Economical Design for Dairy Farm Structures

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Abstract— *In this study a steel framed dairy farm structure designed by considering IS 800-2007. It has been observed that by following the code recommendations for the design of dairy farm structures, it becomes expensive, that an ordinary farmer can't afford it. The basic idea of the investigation is to make these structures more economic for the farmers so that they become affordable. It is proposed to take realistic approach viz-a-viz applicable codes in design of these structures to make them safe and economical. The analysis and design will be done using ETABS software. The factors such as structural capacity and cost involved will be focused in the study.*

Keywords— Dairy Farm, Economic Design, Realistic Loads, Quantity Comparison.

I. INTRODUCTION

India is agrarian country. Agriculture is the profession of more than 75% of the population of the country and dairy farming comes along with it. Dairying is an important source of subsidiary income to small/marginal farmers and agricultural labors. Dairy producers aim to ensure that the safety and quality of their raw milk will satisfy the highest expectations of the food industry and consumers.

The total milk production in the country for the year 2018-19 was estimated at 189 million metric tonnes and the demand is expected to be 230 million tonnes by 2022. To achieve this demand annual growth rate in milk production has to be increased from the present 6.5 % to 9%. Thus, there is a tremendous scope for increasing the milk production through profitable dairy farming. Thus, understanding the requirements for dairy farm structures gain attention of this study.

This includes study of geometry of structure. The structure is used mainly by animals for living purpose. Different areas are to be made for resting and feeding them. These structures are situated in farms which are plain terrains. All these put challenges in selecting the shape and size columns. Therefore, careful designing is essential.

The productivity of animals in India is not as much to justify the cost of production of safe milk. Therefore, farmers look for lower costs. Even the financial institutions stress to lower the cost for better feasibility and sustainability of these farms. Hence the thorough study is needed to lower down the costs of these structures.

II. LITERATURE REVIEW

Indian Standard Recommendations for Cattle Housing for Large Dairy farms [12] in 1970 suggested that better breeding coupled with selection, feeding and disease control, proper housing is an important feature in raising the productivity of animals. At present only a small proportion of cattle is maintained on scientific lines. Proper housing which is conducive to good health, comfort and protection from inclement weather, and which would enable the animals to utilize their genetic ability and feed for optimal production, is grossly lacking except at a few organized farms. India’s climatic conditions, unlike most of the principal dairy countries of the world, are very varied. Hence designs of cattle sheds would also vary according to the climatic conditions prevailing in a particular region. To meet this requirement code has adopted the classification as plain areas with medium rainfall, heavy rainfall and high humidity areas, arid areas, and high altitude areas.

Indian Standard recommendations for Gaushala[15] in 1986 gave the general layout for dairy structures and various components of the structure. It gave the detail classification of each and every required area for dairy farm structure and defined all the terminologies used in dairy farming. It also provided site selection criteria.

S.K. Mosielele[20] in his “Dairy Farm Handbook” pictorially explained about different types of breeds of cows, the country in which the breed is developed, their nature, weights and per day milking capacities that helped in understanding the facts about different breeds so as to design the farm accordingly.

Indian standard recommendations for Cattle Housing in Rural areas[17] in 2005 provided recommendations for layout and constructional details of a cattle shed meant for an average farmer normally having three milch animals with their calves and a pair of bullock and rural milk producer normally having 20 animals which may include about 12 milch animals, their followers and a pair of bullocks.

International Dairy Federation in their research paper titled “Guide to Good Dairy Farming Practice”[4] in 2011 provided information about animal’s health, milking hygiene, animal’s nutrition that includes food and water, animal welfare, environment and socio-economic management. It is said that these practices must ensure that the milk and milk products produced are safe and suitable for their intended use, also that the dairy farm enterprise is viable into the future, from the economic, social and environmental perspectives. This study approaches to highlight relevant aspects that need to be proactively managed on dairy farms, to identify the desired outcomes in dealing with each of these areas, to specify good practice that addresses the critical hazards, and to provide examples of control measures that should be implemented to achieve the objectives. This Guide is intended as a resource for dairy farmers, to be used or implemented in a way that is relevant to their particular farming system. The focus is on the desired outcomes, rather than on specific, prescriptive actions or processes.

