Modular building system for cattle folds at high altitude with timber structure

1. Abstract
Infrastructure for cattle at high altitude must be cheap, easy to assemble and blend into the landscape. In this paper we propose a modular building using simple structures, designed according to Eurocode 5, with redwood pine impregnated timber for risk class 4 according EN 335. Portal frames with posts and trusses form the main structure, while the secondary structure is composed of timber roof purlins and steel panels. This construction system is competitive and efficient.

Key words: construction, timber, structures, fold

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22 figures and 1 table

2. Resumen
Construcción modular de apriscos ganaderos de alta montaña con estructura de madera
La construcción de infraestructuras ganaderas en alta montaña debe orientarse hacia la reducción de costes, la facilidad de montaje y la integración en el paisaje. En este artículo se plantea una solución basada en una construcción modular de estructuras sencillas de madera de pino silvestre, calculadas de acuerdo con el Eurocódigo 5 e impregnadas en autoclave para garantizar su durabilidad en clase de riesgo 4, de acuerdo a la norma EN 335. Se trata de pórticos formados por cerchas sobre pilares que forman la estructura principal, y unas correas para soporte de una chapa de acero ondulada como estructura secundaria. Este sistema constructivo resulta competitivo y eficiente.

Palabras Clave: construcción, madera, estructuras, apriscos

3. Introduction

Timber is extensively used in rural buildings in the North of Europe. In some countries such as Sweden, Finland, Norway and Switzerland more than 90% of load carrying roof structures are timber for rural buildings. Many Swedish farmers have their own woodland and use the timber for do-it-yourself purposes (Dolby et al. 1988). Even in France and Germany more than 60% of structures in this field use timber. In Spain very little timber is used in rural constructions, probably at a percentage similar to that in Italy (3%). However, timber is increasingly being used for structural purposes in Spain, for housing and other non-rural buildings. Although there are few examples of new rural buildings with timber structures in the North of Spain, there is a growing tendency for these to be used.

The aim of this work is to propose a competitive and efficient building system for infrastructures for cattle at high altitude. Timber is the principal material used for the structure, while other low cost materials make for economic and simple transport and erection. Finally, stone is used for cladding to ensure integration with landscape.

This system has been used successfully to date in the North of Spain in the construction of more than 20 cattle folds in mountainous areas not higher than 1,700 meters above sea level.

4. General description

4.1. Previous conditions

The design of construction is determined by how this kind of building is used and the special conditions at the high mountain areas where they are located.

The main factors to be considered in the design are the following:

- The requirement for economy in design, materials and erection;
- Simplicity of transport and erection;
- High snow load values lasting for long periods
- Wind loads in exposed areas;
- Durability;
- The possibility of enlargement according to the needs of cattle owners;
- How the buildings blend into the landscape.

4.2. Materials

As economy in materials, transport and erection is one of the main parameters of this building system, redwood pine (Pinus sylvestris L.) sawn timber is used in commercial dimensions that are easily available in the area where the first cattle fold was built. The sizes of cross sections are determined by the structural design, and timber must be chemically protected to

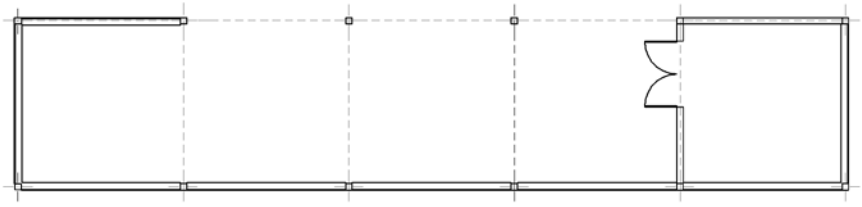

Figure 1. Plan of a cattle fold with 5 modules in I

ensure durability. The exterior walls are built with prefabricated concrete blocks and are independent of the main timber structure. They are self-supporting rather than structural, and cannot be considered to play any role as a bracing element in adding to the general stability of the construction. This is makes it possible for modifications to be made to these buildings in the future, in the form of new openings in the walls.

The roof cladding is metal or fiber-cement corrugated sheets, but it is also possible to use tiles. All of the outside surfaces of walls are covered with natural stone to blend the building into the landscape.

4.3. Description

This is a modular construction that makes it possible to distribute areas in U shapes, as is frequent in buildings of this type. It can be adapted not only to the particular needs of clients, but also to the specific soil conditions where it is to be located. Models with 5 (I plan), 7 (L plan) or typically 12 modules (U plan) are shown in Figures 1, 2 and 3.

