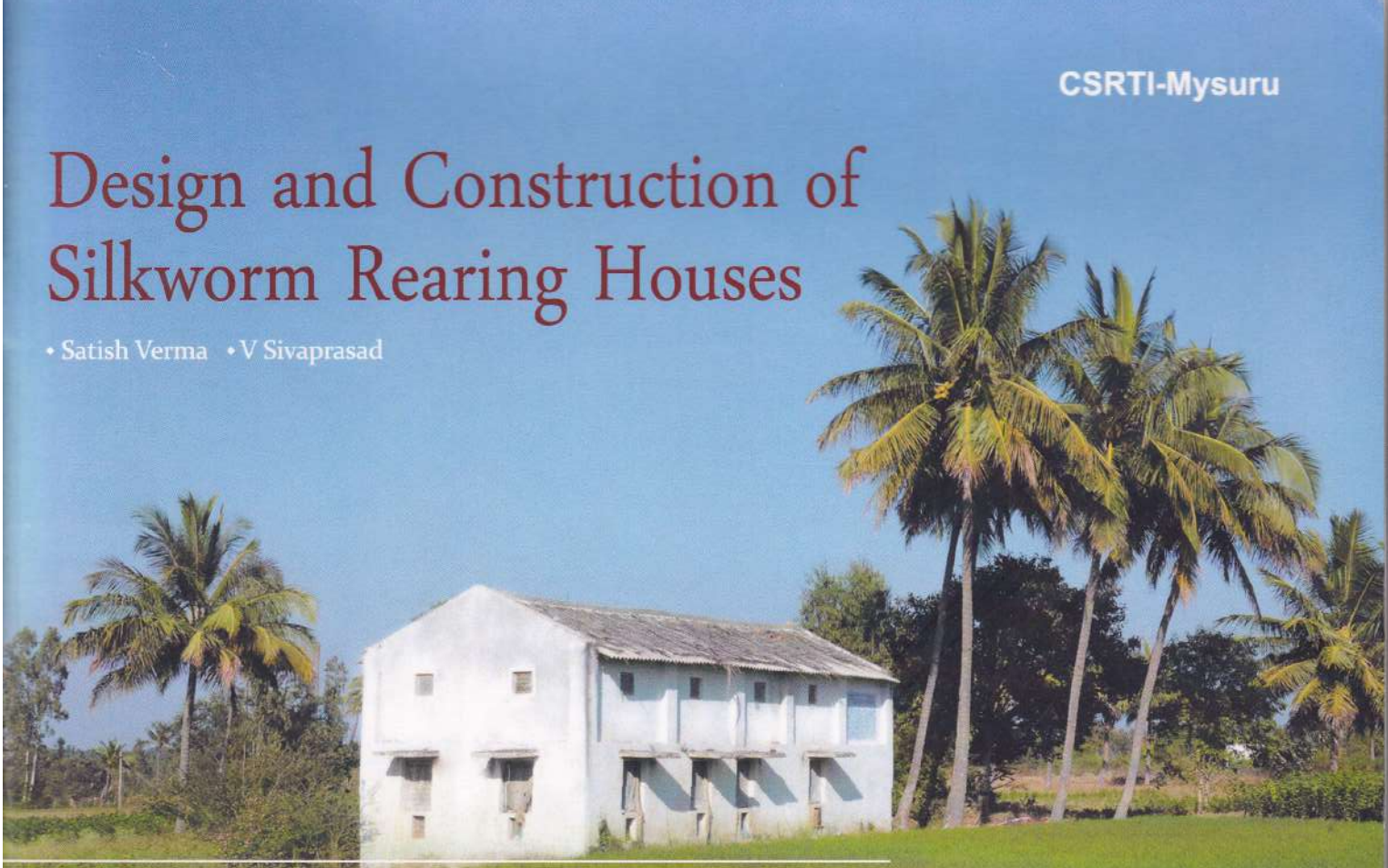
CSRTI-Mysuru

Design and Construction of Silkworm Rearing Houses

• Satish Verma • V Sivaprasad



Central Sericultural Research & Training Institute (CSRTI)
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PREFACE

Silkworm-rearing house is the place where silkworms are raised to produce cocoons. The quality and yield of cocoons depend on the environmental conditions provided to grow the silkworms. Exclusive and independent silkworm rearing houses have brought tremendous improvement in the quality and the productivity of silk cocoons during last two decades. The silkworm rearing house models designed and developed by CSRTI-Mysuru are very popular and adopted by farmers. The models designed and developed by CSRTI-Mysuru during nineties were based on the climatic conditions prevalent in southern Karnataka. This region is bestowed with moderate indoor temperature and relative humidity for most of the times during the day, which is around 24–28°C and 60-70%, respectively. These are conditions almost ideal for silkworm rearing.

Today, sericulture in southern India has spread to many new areas in Karnataka, Andhra Pradesh, Telangana and Tamil Nadu, which have climatic conditions different from that of traditional areas, where sericulture is practiced. The new areas are located in central and northern parts of Karnataka, central and western parts of Andhra Pradesh, central and southern parts of Tamilnadu, etc. These areas have high temperature and very low relative humidity during most parts of the year. The atmospheric air in these areas contains more heat energy compared to traditional areas of sericulture in Karnataka, Andhra Pradesh and Tamilnadu. In past 10 years, the sericulture has also spread rapidly in the coastal areas of Andhra Pradesh, which has very hot and humid climatic conditions.

The basic difference between traditional and non-traditional areas of sericulture is that in traditional areas the farmers should conserve heat and evacuate humidity from rearing house whereas in non-traditional areas arrangements should be made to evacuate heat from rearing houses and simultaneously add moisture to raise relative humidity. Therefore, the rearing house designs for non-traditional areas of sericulture require facilities for creating and maintaining appropriate rearing conditions suitable to produce good quality silk cocoons.

This guide will help the sericulturists in design and construction of an appropriate silkworm rearing house for production of quality silk cocoons under different climatic conditions of traditional and nontraditional areas of sericulture.

Satish Verma
V Sivaprasad

Contents

1. Environmental Requirements for Silkworm Rearing

Mulberry silkworm, *Bombyx mori* L. is fully domesticated and reared in silkworm rearing house to produce cocoons. The cocoon quality and yield are adversely affected, if the recommended optimal environmental conditions *i.e.* temperature, relative humidity, ventilation, illumination, light, hygiene etc. are not provided to the silkworms. The rearing house should be designed rationally in order to maintain the micro-climate for rapid and healthy growth of silkworms. It should, therefore possess facilities for creation and maintenance of optimal environmental conditions inside the silkworm rearing house. The rearing house should also facilitate healthy environment for the personnel attending the silkworm rearing.

Optimal Environmental Conditions for Silkworms

The environmental conditions *i.e.*, a temperature of around 25ºC and 70% relative humidity are considered ideal for late-age silkworm rearing, but most of times these conditions need to be arranged to create and maintain optimal environmental conditions in a rearing house for facilitating proper growth of silkworms.

Optimal temperature and relative humidity to be maintained for different stages of silkworms

Instar	Temperature (°C)	Relative Humidity (%)
I	27-28	85-90
II	27-28	85-90
III	26-27	75-80
IV	25-26	70-75
V	25-26	70-75

Now-a-days, mulberry sericulture is spreading rapidly into several new districts such as Central and North Karnataka; Southern, Central and Coastal regions of Andhra Pradesh, all districts of Telangana and Tamil Nadu including parts of Maharashtra and Madhya Pradesh which have climatic conditions very much different from the traditional areas of sericulture. Most of the non-traditional areas of mulberry sericulture fall under hot and dry zones with temperatures going up to 40ºC and above and lower relative humidity as low as 15-20%. Similarly, in the coastal areas of Andhra

Pradesh, temperature and humidity are very high during most part of the year. CSRTI-Mysuru developed an Environment Management System based on the overall heat of the air (called *Enthalpy*) for late-age silkworms. The overall enthalpy of air at 25ºC temperature and 75% relative humidity is 63 kJ/kg of air. Based on enthalpy level of 63 kJ/kg of air, various combinations of temperature and relative humidity for a comfortable environment inside the silkworm rearing house have been worked out. In fact, balance between sensible heat of air and latent heat of water vapour is made for providing comfortable environment for silkworms by maintaining the enthalpy at the level of 63 kJ/kg of moist air. For each degree of raise in temperature >25ºC, the relative humidity should be decreased by 5%. Similarly, for each decrease in temperature <25ºC, the relative humidity should be increased by 5% to maintain enthalpy at 63 kJ/kg of moist air.

When the temperature and relative humidity inside the rearing house are below optimal enthalpy level (63 kJ/kg of moist air), temperature and relative humidity should be artificially raised through charcoal burners or electric heaters and humidifiers. When the rearing room temperature and relative humidity are above the optimal enthalpy, arrangements for cooling through natural ventilation or forced cooling through wet curtains on windows, air coolers or air-conditioners should be made; besides covering the roof top with mats made of coconut fronds, grass etc.

Light or illumination

Light intensity influences the distribution of larvae in the rearing bed. Young (chawki) silkworms prefer dark or dim light [15-30 lux]. Silkworms get crowded in the rearing bed under the dark as

Combinations of temperature and relative humidity to be maintained for providing comfortable environment to silkworms (Optimal Enthalpy ≈ 63 kJ/kg of moist air)

Temperature ºC	Relative Humidity to be maintained (%)	Enthalpy of Air (kJ/kg of air)
20	100	57.41
21	100	60.88
22	95	62.31
23	85	61.32
24	80	62.34
25	75	63.19
26	70	63.85
27	65	64.30
28	60	64.53
29	55	64.50
30	50	64.19
31	45	63.59
32	40	63.66
33	35	63.85
34	30	64.06
35	25	62.23

compared to lighted areas.

Ventilation

A silkworm rearing house should be well ventilated. Poor ventilation leads build-up of humidity and accumulation of gases like carbon monoxide, carbon dioxide, ammonia etc., which adversely affect the growth of silkworms and make them susceptible to diseases.

Silkworm Rearing Bed Area Requirement

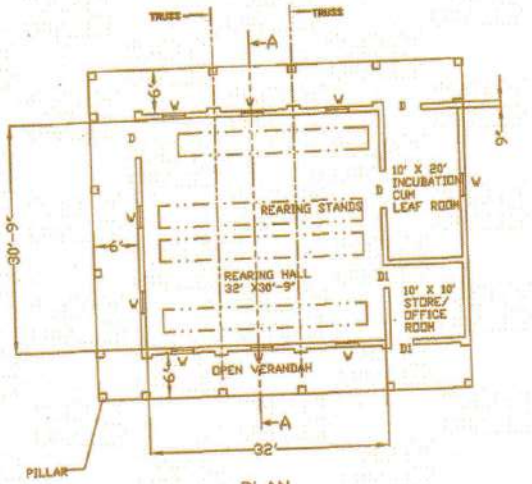
The rearing bed area required for the silkworms during different stages of growth is given below for 100 dfls (2 boxes; approximately 50,000 larvae). Bivoltine hybrids require much larger space than crossbreeds.