K. Suresh Kumar, C. Cini, Valerie Sifton [6] in their research paper “Assessment of design wind speeds for metro cities of India” recalculated the design wind speeds based on the local airport data. In this study it is seen that the design wind speeds for metro cities of India have been found to be about 5-10% lower than wind speed provided in Indian Standard. This can have significant impact on the prediction of wind induced loads of structures.

N. Lakshmanan, S. Gomathinayagam, P. Harikrishna, A. Abraham and S. Chitra Ganapathi[9] collected long-term data on hourly wind speed from 70 meteorological centres of Indian Meteorological Department. The daily gust wind data is processed for annual maximum wind speed for each site. Extreme wind value quantities have been derived using the Gumbel probability paper. A revised basic wind speed map for the country is suggested in which it is found that basic wind speed for most of the cities in India is found to much lower than the one suggested by Indian Standard.

American Society of Civil Engineers [1] in 2003 provided requirements for dead, live, soil, flood, wind, snow, rain, ice, and earthquake loads, and their combinations that are suitable for inclusion in building codes and other documents. Substantial changes were made to the wind, snow, earthquake, and ice provisions. In addition, substantial new material was added regarding the determination of flood loads. The structural loading requirements provided by this Standard are intended for use by architects, structural engineers, and those engaged in preparing and administering local building codes.

Indian Standard code of practice for design loads for building and structures IS: 875 (Part 2)-1987 for imposed loads. [16] By referring this code stepwise imposed loads are calculated for different components of dairy farm structure. This gave thorough and systematic method for finding out wind load intensities.

Roberto Mosheim and C. A. Knox Lovell [11] surveyed different farms based on the 2000 Agricultural Resource Management Survey, the most recent national survey of dairy producers in the United States. They employed a shadow cost function to decompose and analyze economic efficiency and scale economies. Preliminary results point to important scale economies and suggested that surviving small farms are on average more economically efficient but can exploit scale economies to a much lesser degree than larger farms.

Nikhil Agrawal, Achal Kr. Mittal, V. K. Gupta [10] in 2009 performed the load analysis by referring several different countries codes. For this analysis they have used Howe truss with different roof angles like 5^o,10^o,15^o,20^o, and 25^o slopes. It has been observed that the minimum forces are obtained for 15^o roof slope. Thus, in this study we are adopting 15^o slope for roof slope.

Indian Standard Design Loads for Building and Structures – Code of Practice IS 875: (Part 3) -2015 for wind loads. [19] The wind load intensities for different components of the structure are calculated by the reference of this code.

Indian Standard General Construction in Steel- Code of Practice IS 800: 2007 [18] gave the details regarding the steel design for various types of steel structures by both limit state and working stress method. It provided section properties for hot rolled sections.

James M. MacDonald, Erik J. O’Donoghue, William D. McBride, Richard F. Nehring, Carmen L. Sandretto, and Roberto Mosheim [5] in 2007 concluded in their paper Profits, Costs, and the Changing Structure of Dairy Farming that larger farms realize lower production costs. Although small dairy farms realize higher revenue per hundredweight of milk sold, the cost advantages of larger size allow large farms to be profitable, on average, even while most small farms are unable to earn enough to replace their capital. On average, farms with at least 1,000 cows realize costs, per hundredweight of milk produced, that are 15 percent lower than farms in the next largest size class (500–999 head) and 35 percent lower than farms with 100–199 head. Other evidence suggests that costs may continue to decline as herds increase to and above 3,000 head.

Dejun LIU, Guangsheng ZHANG (2010), [2] used various sensors, automatic machines and intelligent technology (IT) applications make it possible to manage a dairy farm supply chain on a more detailed level than before and described a new system which can be used to develop an Intelligent Communication Technology (ICT) system as dairy farm management tools to describe, document and control all processes on dairy production. With the intelligent and integrated system, the farm managers never needed to operate several computers each day and manually transfer data from one unit to another, and even made more rational decision through acquiring amount of information.

