stores could be said to meet the requirement of a general purpose transit store that can be fumigated and they represent isolated cases.

It must therefore be concluded that caution is needed in laying down precise design criteria for fumigable stores where resources for construction, management, operation and maintenance are severely limited. What limited field experience there is suggests that whilst building standards may be different from those employed in industrialised countries, they may be satisfactory for local requirements and that local materials may provide adequate sealing even though these materials would not be accepted as sealants in industrialised countries. The design of fumigable stores where materials and an understanding of the technology is very limited, has been seriously neglected and requires urgent attention being paid to it. Even the minimum standards of gas retention and sealing are not widely known or applied. The increasing number of reports that local organisations of developing countries are carrying out "total store" fumigation in what are clearly unsuitable buildings is causing serious concern about what the possible consequences might be. The recent work by Taylor (1982) and by Tyler *et al* (1983) in Bangladesh showed that a high degree of resistance to fumigation by phosphine by a number of pest species was due solely to regular and frequent fumigations by phosphine in unsuitable stores, lends

weight to this concern and emphasises the need for urgent action to provide adequate store design criteria. The current increasing costs of carrying out under sheet fumigation compared to the apparent simpler operational procedures of total store fumigation is leading to its wider use in buildings, with insufficient attention being given to their suitability.

CONCLUSIONS

The need for very rigorous phytosanitary standards for export grain in Australia has clearly led to design criteria for flat grain stores that are suitable for controlled atmosphere storage and fumigation, and also the perfection of techniques for sealing already built conventional warehouses. There are, however, very few developing countries with the material resources or standards of technology to emulate the Australian methods. In the general case it may also be impossible to maintain a standard of insect free grain and it is arguable that it is not economically feasible or necessary to attempt to do so. Furthermore the long established tradition of handling grain in bags in developing countries and the unlikelihood of this practice changing rapidly in the near future, means that ubiquitous godown or bag warehouse provides a basic and fundamental design for a grain store. A design for fumigable stores must therefore be based very largely on these godown designs and on the minimum efforts and standards needed to make existing godowns suitable for fumigation and controlled atmosphere storage. Whilst many of the materials and techniques currently in use in Australia and elsewhere are relatively simple in principle, it must be recognised this technology is generally not available in developing countries and the materials may be largely unavailable because of scarcity of foreign exchange. Design standards and sealing techniques need to be based as far as possible on local standards and locally available materials.

The increasingly wide adoption of total store fumigation in developing countries in quite unsuitable buildings, with incontrovertible evidence that this is leading to increased resistance to fumigation by common insect pests, adds urgency to the development of appropriate designs and techniques for sealing.

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