Engineering input in the design of on-farm storage in India

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Abstract

The present production of foodgrains in India is 176 million t against an estimated need of 220 million t by the end of this century. Hence, the production in future must increase to meet the need of the ever growing population of the country. Nearly two–thirds of the foodgrains produced are retained by the farmers for their personal use. Hence, the majority of the total produce is handled and stored by the farmers in about 6000000 villages in various types of stores. Traditional storage structures are still practiced to a great extent in these villages, which have a wide variation in socioeconomic conditions of the farmers. It is a herculean task to cover all the villages and all the farmers for improving their storage facilities through the Government's efforts, but during the last decade, scientifically designed improved storage structures have been adopted in rural India and the avoidable quantitative and qualitative losses have been reduced. Engineering input, like design data, foundation design, construction materials, construction or fabrication technology, material balance, insect-pests infestation technique, etc., have been used in design of appropriate structures, keeping in mind the socioeconomic condition of the farmers. Based on the construction materials and placement, these structures can been classified as: (i) indoor metallic bins, (ii) indoor non-metallic bins, (iii) outdoor metallic bins, and (iv) outdoor non-metallic bins. The essential design factors of each bin type have been described in terms of its capacity, strength, material used, location, handling of grain, and quality of grain and economics.

Introduction

The expected world's population by the Year 2000 is about 5000 million. In India, the population is expected to reach 1000 million. How to feed these people is the concern of everyone. Hence, in a country like India, agricultural production must increase to a target of about 220 million tonnes by the end of this century.

Immediately after harvest, the foodgrains undergo several types of physiological changes which are governed by the environmental conditions. They must be protected from spoilage and pillage, and they must be preserved under conditions which are not prejudicial to their qualities and do not render them unfit for human consumption. Therefore, suitable transportation and storage of grain are essential.

In India, nearly two-thirds of the foodgrains produced are retained by the farmers for their personal use. Hence, the majority of total production is handled and stored by the farmers in about 6 000000 villages, The farmers in rural areas use traditional stores made of mud, plant stem, straws, stones and several types of other local materials. These storage structures have several drawbacks (Shukla and Patil 1988) which ultimately affect the quality of grains and reduce the storage life.

In a developing country like India, it is a herculean task to cover all the villages and all the farmers for improving their storage facilities through the Government's efforts, but during the last decade, scientifically designed, improved storage structures have been adopted in rural India and the avoidable qualitative and quantitative losses have been reduced. Engineering inputs like design data, foundation design, construction materials, construction and fabrication technologies, material balance, insect pest infestation technique, etc. have been used in design of such structures, keeping in view the socioeconomic conditions of farmers. These structures have found a place in rural areas and have been able to replace the traditional and age-old technology of storing the foodgrains. This paper briefly highlights the engineering aspects of design and development of farm storage of small capacity to meet the need of farmers who are responsible for preserving a huge quantity of the country's produce.

Classification of Structures

In terms of the engineering design, the storage structures on farm level can be classified by two means: (i) indoor and outdoor structures and, (ii) metallic and non-metallic structures (Raman 1988, 1990).

Selection of materials suitable to local climatic conditions is the main basis in the design of these structures. Because India is a vast country with varied resources and climatic conditions, a single design cannot cater for the requirements of farmers of different regions.

However, in general, the metallic structures are designed using materials like galvanised plain sheets, galvanised corrugated sheets and aluminium sheets, while the non-metallic structures are designed using materials like bricks, cement, wood, stone slab, and to some extent with plant stems. The reinforced cement concrete (RCC) structures are designed using steel as well as cement.

