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DESIGN AND DEVELOPMENT OF PADDY STORAGE STRUCTURE FOR KONKAN REGION

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ABSTRACT

Improved on farm structure of 1 tonne capacity from locally available laterite stone was designed. Engineering properties of the paddy (variety R-117) and the laterite stone were determined. The engineering properties of the laterite stone were recorded as compressive strength (210 N/cm^2) and water absorption (3.78%). Rankine's theory was used to design the height and diameter of the bin. Safe height of the bin was 1.6 m and the diameter was 1.2 m. Maximum lateral pressure exerted by the paddy grains on the wall of the bin of the designed dimensions was 248.78 kg m^{-2}. Design wall thickness, depth of foundation and total load supported by the foundation was 150 mm, 750 mm and 7935.93 kg m^{-2}, respectively. Roof of the bin was designed as a circular R. C. C. slab with its Design thickness of 100 mm and design diameter of the reinforcement was 6 mm with 140 mm c/c spacing. Total span of the roof is 2 m with 0.2 m overhangs. Laterite bin was constructed according to the dimensions determined by calculations. The total cost of the structure is ` 7525. Average paddy temperature remains nearly constant throughout the day. Axial temperature was greater than the peripheral because of heat added by the respiration of the paddy grains. Average moisture content of the paddy in the top layer was greater than that in the bottom layer. Moisture gradient due to difference in relative humidity has might have resulted in wetting upper paddy to become wet. Relative humidity inside the bin was greater than the outside because of vapour addition by the respiration of the stored paddy.

KEYWORDS: Design, Development, Paddy Storage Structure Low Cost, Moisture Content

1. INTRODUCTION

Food grains are required to be stored for human food, for animal feed, for seed and for sale or barter. Recent advances in the irrigation science and introduction of hybrid varieties of cereals has resulted in the upsurge in the food grain production. Grains produced in the country is stored at farmers, traders, government, semi-government and cooperative levels in various types of storage structures. A survey of the existing farm storage structures reveals that the grain losses take place due to lack of utilization of scientific methods of storage and improved storage structures. Improved storage structures are the most important factor in preservation of damage free grains. It prevent stored grain from spoiling, preserves seed grain viability, reduces running cost of storage, permits effective pest control practices and facilitates convenient and economical grain loading and unloading operations. Farmers store grains usually in bulk in different types of storage structures constructed from locally available raw materials. Some of the most commonly used indoor and outdoor structures are primarily made of mud, paddy straw or reed and split bamboo. Mud structures are neither completely moisture-proof nor airtight.

Studies on storage structures for grains made from various materials were undertaken by various research workers Eswarappa, *et al.* (1991) evaluated different storage structures for storing paddy and reported germination of paddy stored in gunny bags under ambient conditions was decreased from 85% (in August) to 48% (in March), while germination of the grains stored in a coal tar drum or plywood bin was 80-90 and 84-95%, respectively, throughout the storage period. Pest infestation and storage temperature was increased in paddy stored in the gunny bags as compared to other containers. Moisture contents were similar in grains stored in the 3 containers. Paddy (type Nadu) was stored outdoor for a period of 6 months in jute bags of 65 kg capacity in Sri Lanka. Bags were placed in flexible liners (10 or 20 t capacity) known as storage cubes. No insect infestation was reported by Donahaye *et al.* (1991) during storage. 1000-grain weight evaluations indicated a 0.33-0.64% loss in DW due to metabolic activity in stored paddy. A two dimensional mathematical model, based on calculating heat transfer by finite-difference methods, was developed by Abe and Basunia (1996) to simulate the temperatures in cylindrical storage bins Basunia *et al*. (1996) solved two dimensional heat conduction problem in a cylindrical coordinate system, expressed as a partial differential equation, using the finite difference method to predict the temperature distribution in cylindrical rough rice storage bins Ileleji *et al*. (1998) presented an experimental design for simulating grain storage systems to be used in validating mathematical and computer models of heat and mass transfer in stored grain Bala *et al.* (1993) studied three types of traditional bamboo storage bins (dhangola, berh and dool) used in Bangladesh. A study was conducted by Savanur *et al.* (1996) in Dharwad taluka, Dharwad district, Karnataka, India, to investigate the adoption of improved methods of food grain storage. Parameters like chemical pest control, disinfection of storage structures with Malathion were studied.