Nicholas S Trahair (2012) [13] concluded that future designs might allow the use of purpose-built computer programme which can provide accurate predictions of members strength, and might only describe the characteristics of the methods of structural analysis and the member design strength which may be used. Such a code would have some of the present member strength inaccuracies and shortcomings removed and allow them to be replaced by the more accurate member strength computer programs.

Steffe Jerome and Grenter [14] in their paper namely Gilbert Information System for Farms using Precision Agriculture Techniques and EDI standards tried to define an up-dated general Information System for farming. This general Information System is based on a central module, to which are connected several peripheral thematic modules. One of these peripheral modules was designed for crop production, taking into account the needs of Precision Farming. Compatibility of this Information System with ISO standards for EDI in agriculture was tested, and a review of the critical points was carried out.

III. DESIGN DETAILS

3.1 Selection of type of Structure

As economy is major concern of this study, we have started with very basic structures like frame structures with different fixity at bases. Trails are conducted to arrive at final types of structure. Thus, after trying out different frames and trusses we arrived at Dual pitched roof truss with semi-rigid joints.

3.2 Selection of suitable Roof Slope

While designing any industrial building with Pitched roof, studying roof slope is of paramount importance as it influences the components of loads acting on it. Thus, while moving for the design of dairy farm structures initially we focused on selection of roof slope. In IS 6027-1970 “Recommendation for Farm Cattle Housing for Large Dairy Farms” section A -5.1 it is suggested to adopt roof slope of 22 to 30^o. But several studies says that roof slope of 15^o is practically better.

FIGURE 1: Frame with 22^o slope

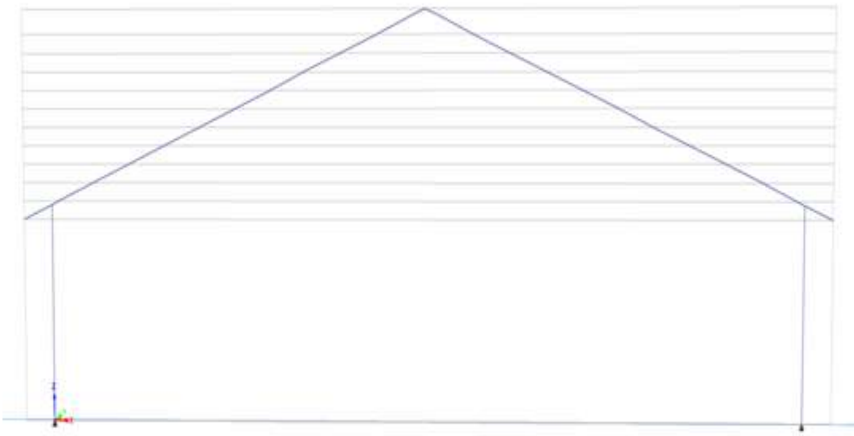

FIGURE 2: Frame with 15° slope

Thus, here we are going to take two different models with both 15° and 22° slopes.

3.3 Load Calculations

Load calculations are done separately for both designs. Thorough study of different loads and load combinations are done.

Loads calculation for 15° slope model

Economy can be achieved by considering loads which actually going to act on the structure and designing it for those specific loads. Thorough study is conducted for finding out realistic loads on the structure. Various Indian Standard codes and several research papers are referred. Load calculations were done as follows.

Dead Load,

GI sheeting = 0.037 KN/M^2

Fixings = 0.025 kN/m^2

Live Load, (As per IS: 875 Part 2 – 1987)

Adopted roof slope is 15° therefore from table no.2 of IS 875:1987 Part-2

For sloping roof with slope greater than 10°

0.75– (0.2*5) = 0.65 kN/m^2 for purlins

Wind Load, (As per IS: 875 Part 3 – 2015)

The Structure is considered to be located in Nashik city in Maharashtra.