Indoor metallic structures

These structures are of small capacity and used by individual farmers. They are of the following types:

Domestic bins

These bins have been designed for capacities ranging from 0.3 –2.75 t with 24 or 22 gauge galvanised plain sheets. The thickness of the sheet depends upon the capacity of the bin. The outlet of these bins is designed according to the rate of consumption of stored materials (grains) and the properties of the stored commodity. For example, in the structure designed for storing wheat, the outlet is inclined as the quantity of grain withdrawn each time is usually not large. The inlet is reasona-

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bly big for easy loading. The larger capacity bins such as 1 t and 0.62 t is designed in two sections, joined by a metallic belt and mild steel clamps for easy transportation. Even though main body of the bins is fabricated with 22 or 24 gauge galvanised plain sheet, it becomes necessary to use thicker gauge materials for other components such as inlet and outlet surrounds, covers, etc. For these components 20, 18 and 16 gauge galvanised plain sheets are used depending on the load, number of handlings, etc. In high capacities, two sections of the bins are tightened by means of metallic belt and clamps with the help of nuts and bolts. All the mild steel components have been painted properly. A locking facility has also been provided for inlets and outlets.

Urban bins

These bins are designed either circular or rectangular in shape in capacities ranging from 0.09–0.3 t. Since these bins are small, there is no need of providing outlets. The body of the bin is designed using 24 gauge galvanised plain sheets. With a little more strengthening of joints, either with mild steel flats and mild steel angles, some of the designs can also be made multipurpose, so that they can be used as a bed or seat. Castor wheels can be fitted to the structures so that they can be moved from place to place.

Spiral lock seam tube bins

Light weight, machine-made metal tubing is used for the construction of this bin. The tubes are usually made of 24 gauge galvanised plain sheet strips spirally wound, with locked seams for greater strength and rigidity. They are mainly used for ducting and are available in different diameters: 700 mm and 900 mm diameter are found to be most convenient for the design of domestic bins. By fixing top and bottom plates, and inlets and outlets, these tubes are made indoor storage structures.

Welded wire mesh bins

For high moisture grain not infected with microorganisms, this type of bin is useful. The design of this bin is simple: a 75 × 25 mm welded wire mesh bolted to a metallic base supported by steel legs. To ensure air circulation which is essential to bring down the moisture content of the grain, hessian cloth lining inside the mesh is provided. A $4m^3$ size structure is the most economical capacity of this type bin. The roof can be designed with 16 gauge mild steel sheet or rubberised cloth. All the components made of mild steel should be painted properly.

Indoor non-metallic structures

These structures are designed to meet the need of farmers with the help of locally available materials either for direct application or in modified forms.

Pucca kothi

Pucca kothi is a storage structure made of burnt bricks. To protect against rodent invasion and to provide strength, 2–3 walls are sometimes constructed. The floor and roof are constructed using reinforced bricks and stone slabs and the floor is elevated. Bins have a capacity of about 1 t and wooden and steel inlets and outlets respectively.

Cavity wall bins

Unburnt sun-dried bricks are used for the construction with an air-gap of 100 mm to provide insulation, and wood and burnt bricks are used for the construction of roof and floor respectively. These storage structures are provided with metallic outlets with covers and inlet covers of wood or other materials.

Plywood bins

Rectangular, circular and square sheets of 4mm plywood are glued with synthetic resin and hessian cloth and then nailed together according to the design. The plywood flooring is elevated and a skirting is provided at the bottom with stone chips and cement to prevent rodent attack.. The capacity of this structure is 1 t.

Outdoor metallic structures

High capacity outdoor structures are required to store grain for longer periods. Engineering inputs have helped to minimise cost, provide strength, and protect grain from insect pests and rodents. Design features of some popular structures are described below.

Flat and hopper bottom module bins

Flat and hopper bottom bins of different designs are used. Capacities vary from 2–2.5 t. In the modular design, bins having fixed diameter and variable capacities can be constructed by varying the height of the bin. Both galvanised iron sheet (GI) of 20 gauge and aluminium sheet of 15 gauge are used for construction of these bins.

