FEEDLOT DESIGN AND CONSTRUCTION

30. Grain storage and handling

AUTHORS: Rod Davis and Ross Stafford

Introduction

The infrastructure associated with grain storage and handling is a major component of the feed management system when rations are prepared on site. On site infrastructure for bulk storage and handling may also be required at feedlots that are using commercial pre-prepared or pre-mixed feed.

Facilities for on site grain storage and handling, or for pre-mixed feed storage, must be adequate to ensure that no component of the feed supply is depleted, forcing the ration to be altered unnecessarily or at short notice. Significant on site storage also allows for opportunity purchases of grain and provides for any extended interruption in grain deliveries.

A grain storage and handling facility includes grain receival, grain movement, grain cleaning, reclaim, storage and possibly drying and cleaning operations. This is a major investment and the whole system must be carefully planned.

Facilities for the storage and handling of grains (and processed grains) should be compatible for whole grains, ground grains or processed grains.

Design objectives

Grain storage and handling facilities should be designed, constructed and maintained to ensure that

- An overall system is developed that accommodates the grain storage and handling operational requirements of the feedlot.
- Adequate volume of storage is available to allow strategic purchasing of commodities.
- There is adequate volume of storage to ensure feed is available to cattle following any likely contingency (e.g. local flooding).
- Process flow and layout of the distribution system is suitable for the types and characteristics of the materials to be handled and the operational requirements of the facility.
- Quality of the grain handled is not compromised by contamination by insects or rodents.
- Personnel, equipment and overall facility safety issues are implemented.

Mandatory requirements

Compliance with

- AS1657 -1992 Fixed platforms, walkways, stairways and ladders – Design, construction and installation for access, stairs, landings etc on grain storage and handling equipment.
- AS2865-2009 Confined Spaces for confined spaces entry requirements.

Design choices

Planning should include strategic planning, economic factors, location on site and facility layout and allow for potential facility expansion, rather than new construction.

Strategic planning

For optimal long term feedlot profitability, capital spending on new facilities needs to reflect the strategic planning objectives of the feedlot.

Economic considerations

Local issues, such as grain types and volumes produced in a particular geographic location, will directly affect facility design.

Site location

Selection of an appropriate site within the overall layout of the feedlot will optimise the efficiency of feed preparation and delivery systems. Site considerations are discussed in *Section 2 – Feedlot site layout* and *Section 28 – Feed preparation and storage*.

Facility layout

The type of construction and the amount of available land may determine the physical layout of the facility.

The relative location of the areas designated for commodity receival, feed preparation, loading and feeding out will affect the operational efficiency and costs of running the facility.

Design considerations for each storage and handling facility should include

- Storage capacity
- Handling rates
- Capital cost
- Short-term (e.g. pad/bunker) versus long-term (e.g. silos) infrastructure
- Allowable level of grain degradation
- Protection of grain from spoiling, insects, pests and vermin
- Maintenance requirements
- Process flow/layout requirements
- Automation
- Lot identity preservation
- Built in flexibility
- Expected life of the system
- Safety (e.g. dust explosions).

Grain characteristics

Grains can be divided into three groups: cereals (maize, wheat, barley, sorghum, rice); pulses (lupins, beans, peas); and oilseeds (soybeans, sunflower, linseed, canola).

Different grains and grain types have a range of characteristics that can affect the type of distribution system selected and the components required in the distribution system. These characteristics include moisture content, weight of the grains, angle of repose of the grains, abrasion of the grains against contact surfaces and ease of flow of the grains. A brief description of moisture content and angle of repose follows.

Gravity fall of grain through tubes from the bucket elevator to cone-bottom silos using a diverter. Greater height of bucket elevator is required for gravity fall of grain.

Moisture content

Moisture content in grain is defined as the amount of water that is absorbed into the grain kernel as a percentage of the total weight of the grain kernel.

The moisture content of a grain is typically provided on a 'wet basis' (wb) and is calculated as

$$\text{Moisture content wb} = \frac{\text{Weight of moisture}}{\text{Weight of wet sample}} \times 100$$

Standard grain grades with moisture contents of 13–18% do not usually cause material flow problems. But high moisture content grain, when coupled with high foreign material contents and fines, can lead to material flow and handling problems. Moisture content of the grain can change with the environment in which it is stored and this should be monitored to help ensure the overall condition of the grain.