The traditional structures prevailing in Konkan are kananj or sathi, mudi, kangee, matkae, tatti, hadpa. In such structures insects, fungus and rodents usually damage the grain. They are also not suitable for fumigation as the gas leaks out. Paddy (Oryza sativa Linn) is the major cereal crop grown in the Konkan region. Farmers store the paddy in locally made structures in their houses. But there is loss of time as well as money for transporting the grain to the place of storage. Therefore, it is necessary to develop the on farm storage facility for storing rough paddy, hence the study is aimed to arrive at a cost effective practical solution for this problem faced by the farmers by using locally available material.

2. MATERIALS AND METHODS

2.1 Theoretical Design of Paddy Storage Structure of 1 Tonne Capacity

Paddy storage structure of 1 tonne capacity is theoretical designed considering following criteria

2.1.1 Diameter and Height of the Bin

- Weight of paddy to be stored = 1000 kg
- Bulk density of paddy

It varies from 550 kg/m^3 to 610 kg/m^3 (Kachru, 1999). The minimum value was selected for design. Thus design bulk density of paddy is 550 kg/m^3.

- Volume of paddy to be stored = $\dfrac{\text{Weight of paddy to be stored}}{\text{Bulk density of paddy}} = \dfrac{1000}{550} = 1.82\text{m}^3$

- Natural angle of repose of paddy = 30^0 (Sahay and Singh, 1999)

  By Rankine's theory, height and diameter of the bin was taken as 1.6 and 1.2 m.

2.2 Design of Roof

- The roof is designed as a circular R. C. C. slab with overhang of 200 mm.

  Design load = 5.25 × 1.5 = 7.875 kN/m^2 ≈ 8 kN/m^2

  Let the bending moment and shear force for circular slab could be calculated as follows (Shah, 2001)

  M_r = Bending moment in radial direction

  M_r at Edge = 0 at Center = $\frac{3\times w\times a^2}{16} = \frac{3\times 8\times 1^2}{16} = 1.5$ kN-m

  M_θ = Bending moment in circumferential direction

  M_θ at Edge = $\frac{2\times w\times a^2}{16} = \frac{2\times 8\times 1^2}{16} = 1$ kN-m

  M_θ at Center = $\frac{3\times w\times a^2}{16} = \frac{3\times 8\times 1^2}{16} = 1.5$ kN-m

  V_r = Shear force in radial direction

  V_r at Center = 0.5 × w × a = 0.5 × 8 × 1 = 4 kN

  Maximum bending moment at center (M_{rmax}) = 1.5 kN-m

  Maximum bending moment at edge ($M_{\theta max}$) = 1 kN-m

- Percentage of steel at center (p_t) is given by

$$p_t = 50\left(\frac{1-\sqrt{1-\frac{4.6}{f_{ck}}\times\frac{M_{r\max}}{bd^2}}}{f_y / f_{ck}}\right) \quad p_t = 50\left(\frac{1-\sqrt{1-\frac{4.6}{20}\times\frac{1.5\times 10^6}{1000\times 100^2}}}{250/20}\right) = 0.0696$$

where,

f_{ck} = Characteristic compressive strength of concrete (for M20 concrete, f_{ck} = 20 MPa)

f_y = Yield strength of mild steel = 250 MPa

Take factor of safety = 3,

Thus design percentage of steel = 0.0696 × 3 = 0.2088

- Area of steel required at center per meter length of slab = $A_{st} = \frac{p_t}{100} \times 1000 \times t_s$

where, t_s = thickness of slab = 100 m $\therefore A_{st} = \frac{0.2088}{100} \times 1000 \times 100 = 208.8\ mm^2$

Thus, provide 6 mm Φ M. S. bars at 140 mm center-to-center spacing (As per steel table).

- Percentage of steel at edge is given by

$$p_t = 50\left(\frac{1-\sqrt{1-\frac{4.6}{f_{ck}} \times \frac{M_{\theta max}}{bd^2}}}{f_y / f_{ck}}\right) \quad p_t = 50\left(\frac{1-\sqrt{1-\frac{4.6}{20} \times \frac{1 \times 10^6}{1000 \times 100^2}}}{250/20}\right) = 0.0463$$

Factor of safety = 3

Thus, design percentage of steel = 0.0463 × 3 = 0.1389

- Area of steel required at edge per meter length of slab

$$A_{st} = \frac{0.1389}{100} \times 1000 \times 100 = 138.9\ mm^2$$

Thus, provide 6 mm Φ M. S. bars at 210 mm center-to-center spacing. (According to steel table)

For convenience in layout and to avoid the stresses developed at the edge of the lid the minimum spacing of 140 mm center-to-center was adapted for design.