Rearing bed area required for 50,000 silkworms (1 sqm=10 sq.ft)		
Instar/Stage	Bed Area Required	
	Multivoltine	Bivoltine
First	2/20	2/20
Second	6/60	7/70
Third	11/110	15/150
Fourth	30/300	40/400
Fifth	75/750	100/1000

2. Young-Age Silkworm Rearing House (CRC- Chawki Rearing Centre)

The Young age silkworm rearing houses are called as Chawki Rearing Centres (CRCs). Proper temperature, relative humidity and hygienic conditions should be provided to young age silkworms for good and healthy growth. The micro-climate to be provided to young age silkworms is different from late age silkworm rearing. CSRTI-Mysuru designed and developed a model CRC, which is followed widely throughout the country.

A CRC for brushing 5000–6000 dfls per batch consists of a rearing hall of 30'x30', leaf storage room (10'x20') with an ante-room (10'x10'). Adequate ventilation to the rearing hall is recommended. A continuous water channel inside the rearing hall along the walls helps in keeping the ants away from silkworms and also maintaining the humidity. Windows should be fitted with wire mesh. The ceiling should be kept at 9–10' from the floor. In case of CRCs with higher roof height, a false ceiling at 8'-9' from the floor helps in reducing the volume of air in the rearing hall so that required temperature and humidity can be maintained conveniently.



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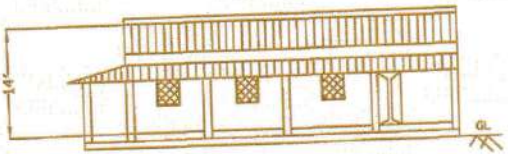

ELEVATION

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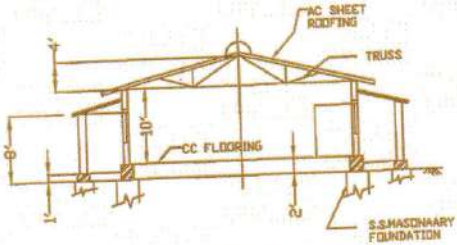
D - DOOR ---- 5' X 7'
D1 - DOOR ---- 3' X 7'
W - WINDOW -- 3' X 4'



SECTION-AA

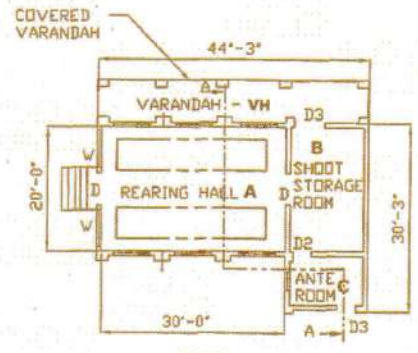
Capacity: 5000 dfls per batch
Farm size: 1 acre
Climate: Moderate

View of a CRC

3. Late-Age Silkworm Rearing House

CSRTI-Mysuru designed and developed model rearing houses for late-age silkworms (from 3rd onwards). A late-age silkworm rearing consists of a rearing hall, a shoot storage room and an ante-room. The minimum width of the rearing hall should be 20 feet. The length of the rearing hall can be determined as below:

Number of tiers	Total length of rearing house (feet)
5-tier shoot rearing stand	0.24 feet x no. of dfls for rearing hall + 10 feet for shoot storage
6-tier shoot rearing stand	0.20 feet x no. of dfls for rearing hall + 10 feet for shoot storage



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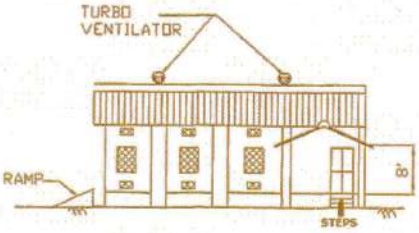
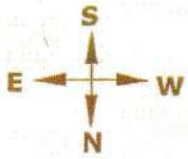


ELEVATION

A-REARING HALL -- 60' X 20'
B-SHOOT STORAGE ROOM -12' X 20'
C-ANTE ROOM -- 12' X 8'
VH-VARANDAH -- 74' X 6'



HEIGHT OF SIDE WALL -- 12'-0"
HEIGHT OF CENTRE -- 16'-0"

D -- 5'X7' -- WOODEN PANELLED SHUTTERS WITH FLY PROOF WIRE MESH SHUTTERS
D1 -- 5'X7' -- FLY PROOF WIRE MESH SHUTTERS
D2 -- 3'X7' -- FLY PROOF WIRE MESH SHUTTERS
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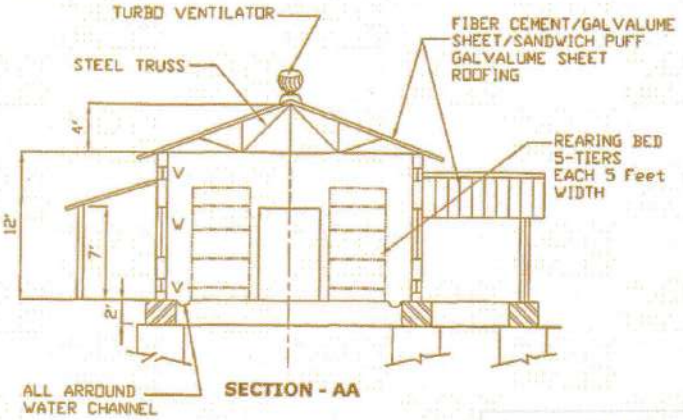
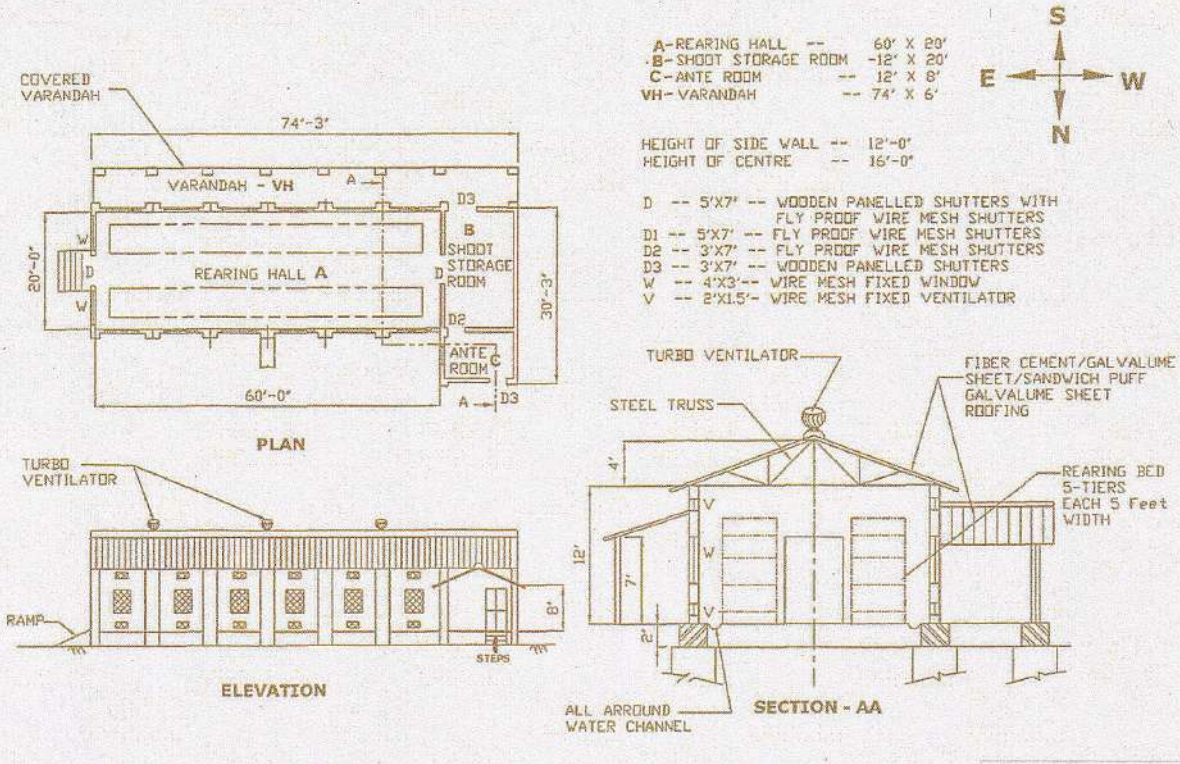
W -- 4'X3'-- WIRE MESH FIXED WINDOW
V -- 2'X1.5'- WIRE MESH FIXED VENTILATOR



SECTION - AA

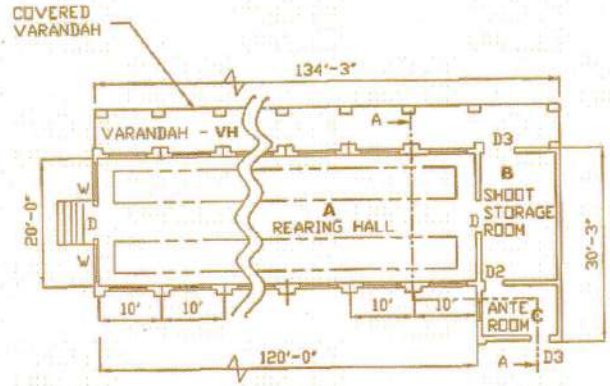
Capacity: 125 dfls
Farm size: 1 acre
Climate: Moderate



Capacity: 250 dfls

Farm size: 2 acres

Climate: Moderate



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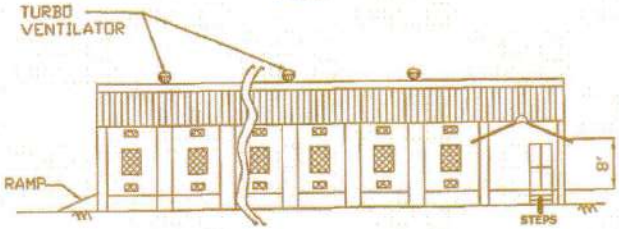

ELEVATION

A-REARING HALL -- 120' X 20'
B-SHOOT STORAGE ROOM -12' X 20'
C-ANTE ROOM -- 12' X 8'
VH-VARANDAH - - 134' X 6'