Figure 1 illustrates the potential issues with stored grain at a range of temperatures and moisture contents. As the temperature rises, the safe level of moisture in the grain must be reduced for good quality storage.

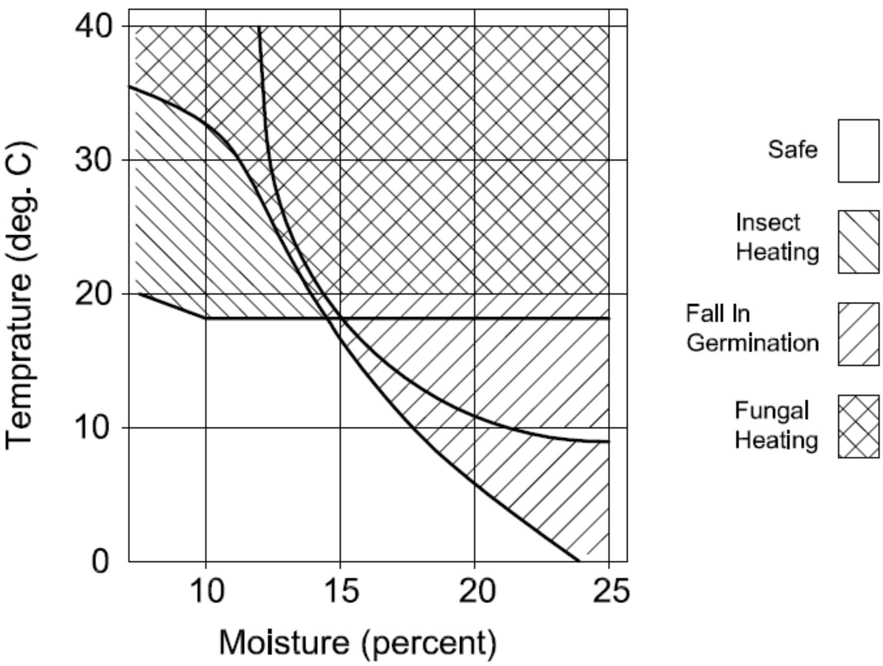

Figure 1. Effects in storage at different temperatures and moisture content.

Angle of repose

The angle of repose is the greatest angle from the horizontal to which a grain can be raised without it sliding or rolling on itself in an unconsolidated form. This determines whether a grain mass will flow by gravity, or need outside forces to move. It will determines the minimum spouting angles for gravity flow. The angle of repose of grains varies with type, variety, moisture content, quality and level of contamination.

Angle of Repose for common grains is shown in Table 1. These angles will increase for wet grain and may also vary slightly depending on grain quality and its admixture content. The grain coefficients can be used for calculating volume of grain when piled at a natural angle of repose.

Table 1. Angle of repose for common grains

Grain	Angle (degrees)
Barley	28
Wheat	25
Sorghum	30
Sunflower	30
Corn	23
Oats	28
Soybeans	25

Abrasion

All grains will wear the surfaces that are in contact with flow. The amount of wear will vary according to the type of grain, the volume of grain, speed of grain, the impact of grain streams on surfaces and the slope of the contact surface. All aspects of the distribution system are affected by these characteristics. When analysing systems, components such as spouting, transitions, gates, valves, conveyors and future access to these components must be designed into the system for maintenance requirements.

Corrosion

Wet grains, ground processed grains and chemically treated grains can corrode standard carbon steel fabrications. Each grain type to be handled must be checked to determine if stainless steel is needed, or will reduce possible life cycle costs. If water wash down, or clean-in-place systems are required, materials used for fabrication in the distribution system should be considered.

Grain storage

All storage systems must be designed to adequately protect and preserve the quality of the grain. Whole grain can sprout under certain conditions and will also attract moulds, insects and rodents. In addition, the storage of grain presents several safety issues.

Grain storage systems come in a range of shapes and sizes, The design of a grain storage facility should be based on

- Length of time for storage – temporary or long-term.
- Degree of segregation of different types of grain.
- Identity preservation requirements.
- Expected useful life of the structure.