2.3 Design of Wall

- Lateral pressure exerted by paddy on wall

$P_h = K_a \gamma h$

where, K_a = coefficient of active pressure given by

$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1-\sin 30^0}{1+\sin 30^0} = 0.3333$$

γ = Bulk density of paddy = 550 kg m^{-3}

P_h = 0.3333 × 550 × 1.6 = 293.33 kg m^{-2}

- Permissible tensile stress of cement mortar (F_s) = 3300 kg m^{-2}

The tensile strength of cement mortar was considered in the design because the stone masonry will fail along the joint of cement mortar, which is the weakest section of the structure.

Thickness of wall (t) = $\frac{P_h \times D}{2 \times F_S} = \frac{293.33 \times 1.2}{2 \times 3300}$ = 0.053 m

Factor of safety = 2.5

Design thickness of wall = 0.053 × 2.5 = 0.1325 m = 132.5 mm.

But the standard size of laterite stone available in the market was 380 mm×250 mm×150 mm. Thus, the minimum thickness of wall provided was 150 mm.

- Volume of stone masonry = Volume of the masonry × Total height

= (Outside cross-sectional area – Inside cross-sectional area) × height

$$= \frac{\pi}{4} \times (1.5^2 - 1.2^2) \times (1.6 + 1.0) = 1.654 \text{ m}^3$$

Number of Stones = $\frac{\text{Total volume of masonry}}{\text{Volume of one stone}} = \frac{1.654}{0.38 \times 0.25 \times 0.15} = 116$

Taking into account the size reduction of stones while cutting and giving curvature total 160 stones were used.

- Design of foundation

Load per unit area to be supported by the foundation

Load of paddy= 212.21 kg m^{-1}

Load of stone masonry=2456.14kg m^{-3}

Total load of laterite stone masonry of wall = 2500 kg i.e. 530.52 kg m^{-1}

LOAD OF ROOF= $\frac{10}{\pi/4 \times (1.5^2 - 1.2^2)} = 15.71$ KG M^{-2}

- TOTAL LOAD OF ROOF PER UNIT CROSS-SECTIONAL AREA = 816.33 + 15.71 = 832.04 KG M^{-2}

Load of roof per unit perimeter = 112.32 kg m^{-1}

Load of floor = 126.75 kg/m

Total load on foundation (P_f) = 5984.05 kg m^{-2}

- Depth of foundation = d = $\frac{P_f}{W}\left(\frac{1 - \sin\phi}{1 + \sin\phi}\right)^2$ = 0.2852 m= 285 mm

Factor of safety = 3

Design depth of foundation = 285 × 3 = 855 mm

- Width of foundation

Total load on foundation per unit length =

212.21 + 530.52 + 112.32 + 126.75 = 981.8 kg m^{-1}

Width of foundation (w_f) = $\frac{\text{Load on foundation per unit length}}{\text{Safe bearing capacity of soil}} = \frac{981.8}{15000}$ = 0.065 m

Factor of safety = 2

Design width of foundation = 0.065 × 2 = 0.13 m = 130 mm

Check against failure of wall

The horizontal section of wall must be checked for the stresses produced due to weight of paddy transferred, self weight of masonry, weight of roof transferred and due to wind pressure.

Thus total stress on the wall = 165.786 + 3929.82 + 832.04 + 981.48 = 5909.13 kg m^{-2}

= 5.791 N/cm^2

Compressive strength of laterite stone = 510 N cm^{-2}

The elevation of laterite bin was shown in Plate 1.

As total stress on wall is very less than the compressive strength of laterite stone, hence the wall is very safe. Materials required and the cost of construction of laterite bin presented in Table 1.

Bin was loaded with paddy of variety R-117. Initial moisture content was 11.7 %. The mass of paddy stored was 375 kg. It occupied height upto 45 cm from bottom. Four thermocouples were installed in the paddy bulk for taking temperature readings. Three of them were installed near wall, 8 cm away from the wall, in such a way that the angular spacing between them was 120^0. Fourth thermocouple was installed at centre. Depth of all thermocouples extended up to 40 cm from the top of the paddy grain mass. Temperature and relative humidity were recorded at an one hour interval from 8 a.m. to 8 p.m. for consecutive eight days from 10th to 18th April 2003. Moisture content of paddy samples at top and bottom of the paddy grain bulk was recorded with the help of Universal Moisture Meter. Reading of moisture content were taken at 8.00 a.m., 1.00 a.m. and 5.00 p.m. for eight consecutive days.