Two basic modules are necessary for any cattle, a standard module and a corner one. The standard module has dimensions of 5.00 x 5.00 m, and the corner one is just 0.45 m larger to prevent assembly as a standard module. The final size of any resulting cattle fold is always a multiple of 5 m. The dimensions are shown in Figure 4.

Figures 5 and 6 are included to show the final appearance of a typical cattle fold with 12 modules, with the rafters and external walls.

4.4. Standard module

The standard module has dimensions of 5.00 x 5.00 m, and is formed by two pillars and a double pitched roof with a slope of 45 %. Figure 7.

The main structure is formed of internal pillars with a cross section of 190 x 190 mm and external pillars with a cross section of 190 x 210 mm, and 2.50 m free height above ground level.

The pillars are fixed to the foundations by means of concrete shafts with a minimum depth of 1.00 m. This rigid joint is required to stabilize the building and makes it unnecessary to use other elements in vertical planes for bracing.

It is recommended to add some dowel type elements (hot dipped nails or screws) in the part of the pillar in contact with concrete to improve fixing.

The structure of the roof is a simple truss with two rafters of 135 x 240 mm cross section and a tie composed of two pieces 50 x 170 mm cross section with intermediate spaced blocks. The truss is held on the pillars by joints of bolts and metal plates.

The secondary roof structure is formed of timber purlins with a cross section of 100 x 180 mm, with a distance between axes of 550 mm over the rafters, scabbled to prevent sliding and overturning. A tension member formed by a steel strap is required in the center of purlin bays to reduce bending with respect to the weak axis of the purlin. As purlins are longer than the separation between portals, there is a cantilever at the end of purlins that allows overlapping. These behave in a way similar to a continuous beam, improving efficiency in the longest span in corner modules.

The bracing in the plane of the roof is resolved by means of crosses with steel straps nailed to the upper side of purlins. One bracing module is installed for each three modules and in end modules. Figure 8.

Finally, although this was not included in the project, the first three cattle folds that were built included a one meter high stone base for the pillars to protect them from the direct contact of animals. The square stone bases are not suitable for bovine cattle and round ones are suggested.