Grain storage and handling options currently available for the Australian feedlot industry are outlined below.

An arrangement of cone-bottom silos with a mobile auger for filling.

Long term storage

In general, grain in long term storage should be held cool and dry. Options include smooth wall steel silos, corrugated steel silos

Large-capacity flat-bottomed silos. Note safety handrails are included on the walkway.

Live bottoms on cone-bottom silos provide a wider opening for handling products, such as moist grain, that tend to bridge.

bins, concrete silos and underground pits. Steel silos are the most common method of long term storage for grain at feedlots, but underground pit storage is an alternative for longer term storage.

Silos

Sizes and construction

Silos are available in a variety of sizes, configurations and materials, including flat bottom or cone base, gas-tight sealable or non-sealed, aerated and non-aerated.

Silos can be built on site or transported fully constructed and ready to stand.

The size of fully constructed, transportable silos is limited by road transport regulations in each State. As a general guide, fully constructed silos can be up to 140t capacity. Most smaller (50–70t) cone-bottom silos are generally prefabricated and transported.

Cone-bottom silos are self-emptying, but are limited to capacities of less than 300t.

Feedlots may require air-tight/gas-tight storage facilities of higher capacity. But the increased surface area of a larger silo requires more sheet metal joins, providing more opportunity for air or gas to escape.

Capacity is commonly quoted in tonnes, but may also be quoted as cubic metres (m^3). To determine tonnage capacity, multiply the cubic capacity by the bulk density of the grain (see Table 2).

Table 2. Grain bulk densities

Grain	Bulk density (t/m^3)
Wheat	0.80
Canola	0.67
Barley	0.68
Triticale	0.62
Sorghum	0.73
Maize	0.72
Lupins	0.80
Mung beans	0.75
Sunflower seed	0.42
Cotton seed	0.40

Structural design considerations

Loads put on grain storage and handling facilities are unique and structures should be designed by a specialist structural engineer.

Foundations

Foundations for elevated silos are different to those for general building construction because of the large loads involved.

The first step in establishing a silo is to construct a good quality pad. These structures are engineered to support grain in a vertical plane, with pressure exerted and distributed evenly around the base support frame. If the pad is not level, the weight of the grain will place excessive stresses on the lower sheets of the silo and possibly twist the base frame - deforming the silo.

The soil engineering requirements for most elevated silos should be determined by a consulting geotechnical engineer.

Safety

Safety issues associated with grain storage and handling include working at heights, working in confined spaces, entering grain silos while being emptied (grain entrapment) and dust explosions.

Silo designs now incorporate ground operated lids, caged ladders, platforms and top rails to minimise the risk of operators falling. Facilities for harness attachments, which should be worn by all operators who are climbing and entering silos, should also be fitted. Silos are classified as confined spaces and correct procedures need to be followed prior to entry.

Safety – confined space warning on silo.

Temporary storage

Temporary grain storage may be necessary when on site storage capacities are likely to be exceeded during unusually large harvests, or for opportunity storing/buying of large quantities of grain at an economical price.

Temporary storage may be a ground dump with or without a cover. Covered ground dumps include grain bags, sheds and bunkers.

Ground dump without a cover

An uncovered pile of grain is the cheapest form of temporary grain storage, but risks damage by water, insects, birds, animals and moulds. Grain should be moved from this type of dump as quickly as possible to minimise damage.

Temporary grain stockpile in a bunker storage with pre-fabricated steel sides.

The dump site should be higher than the surrounding area, well drained, well above the water table and formed with a slight slope away from the centre of the site to prevent water damage at the base of the grain pile. Water must be able to drain away freely from the base of the pile.

The site should be graded and sticks and rocks removed before being hard packed. A hard packed base helps drainage, provides a compact durable base for operation of filling and emptying machines and for minimising spoilage. A long fall slope of 1:200 to 1:300 (0.3%–0.5%) and a cross fall slope of 1:50 (2%) are necessary for drainage.

The pile should be built uniformly to achieve a maximum grain surface slope (angle of repose). This may be accomplished by keeping the drop distance from the grain elevator to the pile at a minimum. The maximum angle of repose and pile height occurs when grain rolls down the side of the pile.