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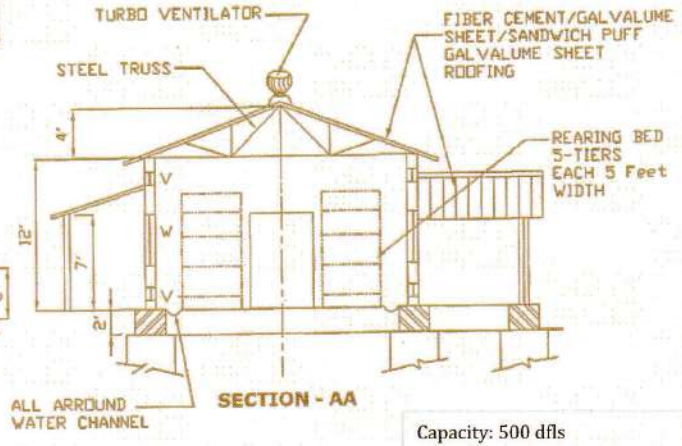
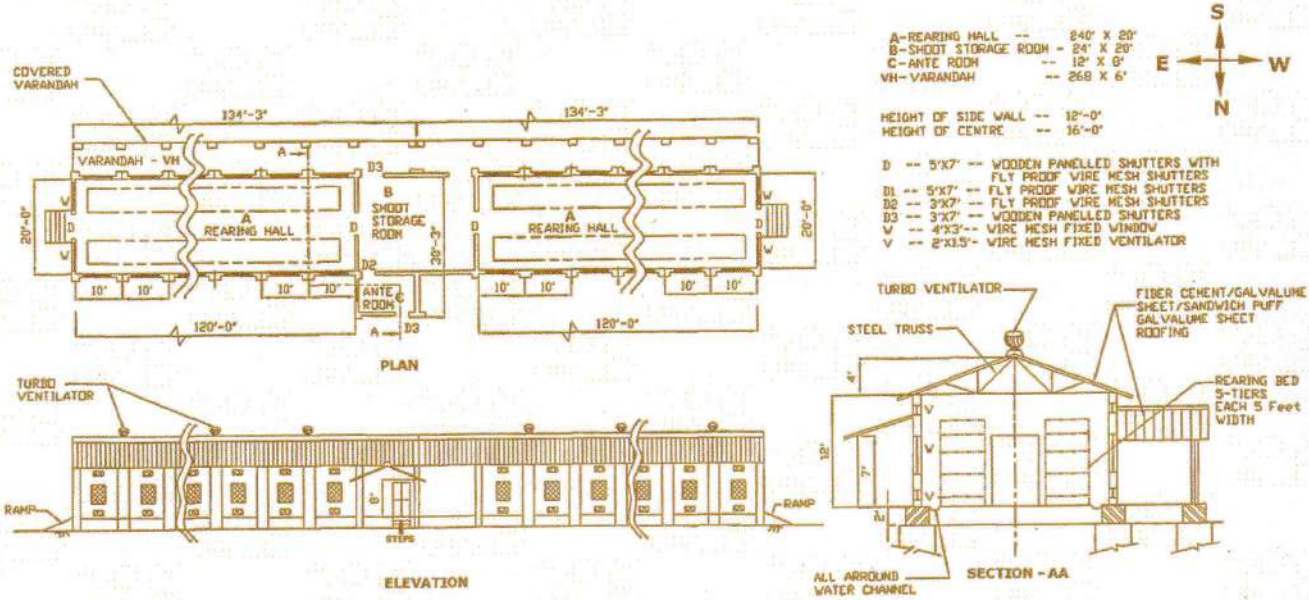


SECTION - AA

Capacity: 500 dfls
Farm size: 4 acres
Climate: Moderate

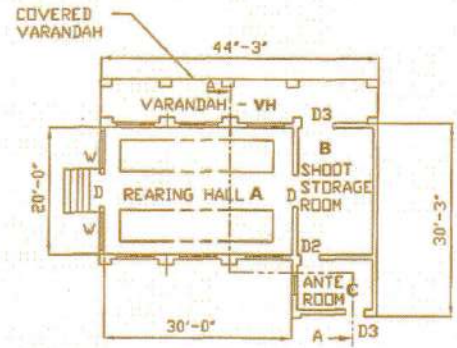


1000 Dfl's CAPACITY SILKWORM REARING HOUSE (8 acre mulberry farm model) for MODERATE CLIMATE

Capacity: 1000 dfls

Farm size: 8 acres

Climate: Moderate



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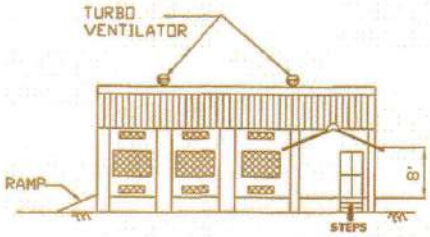

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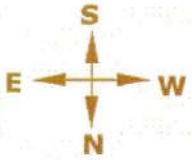

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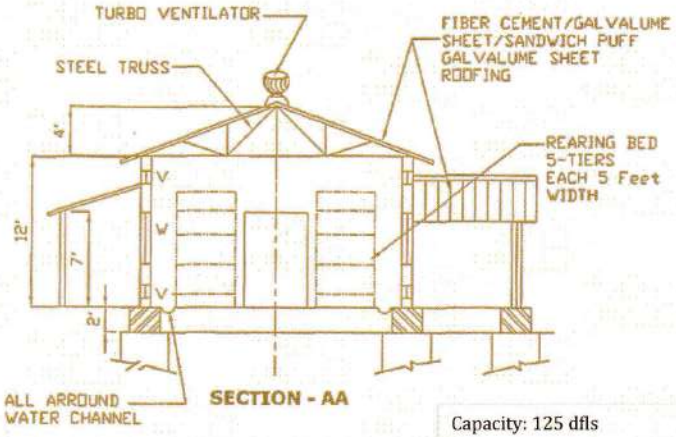
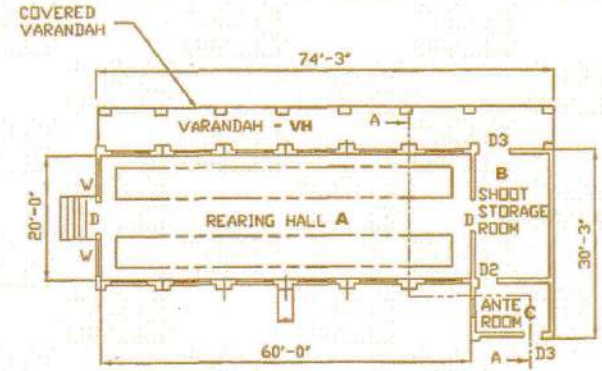


SECTION - AA

Capacity: 125 dfls

Farm size: 1 acre

Climate: Hot & Dry



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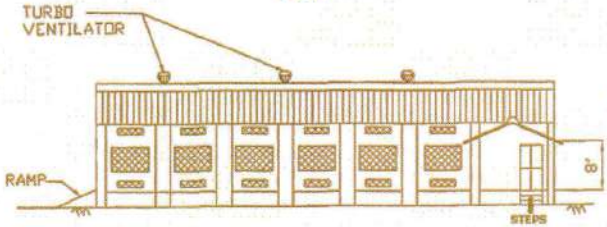

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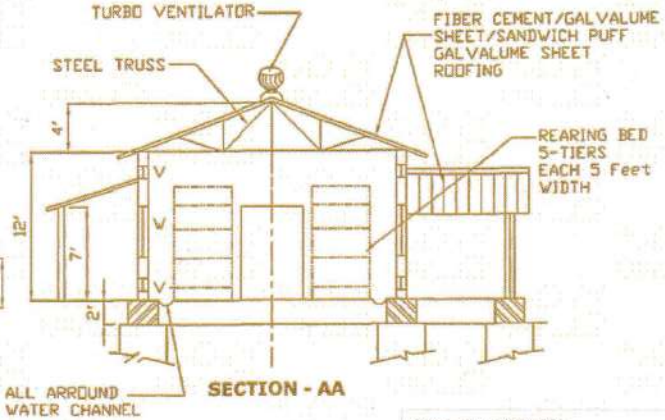

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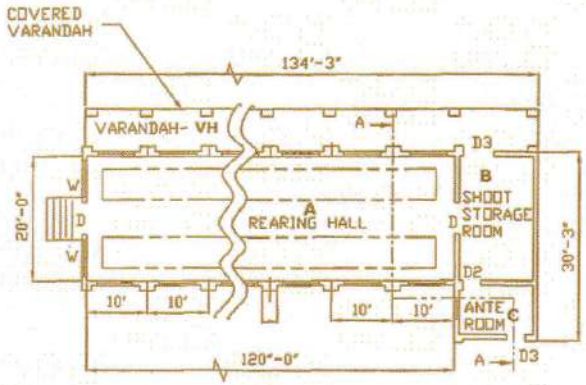
Capacity: 250 dfls

Farm size: 2 acres

Climate: Hot & Dry



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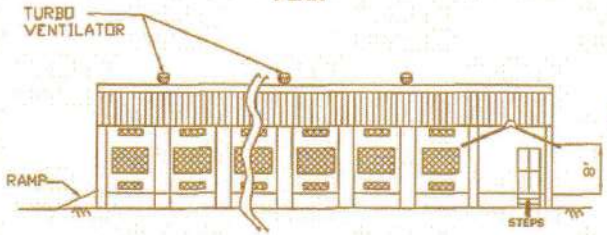

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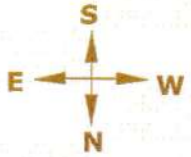

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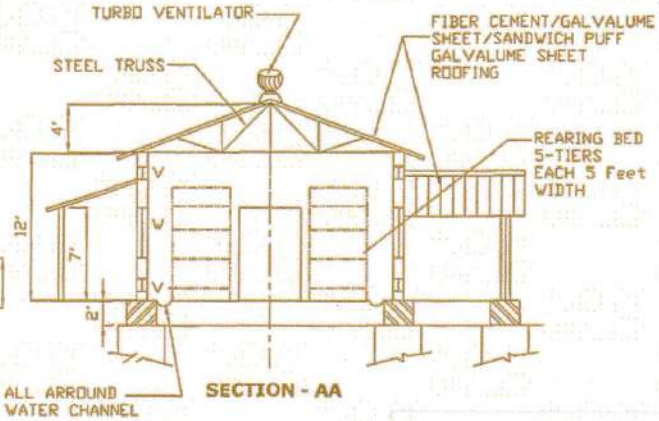