Length = 58 m

Width = 26.66 m

Height = 7 m

$V_z = V_b. k1. k2. k3. k4$

where Vb = Basic Wind Speed = 39 m/s

For Farm Structures,

Mean Probable design life = 25 years

k1 = 0.92….(from Table 1)

k2 = 1….(from Table 2) for Cat 2

k3 = 1….(clause 6.3.3.1)

k4 = 1….(clause 6.3.4)

Vz = 35.88 m/s

$P_z = 0.6 \times V_z^2 = 772.424$ N/m^2

Design wind pressure is,

Pd = Kd. Ka. Kc. Pz or 0.7Pz (whichever is higher)

Where, Kd = wind Directionality factor = 0.9

Ka = Area averaging factor = 1

Kc = Combination factor = 1

Pd = 0.695 kN/m^2

Net pressure co-efficient

(In X-direction)

Maximum positive roof pressure, (angel = 0) = +0.4

Maximum negative roof pressure. (angle = 0) = -0.8

Purlins spacing = 1.3 m

TABLE 1
NET PRESSURE CO-EFFICIENT IN X-DIRECTION.

(Pz x Area x Co-eff.)	Windward (kN)	Leeward (kN)
Intermediate	0.695 x 0.4 x 1.3 = 0.361	0.695 x (-0.8) x 1.3 = -0.723
End	0.695 x 0.4 x 1.3/2 = 0.18	0.695 x (0.8) x 1.3/2 = -0.361

Thus, horizontal and vertical components of windward and leeward forces on purlins for 15° slope can be found out as follows. Taking 10% less loads than calculated as per K. Suresh Kumar, C. Cini, Valerie Sifton paper.

TABLE 2
VERTICAL AND HORIZONTAL COMPONENTS OF NET PRESSURE CO-EFFICIENT (WL 1)

	Components	Intermediate Purlins	End Purlins
Windward	Vertical (cos15°)	-0.3141	-0.157
	horizontal (sin15°)	0.0841	0.0421
Leeward	Vertical (cos15°)	0.6285	0.3141
	horizontal (sin15°)	0.168	0.084

(For Z-direction)
Roof pressure, (angel = 90°) = -0.3

TABLE 3
COMPONENTS OF NET PRESSURE CO-EFFICIENT (WL 2)

	Components	Intermediate Purlins	End Purlins
Windward	Vertical (cos15°)	0.235	0.117
	horizontal (sin15°)	-0.063	-0.0315
Leeward	Vertical (cos15°)	0.235	0.117
	horizontal (sin15°)	0.063	0.315

Seismic Load (IS -1893 part 4 -2005)

Vb = Design Shear = Ah.W

Ah = (Sa/g) / (R/I)

To find Sa/g

Natural period of vibration

Ta = 0.085 $h^{0.75}$

For steel frame

= 0.085 x $8.976^{0.75}$

= 0.4407 sec

From Annex B IS 1893 Part 4 : 2005

Sa/g = 2.5 for Medium Soil

I = 1 (From Table 4 structural in Category 4)

R = 5 (For steel frame)

Ah = 2.5/(5/1) = 0.5

Vb = 0.5 x 16.44 = 8.22 kN

Load calculations for 22° slope model.

Dead Load same as for 1st model

Live Load,

0.75 – (0.2*12) = 0.51 kN/m^2 for purlins

Wind Load,

Pd = 0.695 kN/m^2

Net pressure co-efficient (Calculated from Interpolation between 20° and 25° slopes)

(for X-direction)

Maximum positive roof pressure, (angel = 0) = +0.64

Maximum negative roof pressure. (angle = 0) = -0.94

Thus, horizontal and vertical components of windward and leeward forces on purlins for 22° slope can be found out as follows. considering full load as per codes.