The surface should be trimmed to produce a smooth, peaked profile - without hills and troughs that will collect rainwater and encourage sprouting and mould growth. A temporary fence around the pile helps to keep out people and animals.

Quality can deteriorate rapidly in uncovered grain piles. Grain temperature and moisture content should be checked at several locations every two or three weeks.

Covered grain stockpile in a bunker storage with small earthen walls.

Uncovered dumps are not advisable for storing grain for feeding to feedlot cattle.

Ground dump with a cover

Pad storages, or bunkers, are ground dumps covered with protective sheeting. A waterproof plastic lining laid across the floor and walls of the pad will prevent moisture entering from below and contamination by soil.

Pad or bunker storage requires careful site preparation, labour for handling large tarp covers and machinery to move grain on and off the grain pile.

A pad should preferably be orientated so that the closed end faces into the prevailing wind to reduce problems in handling the cover sheets.

The site should be graded with a floor slope of at least 1 in 200 towards the open end, with sticks and rocks removed. A hard packed base assists drainage, provides a compact durable base for operation of filling and emptying machines and accessibility even when wet.

A drainage area around the pad is essential to divert run-off from the protective sheeting.

Effective treatment of insect infestation is difficult in bunkers, as fumigation relies on a sealed gas-tight storage.

The height to which handling equipment can stack grain, the retaining wall height and the angle of repose of the grain will determine the width of the bunker.

The formula below (along with information in Table 1), can be used to calculate capacities of pad storage for various grain types.

Retaining walls

The capacity of a pad, or bunker, storage facility is increased with the use of retaining walls. These are usually arranged in a U-shape around three edges of the pad site, with an open end for access when filling or emptying.

Retaining walls may be formed from earth or concrete pre-cast or cast in-situ and should be designed and constructed to support the force of the grain exerted on the wall.

Earth walls can be formed using soil from the area immediately outside of the pad perimeter. This creates a channel around the pad, which can be used to drain run-off from the protective sheeting. The soil should be compacted during formation of the walls.

Safety warning – Fumigation with toxic gas.

Earth walls are typically about 0.5m high and 1.5m wide at the base, with a 45° side slope. Walls higher than 0.5m will need to be designed and constructed to ensure slope stability.

Lining and cover sheeting

The protective cover sheet should be gas-tight to allow fumigation and should resist water penetration, puncturing and UV breakdown. Pads are best covered with a single piece of prefabricated cover, as joining methods require specialised techniques and equipment.

Materials include woven polyethylene or PVC coated polyester. Woven polyethylene is cheaper, lighter, more easily handled and will last for several seasons if handled carefully - but may not be as durable as PVC covers. Floors are commonly lined with woven polyethylene or black plastic film.

The cover and floor liner sheets must be sealed to exclude insects, rodents and water and allow effective fumigation. A camber in the surface material around the storage will drain water away.

Sheets can be sealed simply by burying the floor liner and cover in a backfilled trench about 250mm deep at the base of the earth walls. Once buried, the remaining edge of the sheets should be folded back over the soil backfill to minimise erosion of the backfill.

The cover should be ballasted, or tied down, to prevent damage due to billowing and flapping in the wind. Avoid using objects with sharp projections that could puncture the cover. Place wear patches under ropes or ballast objects to minimise abrasion due to wind movement. See *Section 32 – Silage storage and management*.

The cover should be examined periodically for perforations from animals, birds, rodents, wear points, wind or vandalism. Any damage should be repaired.

Ground dump being covered.

Sheds

Sheds can provide multi-purpose storage of other products, including commodities, fertiliser and machinery. Good hygiene must be practiced to avoid the risk of contaminating the grain. As a permanent infrastructure investment, sheds can be continually used and have a retained value on-farm.

Unloading grain into the shed and loading grain out of the shed commonly requires an auger, or belt conveyor, direct to or from the delivery truck.

Effective treatment of insect infestation is difficult in sheds.

Design and construction of structures for commodity storage is provided in *Section 31 – Commodity storage*.

Grain can be temporarily stored under cover. This grain storage shed has a permanently mounted central discharge auger for loading the shed.

Grain bags

Seamless grain bags generally range from 40 to 90m in length and have a 100 to 300t capacity, depending on bag size, the type of grain and how much the bag is stretched during filling. These are best used only for a few months to store grain. They are not suitable for canola or high value legumes.