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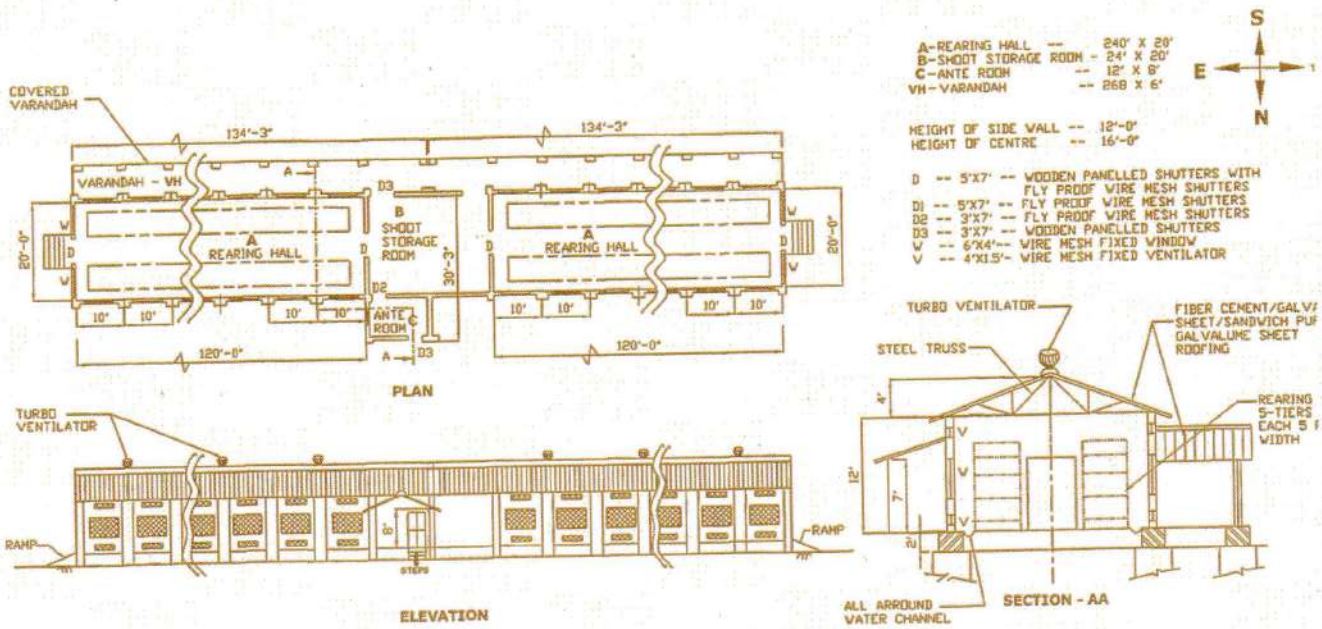
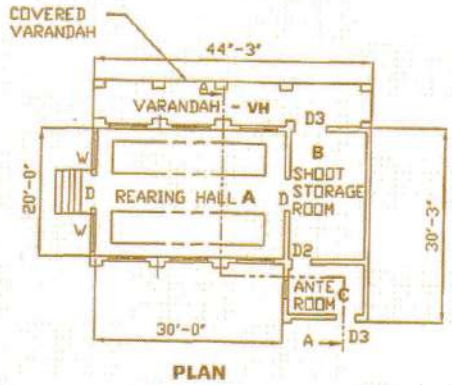
Farm size: 4 acres
Climate: Hot & Dry



Capacity: 1000 dfls

Farm size: 8 acres

Climate: Hot & Dry



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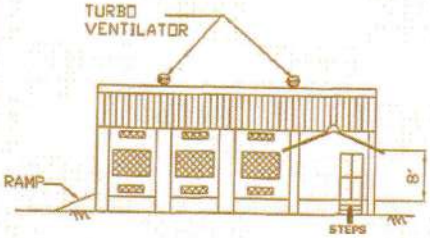

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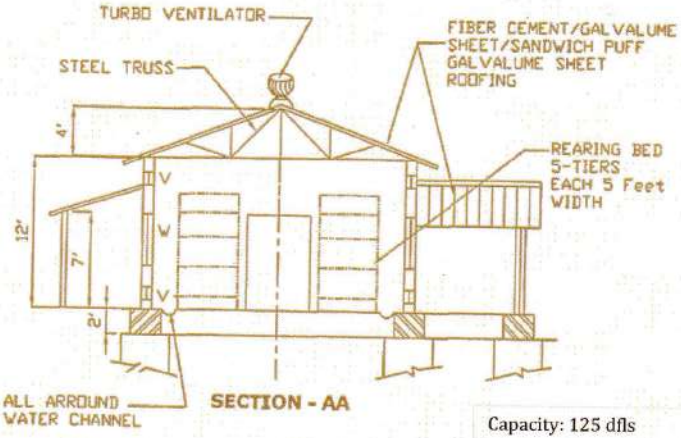
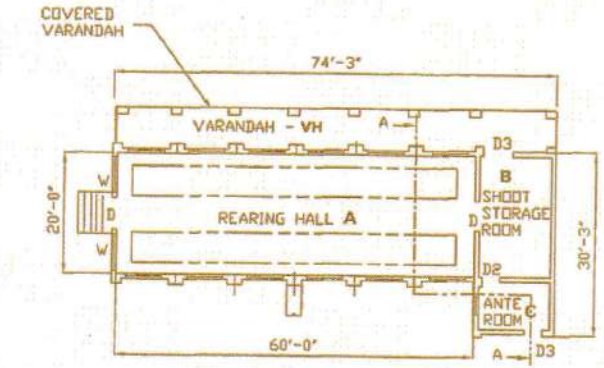


SECTION - AA

Capacity: 125 dfls

Farm size: 1 acre

Climate: Hot & Humid



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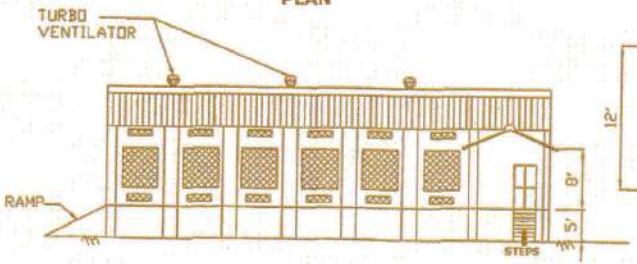
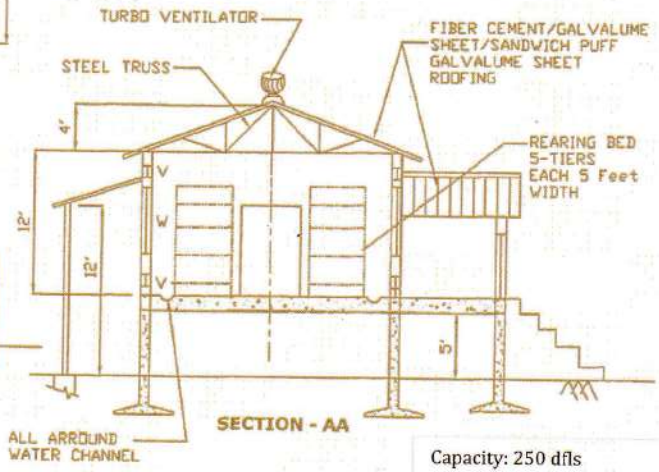


ELEVATION

A-REARING HALL -- 60' X 20'
B-SHOOT STORAGE ROOM -12' X 20'
C-ANTE ROOM -- 12' X 8'
VH-VARANDAH -- 74' X 6'

HEIGHT OF SIDE WALL -- 12'-0"
HEIGHT OF CENTRE -- 16'-0"

D -- 5'X7' -- WOODEN PANELLED SHUTTERS WITH FLY PROOF WIRE MESH SHUTTERS
D1 -- 5'X7' -- FLY PROOF WIRE MESH SHUTTERS
D2 -- 3'X7' -- FLY PROOF WIRE MESH SHUTTERS
D3 -- 3'X7' -- WOODEN PANELLED SHUTTERS
W -- 8'x6' -- WIRE MESH FIXED WINDOW
V -- 6'X2'- WIRE MESH FIXED VENTILATOR