TABLE 4
VERTICAL AND HORIZONTAL COMPONENTS OF NET PRESSURE CO-EFFICIENT (WL 1)

	Components	Intermediate Purlins	End Purlins
Windward	Vertical (cos22°)	-0.535	-0.277
	Horizontal (sin22°)	0.217	0.108
Leeward	Vertical (cos22°)	0.78	0.387
	Horizontal (sin22°)	0.33	0.156

(for Z-direction)
roof pressure, (angel = 90°) = -0.3

TABLE 5
COMPONENTS OF NET PRESSURE CO-EFFICIENT (WL 2)

	Components	Intermediate Purlins	End Purlins
Windward	Vertical (cos22°)	0.262	0.139
	Horizontal (sin22°)	-0.07	-0.035
Leeward	Vertical (cos22°)	0.262	0.139
	Horizontal (sin22°)	0.07	0.035

Seismic Load same as for 15° slope.

Load Combinations

Following Load Combinations are considered for both the models.

1.2 x DL + 0.6 x LL +1.2 x WL 1

1.2 x DL +1.2 x LL

1.5 x DL + 1.5 x WL 1

1.5 x DL + 1.125 x LL

1.2 x DL + 1.2 x SL

1.2 x DL + 1.2 x LL + 1.2 x SL

1.5 x DL + 1.5 x WL 2

1.2 x DL + 0.6 x LL +1.2 x WL 2

IV. ANALYTICAL INVESTIGATION

4.1 Modelling

Two models one with 15° roof slope and 22° roof slope is made using E-tabs Software separately. Load calculations are done for individual models. 1st model is with 15° roof slope and wind loads for this model are considered as 10% lesser as suggested by K. Suresh et al., (2012). Loads are applied in both X and Z directions. Another model is with 22° roof slope is made as it is suggested to adopt 22° roof slope for dairy farm structure in an Indian Standard code. The wind loads applied on this model are as per Code.

4.2 Selection of sections

Sections are assigned on the basis of trial and error method. Both the models have enough strong sections to withstand loads. Design and analysis are done and total quantity of steel is found out. The final design for both the models and analysis is done using E-tabs Software. 3-D view of the 15° and 22° roof slope model is as pictured below.