After the bag is sealed, the moisture content and temperature of the enclosed grain interact to produce carbon dioxide and deplete oxygen. These conditions suppress any fungi or insects and maintain quality. However, a moisture content greater than 12.5% may spoil grain quality and increases the risk of grain swelling and splitting the bag.

Aeration cooling is not yet proven with grain bags.

Grain bags must be installed on a well prepared site and away from bird habitats, including trees and water sources. Site preparation as outlined for pad storage should be followed. An elevated, well-drained pad provides optimal results — with no rocks that can tear the grain bags as they are being filled and unloaded.

A permanently situated, drive-over grain receival hopper for fast unloading of trucks.

A drive-over receival grid with raised covering doors. A screw conveyor transfers grain from the hopper to a grain conditioner or scalper.

Grain scalper and cyclone to remove unwanted vegetable material and dust.

Animals should be kept away from storage bags using temporary fencing.

Grain bags can be used only once, as they are usually irreparably damaged when being emptied. Care must be taken in disposing of the used bag material.

Grain storage management

Good hygiene in grain handling and storage premises will maintain the quality of the products handled.

Problems with grain caking on silo walls, being damp and mouldy in the base of the store and sprouting in the headspace are caused by poor grain management or poor maintenance of the grain store. Other problems have been reported with lupins or peas stored in old silos, where walls have buckled or compressed from the greater pressure exerted by the round seeds. In extreme cases, the silo has collapsed.

Good hygiene can be achieved by ensuring that storages facilitate are

- Easily inspected.
- Regularly serviced for equipment maintenance.
- Cleaned of grain residues, particularly in sheds, around silos, in augers and in silos after emptying.

Good storage design should be complemented by

- Correct training of people in safety and hygiene-related issues.
- Regular monitoring.
- Establishing a system for recording and checking hygiene procedures.
- Developing action strategies if contamination is to occur.

Grain handling

Grain handling and conveyor systems should be designed to minimise damage to grain.

Pulses are more susceptible to impact damage than cereals and should not be moved in pneumatic grain conveyors, as the impact speed of grain is higher than the critical 12m/s. Augers smaller than 125mm in diameter should also be avoided with pulses. Augers should be run full, and preferably slowly, to reduce grain damage. It is easier to modulate auger speed if driven by petrol/diesel engines, than by electric motors.

A wide variety of grain handling equipment and systems is used in the Australian feedlot industry.

Grain receival hoppers

A high capacity receival system is needed for efficient transfer of grain from trucks, or tractors and trailers. Ideally, it should be possible to deposit a trailer load and pull away from the unloading area within minutes. An in ground receival hopper is typically fitted with a screw conveyor, or auger, to raise grain for conditioning or storage.

Grain conditioning and metal detection

Foreign materials and dust must be removed to eliminate problems further down the grain storage and handling system. A grain conditioner, or scalper, removes foreign particles, weed seeds, small size grain, straw and husk. A dust extraction and collection system prevents dust entering the environment.

All foreign metal objects must be detected and removed before they can cause damage. A permanent - or electro -magnet can be located in the chute that feeds the grain conditioner, but needs to be checked and cleaned regularly.

Belt and bucket elevators

Bucket elevators are used mainly to lift grain vertically to silos or other storages. These usually deliver the grain directly into silos using diverters that direct grain into a gravity chute to the selected silo, or by using belted conveyors to transfer grain horizontally to the various silos.

A flat belt between crowned pulleys at the top and bottom of the casing has small buckets attached at regular intervals to carry the grain from the elevator bottom to the top. The capacity depends on the volume of the buckets, the spacing and the speed of the belt. Elevators up to 20m high and with a capacity of 50t per hour are available.

Bucket elevators are self-cleaning by design and are typically fixed in position.

Auger (screw conveyors)

Auger elevators are one of the cheapest methods of elevating grain and can be fixed or portable. These are available in a wide range of lengths and capacities and are usually powered by an electric motor. They are comparatively light in weight, dependable in operation and popular due to good portability. Long augers may be mounted on wheels for easy transport. The angle of operation is adjustable, but the capacity declines as the auger is raised. High moisture content in grain also reduces the capacity of the auger. Old augers with worn flighting can damage split-prone grain.