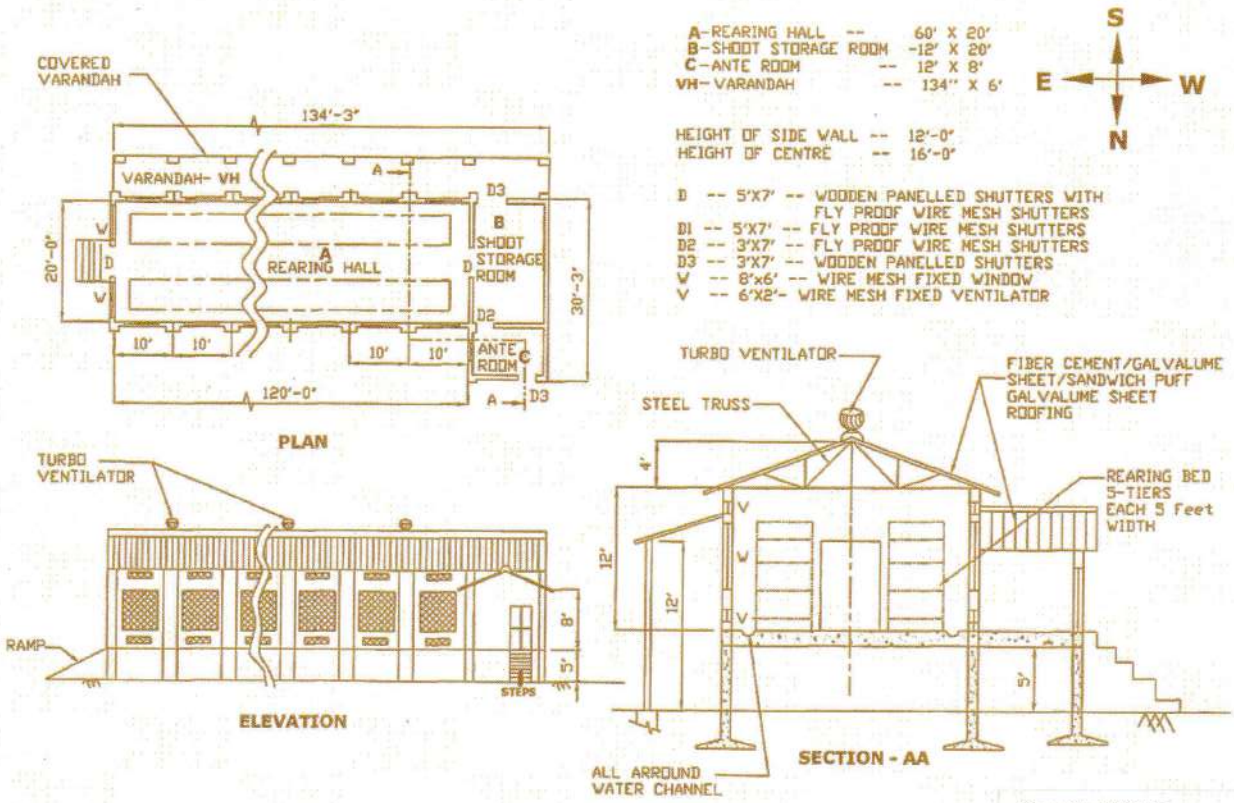


SECTION - AA

Capacity: 250 dfls

Farm size: 2 acres

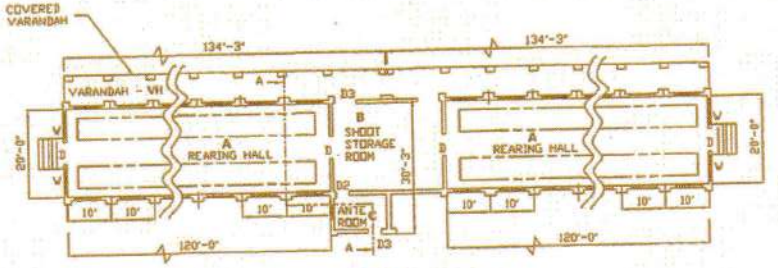
Climate: Hot & Humid



Capacity: 500 dfls

Farm size: 4 acres

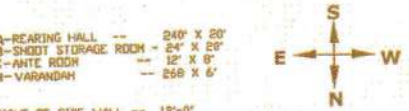
Climate: Hot & Humid

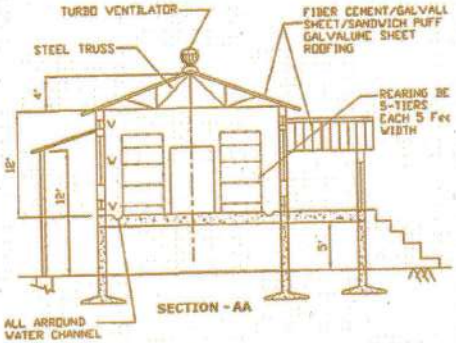


A-REARING HALL -- 240' X 20'
B-SHOOT STORAGE ROOM - 24' X 20'
C-ANTE ROOM -- 12' X 8'
VH-VARANDAH -- 268 X 6'

HEIGHT OF SIDE WALL -- 12'-0"
HEIGHT OF CENTRE -- 16'-8"

D -- 5'X7' -- WOODEN PANELLED SHUTTERS WITH FLY PROOF WIRE MESH SHUTTERS
D1 -- 5'X7' -- FLY PROOF WIRE MESH SHUTTERS
D2 -- 3'X7' -- FLY PROOF WIRE MESH SHUTTERS
D3 -- 3'X7' -- WOODEN PANELLED SHUTTERS
V -- 8'X6'- WIRE MESH FIXED WINDOW
V -- 6'X2'- WIRE MESH FIXED VENTILATOR



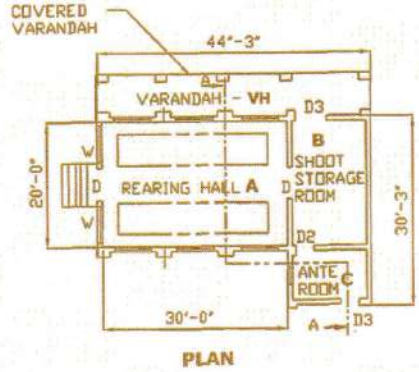


Capacity: 1000 dfls
Farm size: 8 acres
Climate: Hot & Humid

A-REARING HALL -- 60' X 20'
B-SHOOT STORAGE ROOM -12' X 20'
C-ANTE ROOM -- 12' X 8'
VH-VARANDAH -- 74' X 6'

HEIGHT OF SIDE WALL -- 12'-0"
HEIGHT OF CENTRE -- 16'-0"

D -- 5'X7' -- WOODEN PANELLED SHUTTERS WITH FLY PROOF WIRE MESH SHUTTERS
D1 -- 5'X7' -- FLY PROOF WIRE MESH SHUTTERS
D2 -- 3'X7' -- FLY PROOF WIRE MESH SHUTTERS
D3 -- 3'X7' -- WOODEN PANELLED SHUTTERS
W -- 4'X3'-- WIRE MESH FIXED WINDOW
V -- 2'X1.5'- WIRE MESH FIXED VENTILATOR



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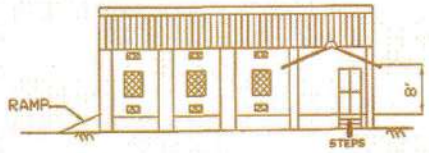
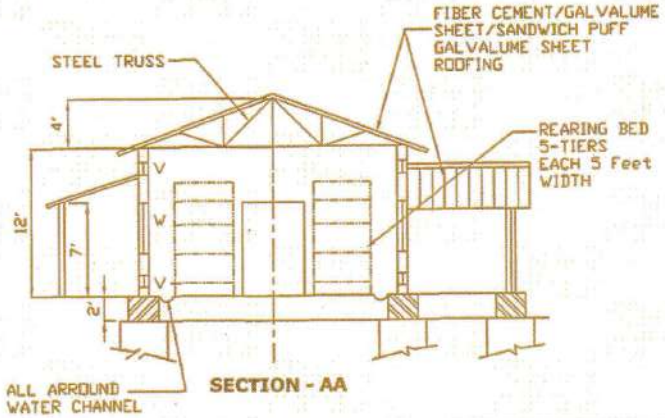


ELEVATION

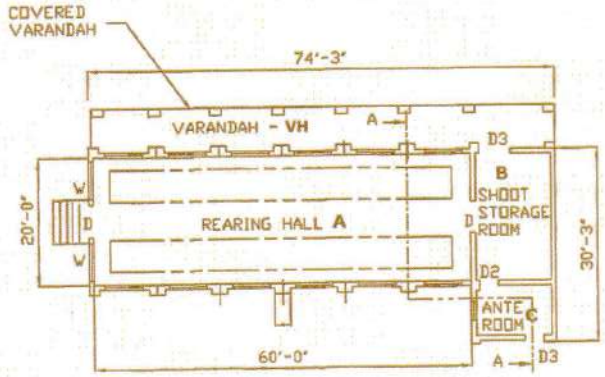


SECTION - AA

Capacity: 125 dfls

Farm size: 1 acre

Climate: Cold & Humid



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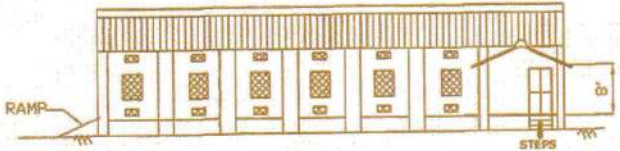
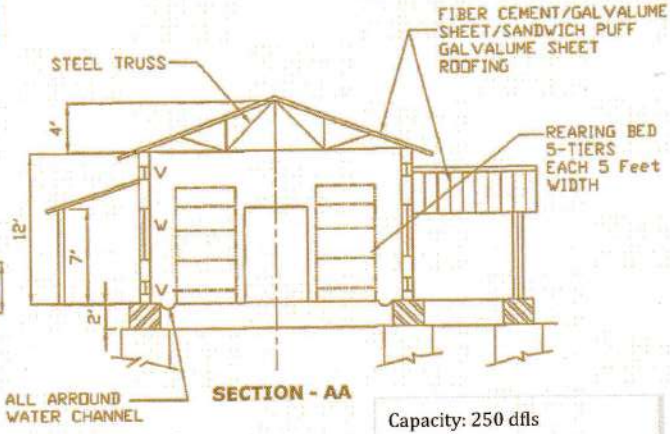


ELEVATION

A-REARING HALL -- 60' X 20'
B-SHOOT STORAGE ROOM -12' X 20'
C-ANTE ROOM -- 12' X 8'
VH-VARANDAH -- 74' X 6'

HEIGHT OF SIDE WALL -- 12'-0"
HEIGHT OF CENTRE -- 16'-0"

D -- 5'X7' -- WOODEN PANELLED SHUTTERS WITH FLY PROOF WIRE MESH SHUTTERS
D1 -- 5'X7' -- FLY PROOF WIRE MESH SHUTTERS
D2 -- 3'X7' -- FLY PROOF WIRE MESH SHUTTERS
D3 -- 3'X7' -- WOODEN PANELLED SHUTTERS
W -- 4'X3'-- WIRE MESH FIXED WINDOW
V -- 2'X1.5'- WIRE MESH FIXED VENTILATOR

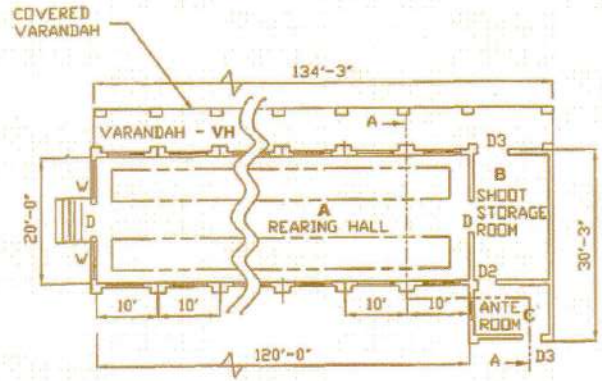


SECTION - AA

Capacity: 250 dfls

Farm size: 2 acres

Climate: Cold & Humid



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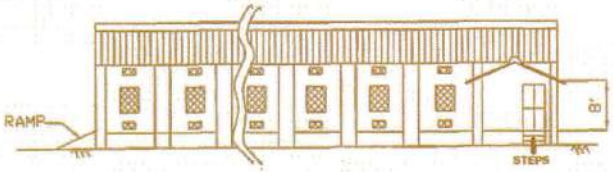
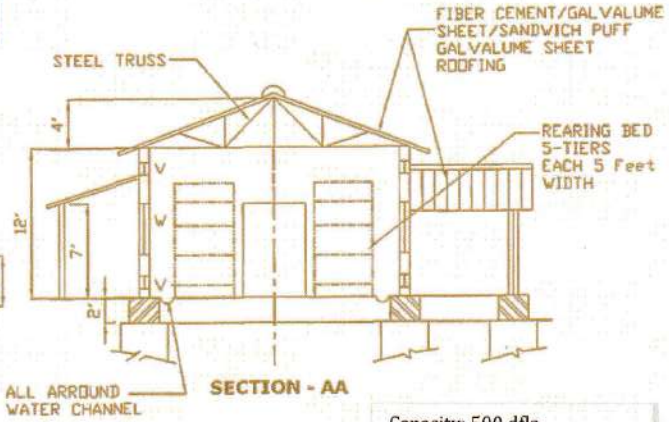


ELEVATION

A-REARING HALL -- 120' X 20'
B-SHOOT STORAGE ROOM -12' X 20'
C-ANTE ROOM -- 12' X 8'
VH- VARANDAH -- 134' X 6'

HEIGHT OF SIDE WALL -- 12'-0"
HEIGHT OF CENTRE -- 16'-0"

D -- 5'X7' -- WOODEN PANELLED SHUTTERS WITH FLY PROOF WIRE MESH SHUTTERS
D1 -- 5'X7' -- FLY PROOF WIRE MESH SHUTTERS
D2 -- 3'X7' -- FLY PROOF WIRE MESH SHUTTERS
D3 -- 3'X7' -- WOODEN PANELLED SHUTTERS
W -- 4'X3'-- WIRE MESH FIXED WINDOW
V -- 2'X1.5'- WIRE MESH FIXED VENTILATOR