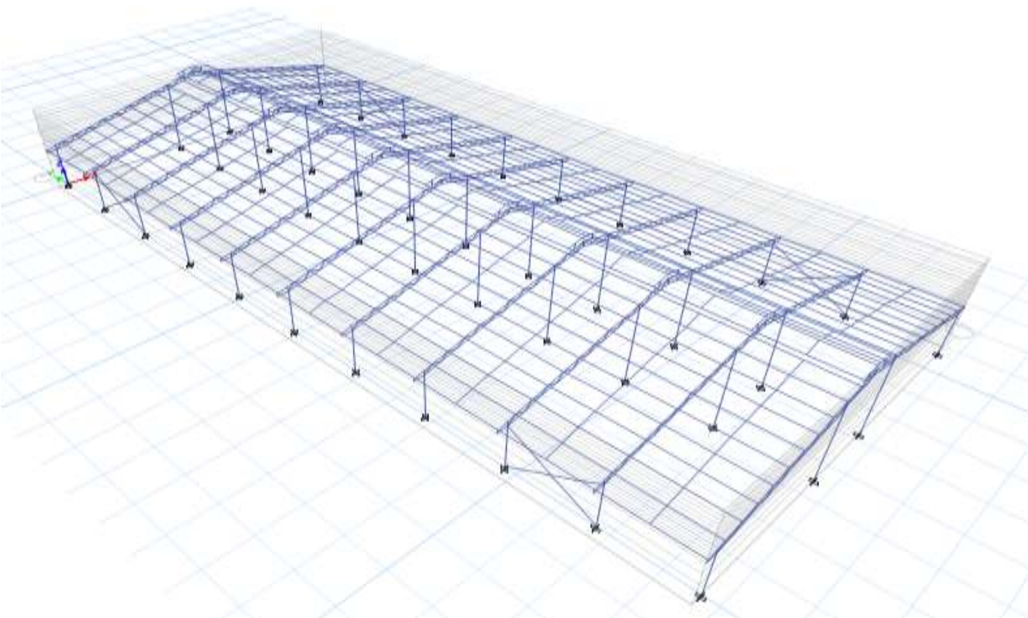

FIGURE 3: 15° roof slope model

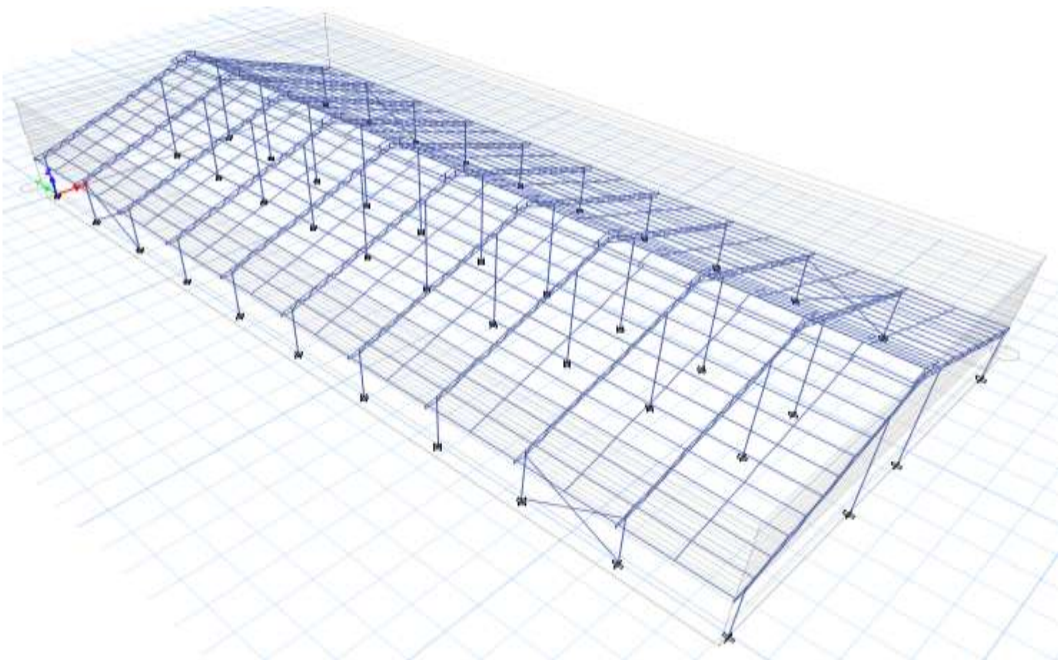

FIGURE 4: 22° roof slope model

V. RESULTS AND DISCUSSION

From Literature study it can be understood that 15° roof slope model proves better in saving material than 22° roof slope model, which is suggested by dairy farming code also minimum forces are obtained with 15° slope, and hence adopted.

Several Studies revealed that the wind load study code in India has not been updated since years and the actual load are approximately 5-10% of that suggested in codes . The 15° slope model is designed using 10% lesser loads than that on another model. As loads decreases smaller truss sections can be used.

The steel consumed by both the models is as displayed in tables below.

TABLE 6
TYPES OF SECTIONS USED FOR BOTH THE MODELS ARE DISPLAYED IN TABLE BELOW.

	Truss Member	Assigned Property
	22° roof slope model	15° roof slope model
External Columns	ISMB300	ISMB250
Internal Columns	TUB1001004	TUB1001004
Columns For Skylight	TUB45452.6	TUB30302.6
Upper and Bottom chord members	PIP1397M	PIP603M
Web Members	PIP483M	PIP337L
Purlins	ISMC150	ISMC125
Bracings	TUB63634.5	TUB63634.5
Sag Rods	Cir 0.01	Cir 0.01

TABLE 7
TABLE OF COMPARISON FOR QUANTITY OF STEEL

Model	22° roof slope	15° roof slope
Quantity of steel	47.1 tonnes	29.66 tonnes

VI. CONCLUSION

- It is observed that 15° roof slope proves ideal for designing of dairy farm shed.
- The reduced wind loads made it possible to reduce section sizes to very small as compared to conventional 22° roof slope model.
- The total savings in quantity of steel is found to be close to 30%.

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