3. RESULTS AND DISCUSSIONS

Survey of the local paddy storage structures revealed that the most popularly Hadpa and Kanang are used for storing the paddy by the farmers, but these structures cannot withstand the wind as well as rainwater impact hence can not be used outdoors. To overcome these drawbacks, a structure was constructed in laterite stone which is plenty available in Konkan region. Plan of structure was decided to be circular rather than square since there are no corners, the cleaning becomes easier and there are no wet pockets. The design capacity of bin was decided 1 tonne since the marginal farmers require small storage structure of about same capacity for paddy.

3.1 Temperature Variation in the Laterite

The data shown are the average of temperature of eight days for particular clock time. It is evident from Figure. 1 that the temperature inside the paddy grain mass is more or less constant irrespective of the fluctuations in ambient temperature. Also the temperature at the axis of the bin was higher than the peripheral temperatures.

3.2 Variation in Paddy Moisture Content

Average data of moisture content of eight days at top and bottom of a bin versus 8, 13 and 18 h is plotted in Figure. 2. It is seen that the moisture content of the paddy at top surface of paddy grain bulk was greater than that of the bottom of the grain bulk. Moisture content was the highest in the morning and it was decreased as the day progressed.

Relative humidity of ambient air and inside the bin is plotted against time in Figure. 3. It was found that relative humidity inside the bin was greater than outside the bin. Moreover, similar trend was observed inside and outside condition of bin.

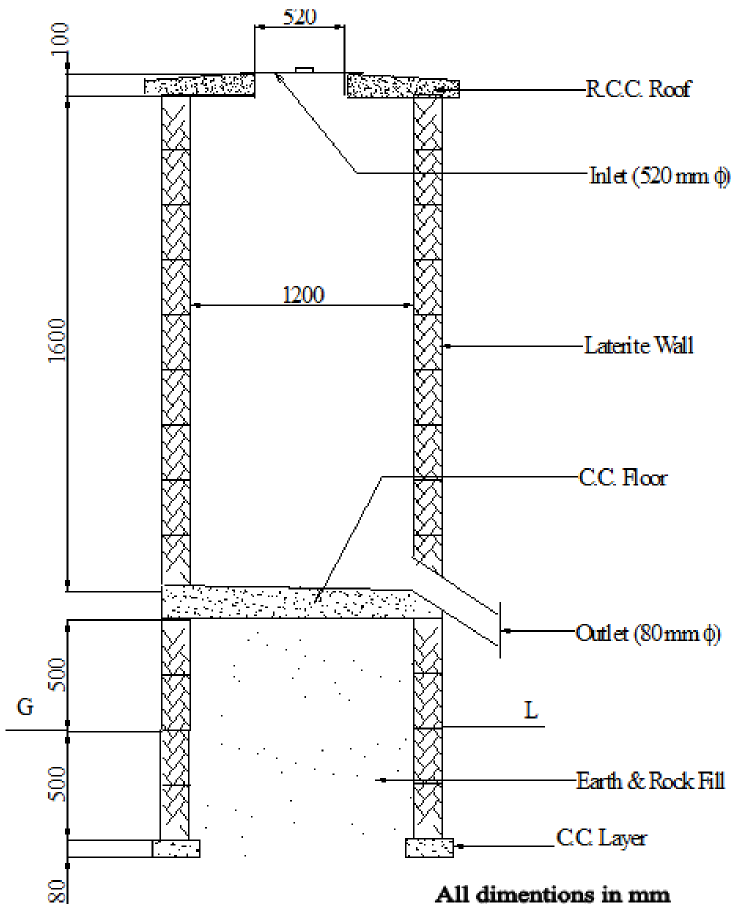

Plate 1. Elevation of laterite bin

Figure 1

Table 1: Costing of 1 Tonne Paddy Storage Bin

S. No.	Item	Approximate Cost	Quantity	Amount
1	Laterite Stone (40cm×25cm×15cm)	Rs.10 per piece	170 pieces	Rs.1700
2	Cement	Rs.145 per bag	10 bags	Rs.1450
3	Sand	Rs.2000 per brass	0.25 brass	Rs.500
4	Stone Chips	Rs.8 per pot	50 pots	Rs.400
5	M. S. Bars	Rs.17 per kg	25 kg	Rs.425
6	Binding Wire	Rs.25 per kg	1 kg	Rs.25
7	Nails (2")	Rs.25 per kg	1 kg	Rs.25
8	Labour			Rs.3000
1) Total				Rs.**7525**