Flat bottom bins are placed on steel legs or brick pillars. Inlets and outlets with locking arrangements are provided, as well as ladder rests and loading platforms. The roof and wall stiffeners are designed either of 18 gauge galvanised sheet or 16 gauge aluminium sheet depending on the body of the bin. Reinforced circular steel concrete is added to the base and roof, and all joints are sealed with cotton cord and thick white paint. Bitumen compounds are used at the joints of base and roof sheets, and nuts and bolts are also provided with washers to make them airtight.

Outdoor flat bin

Bin capacity is 3.2 t using 22 gauge galvanised plain sheets. The base is made of brick masonry and cement. Wall and roof stiffeners are used, with locking inlet and outlets. Bitumen compounds are used at the joints of base and roof sheets, and nuts and bolts are also provided with washers to make them airtight.

Corrugated galvanised sheet bin

A 10 t bin was designed with 24 gauge galvanised corrugated sheets. Special machinery is necessary for curving the corrugated sheets. No wall stiffeners are necessary as the corrugated sheet itself is strong enough to bear the load. The base is designed with 16 gauge mild steel sheet supported by brick masonry column. In these bins instead of roof stiffeners, trusses are used for supporting the roof and these trusses are bolted to the bin wall by means of cleats. Suitable outlets and inlets are provided with locking arrangements. A ladder is provided for easy loading. Proper painting is recommended for mild steel components.

Galvanised plain sheet with adjustable height

In this bin, the sheets are used breadthwise instead of lengthwise so that the height of the bin can be altered without changing the base and roof. This type of bin is designed for capacities of approximately 4 t by using 3 galvanised plain sheets and 4 galvanised plain sheets per layer respectively. The 22 or 24 gauge galvanised plain sheets are used depending upon the capacity. Wall stiffeners are not necessary as there is a join of sheets all round the bin and roof inlets with a locking arrangement as in the case of the module bin. The brick masonry base is economical for this kind of design. A ladder rest and platform are also provided. Proper painting is recommended to mild steel components.

High moisture grain storage bin

This design is able to provide safe storage conditions for storing grain of higher moisture content (as high as 22% moisture content in the case of paddy). The basic design consists of two concentric shells with an annular space in between. The inner shell is of perforated sheet and the outlet shell is designed with 22 or 24 gauge galvanised plain sheet. The base sheet is perforated to facilitate air movement. Ventilation holes (75 mm apart) at the periphery of wall sheets enable hot air to escape. The roof consisted of 22 or 20 gauge galvanised plain sheets supported by trusses made of mild steel as in the galvanised corrugated sheet bin. Suitable outlets and inlets with locking arrangements are provided. An air control gate is incorporated in the design so that air can enter from the sides, thus increasing air movement in the bin. Ladder rests and ladder are also included in the design. Proper precautions are necessary if the bin is to be designed for small capacities (3 t). Larger capacities need more perforated pipes inside for proper air circulation. Extra heating of atmospheric air if necessary, is supplemented by a suitable solar reflector.

Composite bin

The bin consists of both wood and steel. Wooden columns provide support to the galvanised steel wall. Because of the support afforded by the wooden columns, 22 gauge sheets are used. With this technique, bins ranging from 3–14.5 t can be constructed. No wall stiffeners are necessary and wooden beams are used for support in the roof. Suitable outlets and inlets with locking arrangements, ladder-rest and ladder are also provided. A brick masonry base is suitable and all mild steel parts are properly painted.

Outdoor non-metallic structures

The following types of non metallic structures are used:

Reinforced cement concrete ring bin

This type of bin is designed either with locally available reinforced cement rings or rings cast in situ. Rings are cast with 1:2:4 cement, sand, and aggregate mixtures. Cement and sand mortar at a ratio of 1:2 is recommended for joining the 300 mm rings. The brick masonry base is designed with a reinforced cement concrete roof, and metallic inlet and outlets are provided. The outlet cover is lined with wooden inserts/discs to prevent condensation at inlet. Proper water proofing treatment is given for preventing seepage of water into the structure. The structure is designed for various capacities.