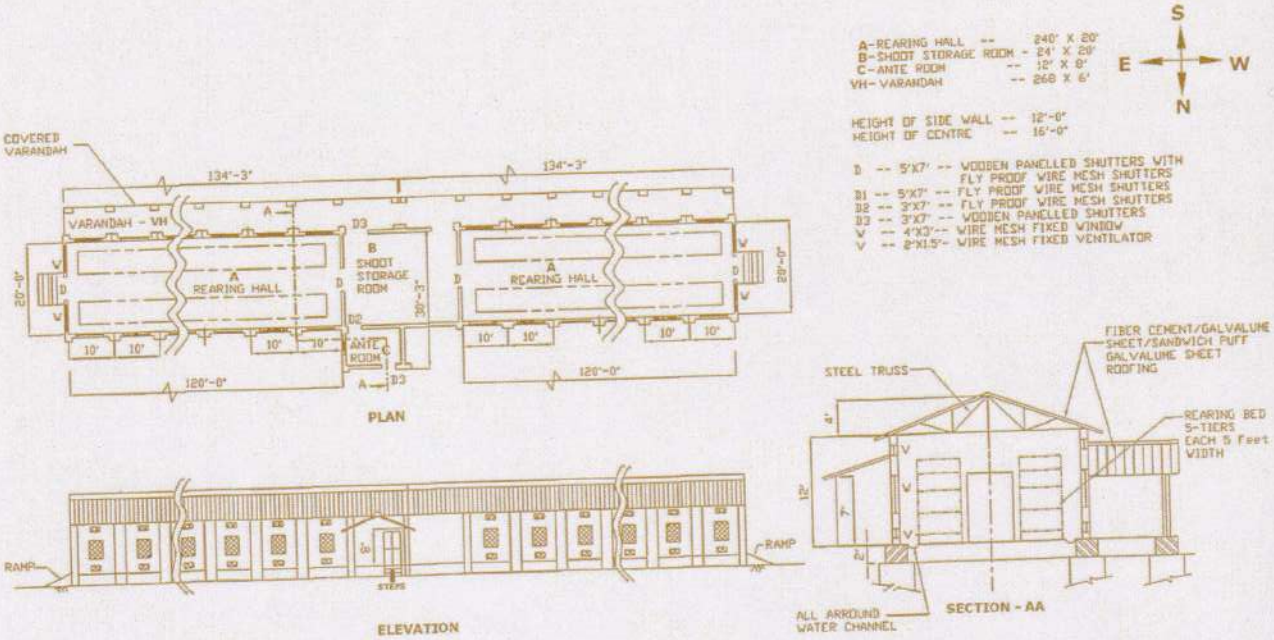


SECTION - AA

Capacity: 500 dfls

Farm size: 4 acres

Climate: Cold & Humid



Capacity: 1000 dfls

Farm size: 8 acres

Climate: Cold & Humid

4. Planning and construction of late-age silkworm rearing house

A rearing house shall provide comfortable and healthy environment to the silkworms for optimal growth. It should also meet the required rearing spaces such as rearing bed, working and storage space etc. along with facilities to maintain hygiene. The following guidelines shall be followed while planning and construction of a silkworm rearing house.

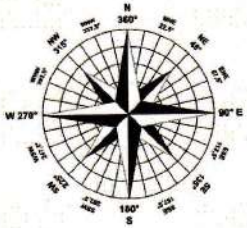
1. The rearing house site should be selected according to the environmental conditions. In areas where rainfall is abundant, a dry sunny, well-ventilated and well-drained highland should be selected. In areas where rainfall is scare, a leeward, warm, sunny and rather moist area should be selected as the wind is strong and climate is dry, the temperature fluctuates severely. The climatic conditions of the Indian peninsula are characterized by high temperature, low to moderate relative humidity and long day zones. Therefore, the rearing house should be built on comparatively high land, with low level of underground water and good ventilation. The location of rearing house at an elevated place will also provide cross-ventilation, good drainage system for washing and disinfection works and during rainy season the water will not stagnate around the building.
2. The rearing house site should have all-season approach road for farm and transport vehicles for transportation of construction materials initially and mulberry shoots, rearing materials, workers, cocoons etc. once farmer starts rearing activities.
3. The orientation of a rearing house is very important as it has direct impact on heating, lighting and cooling costs. By maximizing the southern exposure, for example, one can take optimal advantage of sun for daylight and passive solar heating. Minimizing western exposures will result in lower cooling costs, as it is very difficult to provide shade from the sun.

It is a known fact that the magnetic north is different from solar north as depicted in picture below. We generally use magnetic north to decide the orientation of the buildings. Actually, one should use the sun direction for orientation of the building, particularly in climatically hot regions to avoid direct entry of sun rays inside the building.

It is better to allow the diffused and indirect sunlight within

the rearing house and to direct sunlight only in the early morning, when the intensity of UV rays is lesser.

In fact, sun is lower in the sky in winter than in summer allowing one to plan and construct a rearing house building that capture free heat during winter and reject the heat in summer.

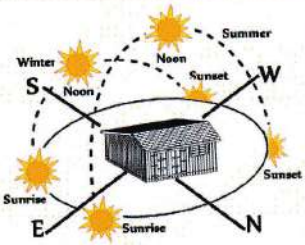


Ideal line for orientation of a silkworm rearing house
Magnetic directions

It is better to allow the diffused and indirect sunlight within the rearing house and to direct sunlight only in the early morning, when the intensity of UV rays is lesser.

In fact, sun is lower in the sky in winter than in summer allowing one to plan and construct a rearing house building that capture free heat during winter and reject the heat in summer.

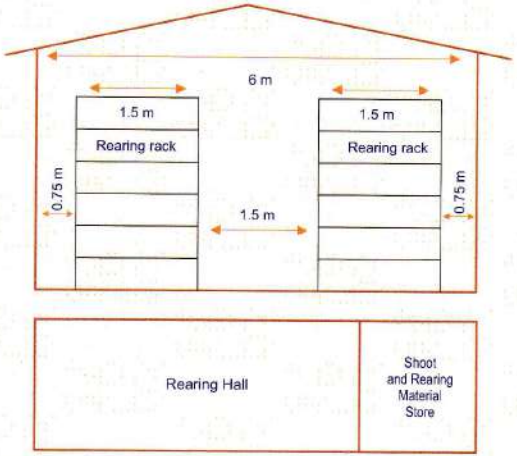
Building Orientation	Solar gain received
True South	100%
22.5° away from South, either South-South-East or South-South-West	92%
45° away from South, either South-East or South-West	92%
67.5°away from south, either East-South-East or West-South-West	36%
A building receives minimum solar radiations when it is located in East-South-East or West-South-West direction	



Ideal direction for location of a silkworm rearing house and solar path over in different seasons

The peninsular India is located in the northern hemisphere. For most part of the year, the wind comes from south or southwest wind direction. Therefore, the longer side of a rearing house should preferably be oriented at 23.5° with respect to East as shown in figure above. But, **the rearing house should be located in magnetic East-West line** as shown in figure above due to continuous change(s) on sun path. The windows and ventilators should face north and south. This would avoid direct entry of sunlight into the rearing hall.

4. Minimum wall to wall width of the rearing hall should be 6 meters (20 feet). This is required to accommodate two rows of rearing stands each with a 1.5 m width. The walk-way between the two racks shall be 1.5 m wide for movement of personnel and transportation of mulberry shoots. The gap between the racks and wall will be 0.75m on each side.
5. The rearing racks shall be provided only in two rows for good ventilation.
6. The silkworms should be provided with adequate bed area for optimal growth. For 50,000 silkworms (100 dfls), the bed area should be atleast 100 m^2 (1000 sq.ft) in hot and dry areas and a minimum of 120 m^2 (1200 sq.ft) in hot and humid regions.

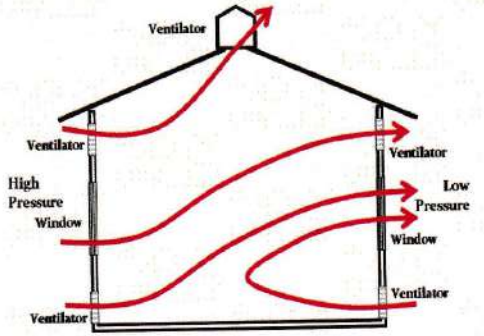


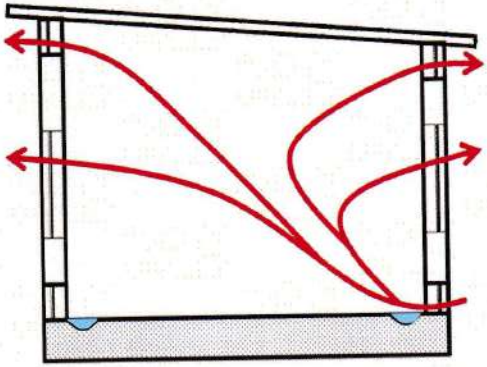
The rearing house should have a rearing hall and a room for storage of mulberry shoots and rearing materials. Thus, the overall length of rearing house is equal to the length of rearing hall plus the length of shoot storage cum store room. It varies from region to region based on quantum of dfls to be reared and prevailing environmental conditions.

Length of Rearing House (feet)		
Region	5-tier rearing racks	6-tier rearing racks
Hot & Dry	= 0.20 x no. of dfls + shoot storage room	= 0.17 x no. of dfls + shoot storage room
Hot & Humid	= 0.24 x no. of dfls + shoot storage room	= 0.204 x no. of dfls + shoot storage room
Length of shoot storage room shall be 15 feet upto 300 dfls; 25 feet for 300–500 dfls; 40 feet for 500–800 dfls; 50 feet for above 800 dfls		

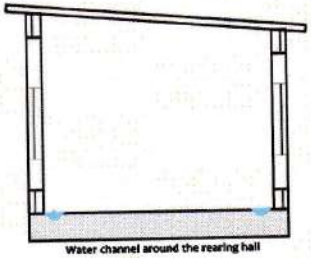
No. of dfls to be reared/ batch	Overall Length of Rearing House (feet)			
	Hot & Dry Regions		Hot & Humid Regions	
	5-tier racks	6-tier racks	5-tier racks	6-tier racks
100	35	30	40	35
200	55	50	65	55
300	75	65	90	75
400	105	90	120	105
500	125	110	150	125
600	160	140	185	160
700	180	160	210	170
800	210	190	240	190
1000	250	220	290	250

7. Positioning of ventilators in hot and humid regions and hot and dry regions is very important for adequate ventilation, evacuation of heat and humidity from the rearing hall. The best location for ventilators is at ground level and another at ceiling level as depicted in the sketch below:





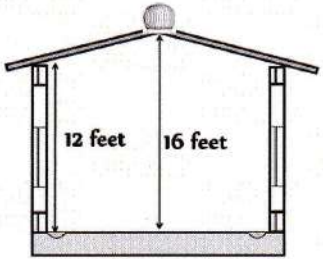
8. A 10-15 cm deep-channel all-around inside the rearing hall should be provided to prevent entry of ants into the rearing area and also to drain out water at the time of washing and disinfection of rearing house. During summer, water in the channel helps to increase humidity and cools the air entering through the lower-ventilators.