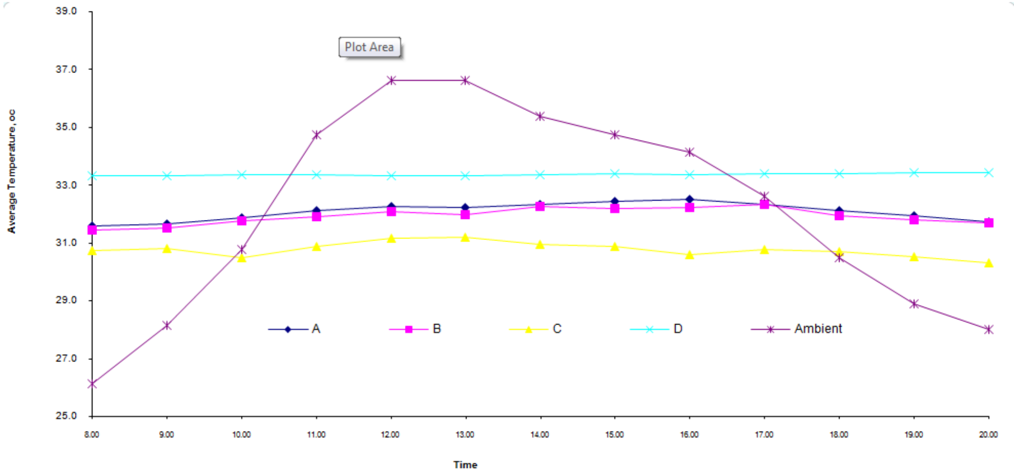

Figure 1: Variation in Bin Temperature

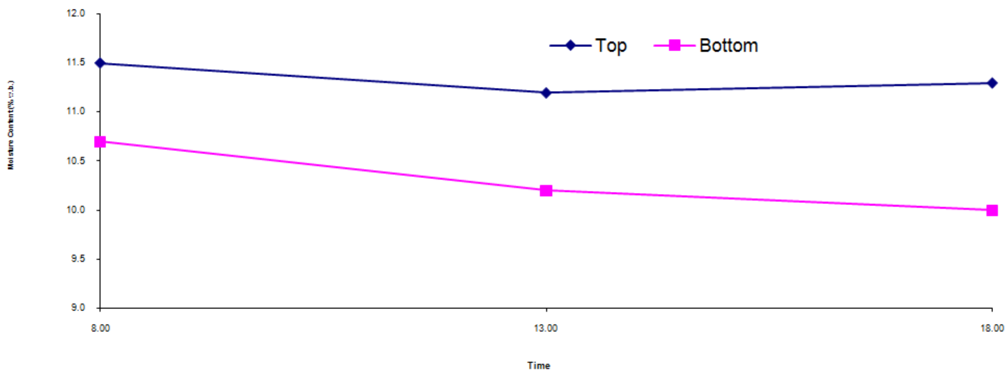

Figure 2: Variation in Moisture Content

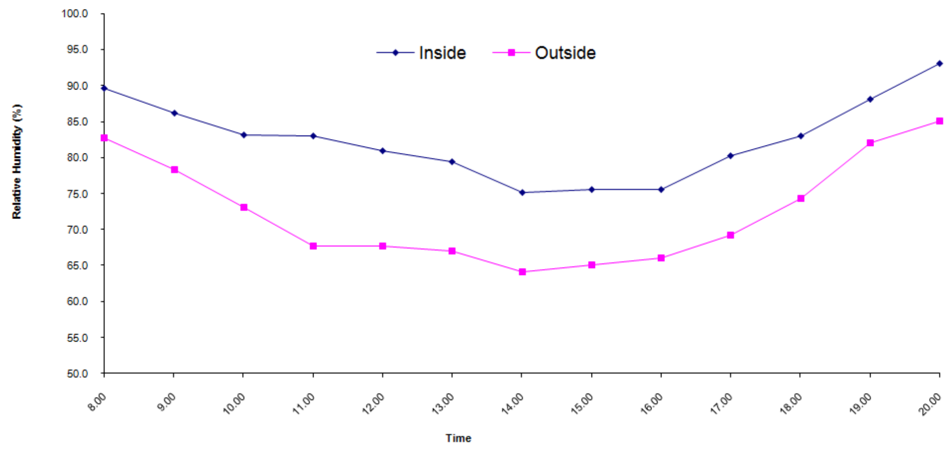

Figure 3: Variation in Relative Humidity

CONCLUSIONS

Improved one tonne low cost paddy storage structure made out of laterite stone with R. C. C. roof and concrete floor is beneficial for marginal farmers.

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