Reinforced brick bin

Designed for various capacities, this bin is made of reinforced steel bricks. The bin is constructed of two reinforced brick walls, with an inner layer of polyethylene. The roof is of reinforced cement concrete, and the inlet and outlets are similar to that of the reinforced cement concrete ring bin.

Hollow block bin

Hollow cement concrete blocks, in a ratio of 1:6 cement and sand mixture are being used to construct storage structures. The remaining features are similar to that of reinforced cement concrete bins or reinforced brick bins.

The Economics of Engineering Input

In modern design there has been a great saving of steel and cement (Shukla and Patil 1990). For example, in warehouse design, mild steel has been replaced by cold twisted deformed steel. The number of compartments are also reduced. The angle iron trusses are replaced with tubular trusses as they are lighter in weight compared to steel trusses. The greatest advantage in this design is that no intermediate columns are provided to hold the structure as single open roof serves the purpose. This gives maximum utilisation of space without any obstruction. A comparison of consumption of steel trusses of different design is given in Table 1.

Table 1. Steel requirement in different designs of trusses used in storage structures.

Type of truss	Weight (t)	Steel (kg/m^2)	Reduction in steel use (%)
Structural steel truss	50	16.70	–
Tubular truss with tubular purlin	36	12.00	28
Tubular truss with cold roll from section purlin	31	10.40	38

Scientific design has reduced the use of steel and cement by 60% in the construction of these structures. The use of high tensile steel for reinforcement and tubular trusses and cold rolled sections for roof purlins has brought down the demand for steel. Cement use has also been reduced due to application of under pile foundation and the elimination of base concrete for floors. A comparison of use of cement and steel consumption in construction of storage structures is given in Table 2.

Table 2. Requirements of cement and steel in different types of warehouse design.

Type of design	Cement (kg/m^2)	Steel (kg/m^2)
RCC flat roof warehouse	193.50	38.00
Warehouse with structural steel designs	139.00	41.50
Conventional warehouse with tubular truss	99.50	23.00
Conventional warehouse with tubular truss and design on ultimate load theory	94.50	18.50
Conventional warehouse by adopting revised design of floor	74.00	18.50
Conventional warehouse with re-designed truss with cold rolled from sections of purlins	74.00	17.00

Reduction of space in alleyways is accomplished by eliminating intermediate covered columns and providing large single spare roof trusses. Space requirements for alleyways in different types of designs are shown in Table 3. Approximate costs of construction of different designs are given in Table 4.

Strategies to meet the need

The basic objectives are to meet the storage requirements of rural producers and consumers so that losses can be reduced, enabling producers and consumers better access to the market.

Table 3. Space requirements for alleyways in different designs of warehouses.

Type of warehouse	Alleyways (%)
RCC roof warehouse	37
Tashspan warehouse	30
Single-span warehouse	25
Modified single-span warehouse	24

Table 4. Cost of construction per tonne in different designs of warehouses.

Design	Capacity (t)	Cost of construction/t	
		Indian rupees	US$
RCC flat roof	5000	1600	54
Twin span warehouse	5000 t	1500	50
Conventional warehouse	5000 t	1200	40
Modified conventional warehouse	5000 t	1000	34
Grain warehouse	650 t	1100	37
Rural warehouse	200 t	1400	47

Decentralised facilities available through cooperatives have to be part of a large network, but should not be too large to cater for the small hinter land. Godowns at village level have a capacity of 100 t, with godowns built at secondary/terminal markets having capacities ranging between 250–500 t.

In order to maintain the viability of investment in godowns, multiple activities have to be undertaken. In a country like India, modernisation of storage is a lengthy process, and bulk storage systems must be encouraged. Constant research is underway to improve the system and design of Indian storage conditions, as well as extension of the improvements to users.

Conclusions

Engineering input in the design of scientific storage structures has played a key role in providing appropriate and economical storage systems on-farm as well as in rural areas of India.

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