9. Roof of the rearing house should either of asbestos or galvalume. This kind of roofing would avoid the entry of uzi fly into the rearing house. Avoid tiled or thatched roofing as they allow uzi to enter into the rearing house. This kind of roofing although very effective for hot and dry regions, it is very difficult to maintain optimal environmental conditions by the farmers.

The asbestos and galvalume sheet roofing also allows installation of turbo- ventilators, which are very efficient to evacuate heat and moisture from the buildings. Turbo-ventilators will be very effective in evacuating heat and moisture from rearing houses particularly in coastal areas having hot and humid climatic conditions during the most parts of the year.

10. Minimum wall height of the rearing house for both hot and dry, and hot and humid regions should be 16 feet at the centre and 12 feet on sides. This would accommodate rearing racks with 5 and 6 tiers easily and facilitate good ventilation during summer and rainy months.



11. An ante-room should be provided at the entrance of rearing hall for hand and feet washing by the rearing personnel to avoid secondary contamination to the silkworms.

12. All the doors and windows should be fitted with corrosion-resistant and fly-proof mesh to prevent entry of uzi flies into the rearing house.

13. RCC structures should be avoided for rearing houses as walled-structures are good-enough.

14. Water facility should be provided in a rearing house for cleaning/washing and disinfection purposes and also for humidification of rearing room.

15. The rearing house should have electrical power supply. The rearing house should have adequate lighting arrangements for working during night.

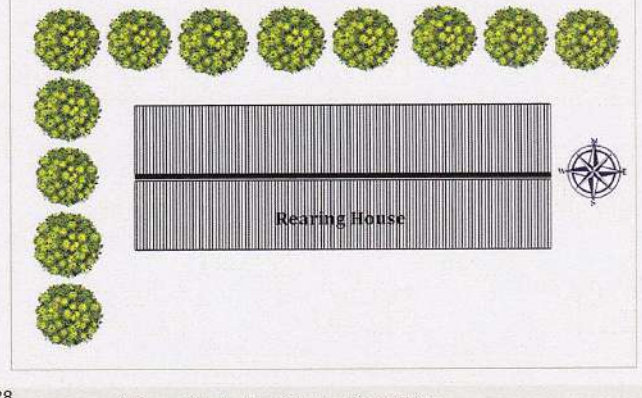
16. Electrical points should be provided for using equipments such as heaters, humidifiers, coolers, power sprayer, deflossers etc. Solar power generation would ensure facilitation of power for the equipments.

17. Fancy-works in the rearing house should be avoided to minimize the cost. Detailed cost-saving measures to be followed while planning and construction are provided in Chapter 5.

18. Growing trees and other tall plants or making vegetation around the rearing house plants would help to cool the environment, a simple and effective way to reduce heat in and around the

buildings. Vegetation lowers surface- and air- temperatures by providing shade and through evapotranspiration. Shaded surfaces, for example, may be 11–25°C cooler than the peak temperatures of unshaded materials. Evapotranspiration, alone or in combination with shading, can help reduce peak summer temperatures by 3-5°C.

In hot and dry regions, planting trees around the building will help in maintaining a cool and humid environment in and around the rearing houses. Deciduous trees shall be planted on north and west side of the rearing house as these will provide shade by cutting the sun light, which is very strong during the afternoon in summer months. In winter months, the trees will shed-off the leaves, allowing more sun light to fall on the building to make it warm.

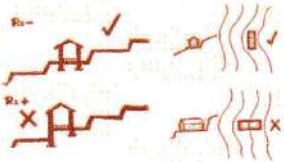


5. Cost reduction in construction

The major expenditure in mulberry sericulture goes for the creation of infrastructure mainly construction of a silkworm rearing house. Hence, cost cutting measures described below could be adopted while planning and construction of a new rearing house.

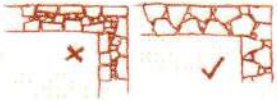
Laurence Wilfred "Laurie" Baker was hired by Central Silk Board in early 1990s to develop guidelines for economic construction of silkworm rearing houses and grainage buildings. He suggested the following measures for reducing the cost of construction of sericulture infrastructural buildings including silkworm rearing houses.

1. Go for simple buildings such as brick wall with asbestos or galvalume sheet roofing, in place of brick walls with RCC roofing.
2. Construct the rearing house in the middle of the terraced land and not on the outer edge of the terrace for better stability of building and reduce the cost.



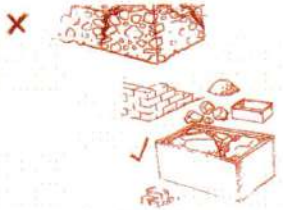
3. Elaborate foundation is not required for a silkworm rearing house. A simple foundation is sufficient.

4. Good bonding (dove tailing) of stones is better than fancy facade looks.

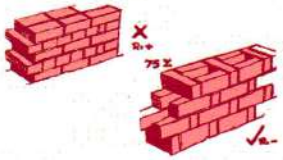


5. The super structure walls are better on the outer foundation-basement walls. The impact of rain water is less on the wall.

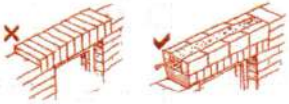
6. If local stones are small rounded or irregular, wall will crack. So use block moulds and pack stones with a weak concrete to form a useful strong block for building.



7. By using Rat-Trap bond, ¼th of construction material is only required and costs for wall can be saved. The Rat-Trap walls have better insulation because of air trapped in the wall.

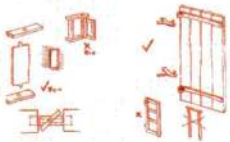


8. Avoid reinforced concrete lintels as they are expensive and unnecessary. Stone slabs can be used in place of RCC lintels.



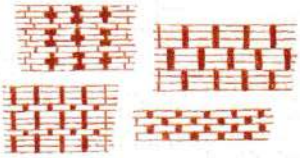
9. Avoid unnecessary architectural add-ons. They add to the cost of the buildings.

10. Frameless doors and windows cost less.

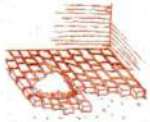


11. Split stones are much cheaper than reinforced concrete for extras in the buildings.

12. Brick *jaali*-walls are less costly than plain solid walls and very much cheaper than a window. They facilitate excellent ventilation in hot and humid regions.



13. Use broken and unused brick for flooring.

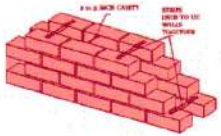


14. Paint the building with slaked lime from outside and inside. It will keep building cool and moist in summer.

15. Provide ventilators at highest point in the building for evacuation of indoor heat and moisture.

16. Provide false ceiling in the rearing hall to cut the heat radiations from roof.

17. Use cavity wall to reduce heat radiation from walls in summer and conserve indoor heat in winter.



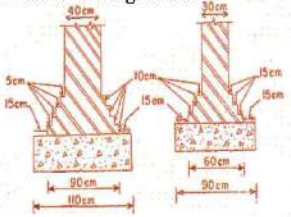
6. Construction of silkworm rearing houses

A rearing house comprises of foundation, superstructure, walls, roofing, flooring, doors & windows, finishing works etc.

Foundation for the silkworm rearing house

The foundations of buildings bear on and transmit loads to the ground. The foundation is that part of walls, piers and columns, which are in direct contact with and transmit loads to the ground.

Strip/standard foundation for load bearing structures



A strip foundation is a continuous strip of concrete under walls, as detailed above can be used for construction of silkworm rearing houses. Strip foundations are made up of brick masonry/stone masonry/concrete formed centrally under load bearing walls.

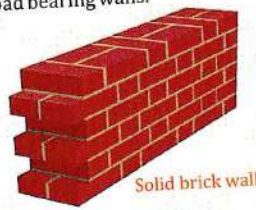
The overall cost of construction of foundation is around 10% of the total cost of the building. It is preferred to utilize locally available and cheaper materials such as stones etc. The places, where stones are available in abundance or in rocky or hilly terrains, the stones shall be used for foundation. By this way, one can be able to reduce the overall costs of construction. In areas where sand is transported from long distance a part of sand can be substituted with stone powders and could be utilized for making mortar for the foundation. One can also use lime mortar, if the lime is available locally at lesser costs.

Walls for a silkworm rearing house

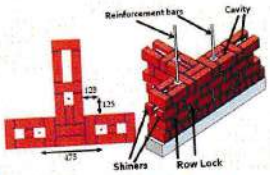
The cost of construction of wall is about 30% of the total cost of construction. Therefore using local materials and skills for construction of walls may provide overall cost economy in building construction. The mortar used for laying the wall also constitutes an integral part of any walling system. Different alternative mortar systems can be tried. In areas where sand is transported from far flung places, a part of sand can be replaced by stone or marble dust

which is available at almost no-cost for making mortars to be used in walls. Also lime can be used instead of cement as an alternate material. It is found that for applications like plastering, mortar, the strength requirement is not much and therefore lime can be used as a part replacement to the cement.

The rearing house walls can be either solid wall, frame wall or rat-trap- bond wall. A solid wall (sometimes called a masonry wall) can be constructed either of brick, burnt clay or stone blocks or concrete blocks laid in mortar. A frame wall is constructed from a frame of small sections of timber, concrete or metal joined together to provide strength and rigidity, over both faces of which, or between the members of the frame are fixed thin panels of some material to fulfill the functional requirements of the particular wall. They are non-load bearing walls.



Solid brick wall



Rat-trap-bond brick wall

Rat-Trap Bond wall

A "Rat-Trap Bond" is a type of wall brick masonry bond, in which bricks are laid on edge (i.e. the height of each course in case of a brick size 230 x 110 x 75 mm, will be 110 mm plus mortar thickness) such that the shiner and rowlock are visible on the face of masonry as depicted above. This gives the wall with an internal cavity bridged by the rowlock. This is the major reason where materials like bricks and cement can be considerably saved. The rat trap bond wall comes under Green technology as its helps in maintaining coolness inside the building with no expenditure on conventional energy.