Belt conveyors

Belt conveyors are typically used to transfer grain horizontally. Inclines up to 15° are possible - and even up to 30° with ribs fitted to the belt. Belt conveyor capacity is high and grain can be loaded or unloaded anywhere along the belt. Belt conveyors do not damage the grain and raise little dust.

Drag chain conveyor

Drag chain conveyors, or paddle conveyors, use a series of paddles fixed to a loop of chain moving inside a fully enclosed conduit. The circular paddles are sized to fit snuggly in the conduit. This fully enclosed system prevents dust in a building or other space. Drag chains can move grain at any angle, including horizontal, and are largely self-cleaning, although corners of the chain loop will typically require attention. Drag chain conveyors are a permanent installation, but can be easily extended for facility expansion.

Mobile equipment

Mobile augers, mobile belt conveyors, grain throwers and pneumatic conveyors may be used to load grain into storage facilities.

Receival grid, grain handling and cone-bottom silos. The grain is conveyed from the receival grid to a bucket elevator, with gravity fall to a horizontal conveyor for transport to the silo of choice. The height of the bucket elevator is reduced by using a horizontal silo loading conveyor.

Bucket elevator, diverter and cone-bottom silos. The feed delivery vehicle is loaded directly from the elevated silos.

A tractor powered auger used for loading these flat-bottom silos. Note the PTO-powered auger at the base of the silo for unloading grain from the silo.

Mobile augers or belt conveyors, with fixed and guarded cross-sweeps, or a front-end loader can be used to empty the pad. Pneumatic conveyors also suit this job and allow easy final clean up of grain.

Operators using mobile elevating equipment must be made aware of any overhead power lines to prevent electrocution.

Automation

Controls, instrumentation and automation systems are key elements in the overall distribution system. The automation system is governed by the overall facility design and operational requirements.

Each individually controlled device can be linked into a main PLC, enabling coordination of the controls between various pieces of equipment.

Quick tips

- Layout and design is a key consideration in the operation of a functional grain storage and handling facility.
- Grain characteristics, including type of grain, moisture content, weight, angle of repose, abrasion of the grains against contact surfaces and flowability, should be considered in the design and selection of a storage and distribution system and the individual components.
- All storage systems must be designed to adequately protect and preserve the quality of the grain.
- Good hygiene in grain handling and storage will maintain the quality of the products handled.
- Grain segregation requirements may determine the number of silos and storage capacity. A larger number of smaller silos allow better segregation.
- Access and safety features, including roof rails, ladder lockouts, platforms and ladder cages on silos and elevated handling systems, are mandatory.
- Road loops that minimise the need for reversing can make loading and unloading quicker and safer.
- Sites for pad, bunker or grain bags should be graded and debris, sticks and rocks removed. A floor slope is necessary for drainage. A hard-packed base helps drainage and provides a compact durable base for filling and emptying operations.

Further reading

Andrews, A. and Jensen, T. 1998, Storing, handling & drying grain: A management guide for farms, Department of Primary Industries Queensland QI 96081.

Australian Building Codes Board (ABCB), 2013, Volumes One and Two of the National Construction Code of Australia.

GRDC, 2012, Grain storage facilities Planning for efficiency and quality A Grains Industry Guide, Grains Research and Development Corporation , Canberra, ACT.

Newman, C. 2003, Stored grain management : Underground storage of grain, Farmnote No. 70/2003.

Newman, C. 2003, Grain storage: Handling and maintenance, Farmnote No. 66/2003.

Newman, C. 2003, Grain storage : Maintaining grain quality, Farmnote No. 65/2003.

Newman, C. 2002, Aeration - for preserving grain quality, Farmnote No. 24/2002.

Standards Australia, 2010, AS 2628-2010 Sealed grain-storage silos - Sealing requirements for insect control

Standards Australia, 2008, AS 2476-2008 General fumigation procedures

Standards Australia, 1989 AS 3729-1989 Farm Silos – Determination of storage capacity

Standards Australia, 2002, AS/NZS 1170.1:2002 Structural design actions – Permanent, imposed and other actions

Standards Australia, 2007, HB 867-2007 Supplementary information for design of farm structures