Advantages of Rat Trap Bond walls

- By adopting this method of masonry, one can save on approximately 20-35% bricks and 30-50% mortar; also reduces the cost of a 9 inch wall by 20-30 % and enhances productivity
- For 1 m3 of Rat-trap bond, 470 bricks are required compared to conventional brick wall where a total of 550 bricks are required
- Rat-trap bond wall is a cavity wall construction with added advantage of thermal comfort. The interiors remain cooler in summer and warmer in winter
- Rat-trap bond when kept exposed, create aesthetically pleasing wall surface and cost of plastering and painting also may be avoided
- Rat-trap bond can be used for load bearing as well as thick partition walls
- The walls have approximately 20% less self-weight and hence the foundations and other supporting structural members can suitably be designed, giving an added advantage of cost saving for foundation
- Materials such as bricks, cement and steel can be considerably saved upon by adopting this technology. It will also help to reduce the embodied energy of virgin materials and save the production of green house gases into the atmosphere

- In case for more structural safety, reinforcement bars can be inserted through the cavity up to the foundation.

Cost Savings

Material saving per cubic meter of masonry: Rat-trap bond vs. Conventional Brickwork.

- 1.11 bags (57% saving)
- 80 nos. of bricks (20% saving)
- 0.18 m3 less sand (61% saving)

Overall, an approximate saving of 20% can be achieved per m3 of Rat-trap bond brickwork as compared to conventional solid brick work on the material costs.

Other wall materials

In hot and dry regions, the grass, bamboo leaves and shade nets can also be used for making the walls of the silkworm rearing house. These materials provide good ventilation and helps in evacuating heat and moisture from the rearing house to make comfortable environment for silkworms.

Silkworm rearing house walls made of shade net

Silkworm rearing house walls made of bamboo leaves

Roofing

A roof is an important part of a silkworm rearing house. The elements in the design of a roof are: material, construction and durability

The material of a roof may range from banana leaves, wheat or paddy straw, galvanized iron or aluminum sheet and concrete. In many parts of India, roof tiles made of terracotta or slate are being used as roofing material for centuries.

The construction of a roof is determined by method of support and how the underneath space is bridged and whether or not the roof is pitched. The pitch is the angle at which the roof rises from its lowest to the highest point. Some types of roofing, for example thatch, require a steep pitch in order to be waterproof and durable. In regions where there is little rain, an almost flat roof with a slight run-off provides adequate protection against an occasional downpour.

The durability of a roof is a matter of concern, because the roof is often the least accessible part of a building for purposes of repair and renewal. The damage to roof has serious effects on the life of the building.

Form of roof

The shape of roof differs greatly from region to region. The major factors which influence the shape of roof are the climate and materials available for roof structure and the outer covering.

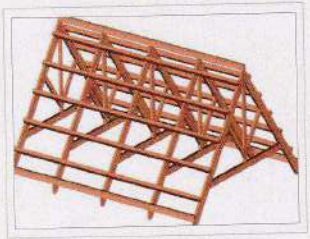
The basic shapes of roofs are flat, mono pitched, gabled, hipped, butterfly, arched and domed. There are several variations to these types. Roofs constructed of flat sections that are sloped are

referred to as pitched roofs (generally if the angle exceeds 10 degrees). Pitched roofs, including gabled, hipped and scallion roofs, make-up the greatest number of roofs for human and animal houses.

Gable end roof

Lean to wall roof

There are two parts a roof, its supporting structure and its outer skin, or uppermost weather-proof layer. The roof structure is generally supported upon walls. The supporting structure of a roof usually comprises of beams that are long and made of strong, fairly rigid material such as timber, and cast iron or steel. Materials like bamboo and timber are also used extensively in India for making roof structures in rural areas.



Wood trusses

Iron trusses

Roofing materials

The common roofing materials which can be used for silkworm rearing houses include thatch, GI sheets and Asbestos sheets.

Thatching

The craft of building a roof with dry vegetation such as paddy, wheat straws, palm leaves, sugarcane trash etc. in layers to shed water away from the roof is called thatching. It is a very old roofing method and has been used extensively in both tropical and temperate climates in rural India. Thatch roof is still used for building low-cost houses.

Advantages

1. A properly, professionally installed thatched roof which is maintained on a regular basis and sited away from any overhanging trees will offer great durability. One can expect thatch to last anywhere between 15 to 20 years in good condition.
2. Thatched roof suits well to hot and dry regions as it will not allow solar radiations to pass through it.

Disadvantages of galvanized iron sheet roofing

Of course, any roofing option has disadvantages to consider, but the advantages of metal roofing outweigh far than disadvantages.

1. Cost: The initial expense of a metal roof is generally higher than other roofing options.
2. Noise: Metal roofs can be noisier than other alternatives.

Asbestos Sheet Roofing

The name, fibro, is short for "fibrous (or fibre) cement sheet", more commonly called "asbestos cement sheet" or "AC sheet". It is a building material in which asbestos fibres are used to reinforce thin rigid cement sheets.

Advantages

1. On the other hand, when asbestos is mixed with cement, it improves the lifespan of that product. In terms of building roof shingles, they could last for about 50-60 years. As compared to plastic and wood, asbestos is undoubtedly first in terms of durability.
2. The natural fire-resistant property of asbestos makes it ideal for roofing, flooring, and thermal insulation. Since a home needs to be fire-resistant, many prefer asbestos. The asbestos material doesn't burn, so placing asbestos near electrical components are advised.
3. Asbestos is also inexpensive. Since it is naturally occurring, you can get asbestos in a cheap price. Asbestos is a very good additive with cement which adds strength to the material. Compared to other cement additives, asbestos is cheaper yet with the same durability.

Disadvantages

Like any other products, asbestos can be health hazardous, if proper precautions are not undertaken. If there is careless construction method concerning asbestos, the asbestos fibres can be lodged into the air. Though it might seem that there's nothing special about it, asbestos fibres pose a great risk to workers health. Those who are directly exposed to asbestos like construction workers and carpenters can be afflicted with lung cancer and mesothelioma which is a rare cancer that affects the linings of the lungs or abdomen.

Flooring

The silkworm rearing houses should be provided with hard flooring to maintain hygienic conditions during silkworm rearing and sustain the weight of rearing stands and equipments. As the silkworm rearing house requires frequent cleaning and disinfection, the flooring should be of cement concrete. The floor should be given

adequate slope to drain-out the water accumulating on it, while cleaning and disinfection operations are on.

Cement Concrete flooring for a silkworm rearing house

Finishing Works

The fancy-works are not at all required for a silkworm rearing house as these add on to the costs of construction and do not serve any purpose. Some of the important finishing works for a silkworm rearing house include smooth cement plastering on inside and outside walls for easy cleaning and avoid places for persistence of pathogens in the rearing environs.

1. A water channel all around the insides of the rearing house to drain-out the water used for cleaning/washing and chemicals from disinfection of rearing house. This channel can be filled with water during the rearing to avoid entry of ants and cool and humidify the air entering through ventilators.

A water channel all around the silkworm rearing hall

2. A water soak pit at an appropriate place near the rearing house and connected with the outlet of water channel in the rearing hall to collect and dispose off the water used for cleaning/washing and chemicals from disinfection of rearing house.

A water soak pit near the rearing house for collection and disposal of water used for cleaning/washing/disinfection from the silkworm rearing house

3. The pathways to rearing houses for workers and transportation of the mulberry shoots and bed refuse should be concreted to avoid entry of pathogens through rearing personnel and transport vehicles.

Cement concrete floor at the entrance of the main door helps in allowing tractor-trailer for collection of the rearing waste and also to keep the entrance pathogen- and dust-free

4. The rearing house should be white-washed with slaked lime, both inside and outside. The advantages of white-washing are many such as
   - Waterproofing, during curing
   - Easy and in-expensive
   - Vapor permeable, allows moisture to escape
   - Unaffected by temperature fluctuations during curing
   - Completely UV resistant
   - Stain-resistant
   - Anti-fungal and bacterial
   - Highly cost-effective
   - Will not shrink or crack
   - Easy to apply

White-washed silkworm rearing house

Doors, Windows and Ventilators

The silkworm rearing houses for hot and dry regions and also for hot and humid conditions shall be provided with adequate ventilation to evacuate heat and moisture from the rearing hall. Hence, the rearing hall shall be provided with maximum openings in the form of windows and ventilators for effective cross-ventilation. This can be achieved through bigger-sized windows and ventilators in more numbers. The jaali-walls could be the simplest way to have large open areas for facilitating ventilation.

(a) Arrangement of windows and ventilators (b) a typical jaali-wall made of bricks for a silkworm rearing house for hot & dry and hot and humid regions

As the silkworm rearing houses have to be cleaned and disinfected frequently, the doors and windows shall be made out of wood, need not have to be of expensive wood. One can use neem or other local woods suitable for making frames of doors, windows and ventilators.

The door of rearing houses be atleast 150 cm (5 feet)or more in width for entry of workers carrying mulberry shoots and facilitate easy removal of rearing waste and shoots after completion of rearing. In large rearing houses, the door should be large enough to make entry of tractor with trailer carrying mulberry shoots and take out bed refuge and rearing waste. In case, if wide wooden door is not feasible, a metal door or a rolling shutter would suffice the purpose.

The rearing windows and ventilators must be fitted with metal or plastic wire-mesh to prevent entry of uzi fly and other predators of silkworms. The entrance door should be a double door with one of the doors as mesh door for ventilation and prevention of predators into the silkworm rearing house.

The entrance door of the silkworm rearing house should be wide- enough for easy movement of rearing personnel with mulberry shoots and bed waste etc.

Cooling Systems for Rearing Houses

The hot and dry areas are characterised by high day temperatures with low relative humidity. The dry weather may be deterrent to silkworms. Hence, arrangements should be made to cool the fresh air entering the rearing house.

Sprinklers on roof top

The simplest method could be providing sprinklers on roof-top to make roof surface wet. The solar radiations falling on roof will evaporate the water and hence cool the roof surface. It is an effective, efficient and maintenance- free method to keep the rearing hall cool. The sprinklers should be operated during the hot hours of day,

generally from 11 am to 4 pm. Installation of sprinklers on roof-top would keep roof cool and avoid solar radiations into the rearing hall.

Foggers near windows and ventilators

To enhance the moisture content and relative humidity of the fresh air entering the rearing hall can be achieved by installing foggers in front of the windows. It is also very effective and cost effective method the cool the air and reduces temperature and enhances the relative humidity in the rearing hall.

Foggers installed along the windows will cool and moist the fresh air entering the rearing hall to reduce heat inside the rearing hall

Cooling and humidification of hot air with wet gunny cloth curtain on windows

The wet gunny cloth curtains provided on windows normally outside will cool and humidify the fresh air entering into the rearing house. This is a cheap and effective method to lower the temperature in rearing houses in hot and dry areas. The only disadvantage is that the gunny cloth should be made wet frequently. This problem can be overcome by installing drippers to keep the gunny cloth moist.

Wet gunny cloth hanged on windows and ventilators allows to cool and humidify the air entering into the rearing house

Wet gunny cloth hanged around 1.5 m (5') away from windows to make humid-air zone with help of foggers to cool and humidify the fresh air entering the rearing hall