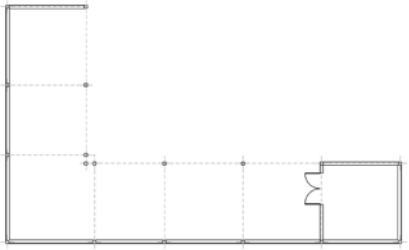

Figure 2. Plan of a cattle fold with 7 modules in L

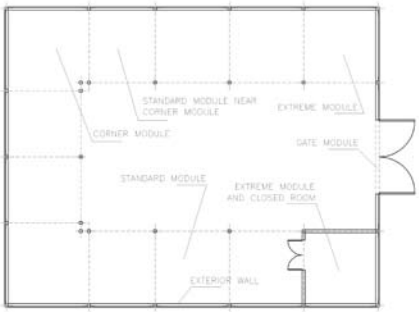

Figure 3. Plan of a typical cattle fold with 12 modules in U

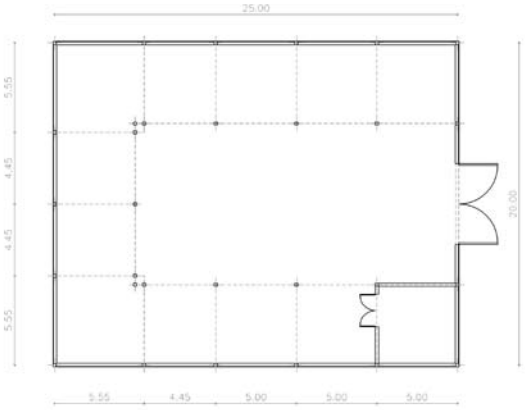

Figure 4. Plan of a typical cattle fold with 12 modules in U. Distances

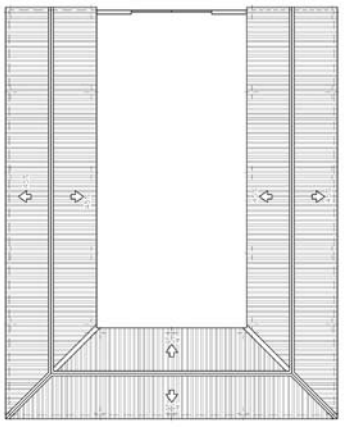

Figure 5. Typical cattle fold. Roof plan

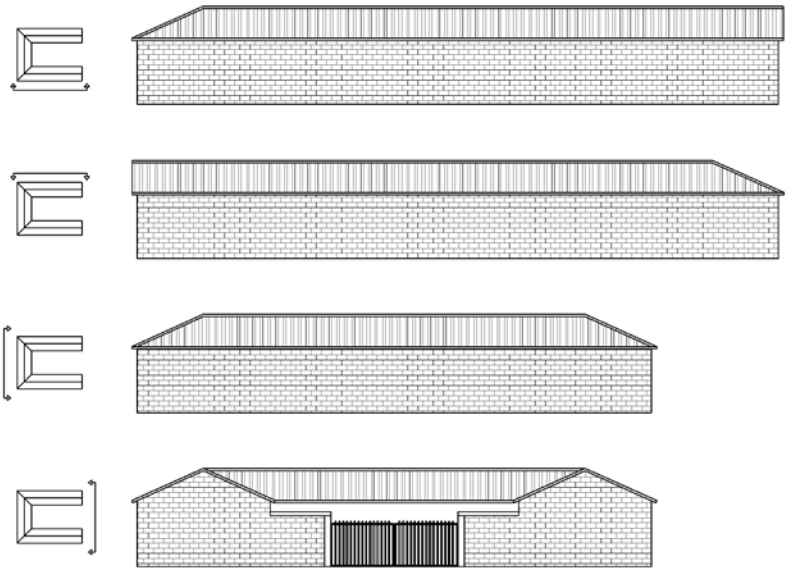

Figure 6. Typical cattle fold. Side views

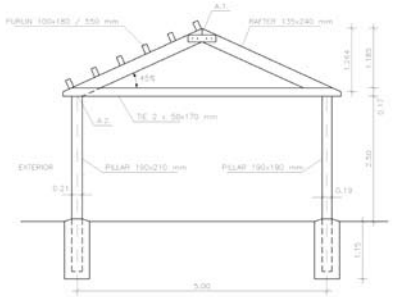

Figure 7. Standard module

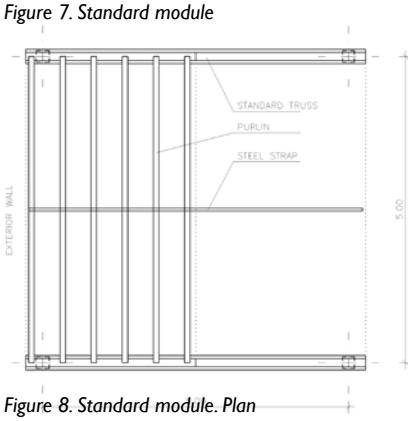

Figure 8. Standard module. Plan

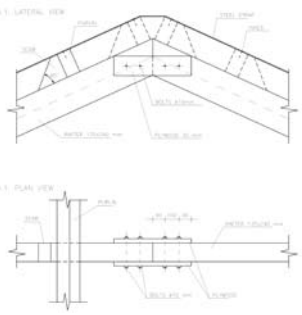

Figure 9. Standard module. Details of connections

4.5. Corner and end modules

Corner modules are specifically designed to contain interior pillars and supports for hip rafters. On the same principle as the standard module, the roofing of the corner module is composed of a truss with rafters, a tie, king post and struts arranged diagonally to form the hip rafters, figures 11 and 12. Details are shown in figures 13, 14 y 15

In this module the span of purlins is the longest, and so it is especially necessary for the ends of purlins to overlap.

Initially the roof at the end of end modules was designed with a third slope, although this was finally not included and it was ended with a standard module.

5. Structural calculations

Structural analysis was performed according to EN 1995-1-1. Eurocode 5, using the following design loads:

- Dead load.
- Snow load up to 1.70 kN/m^2 (NBE-AE 88), medium term duration load, equivalent to snowfall at up to 1700 meters above sea level.
- Wind force, an exposed located corresponding to the wind area of Leon (NTE-ECV 88).
- A concentrated load of 1 kN at the weakest point of the structure, as an assembly or maintenance load.

Timber pieces used on the roof structure are assigned strength class C18 (UNE-EN 338) and posts are strength class C22 or higher, as a result of special requirements due to the fact that they have fixed supports and are in direct contact with the ground, implying service class 3 analysis. The other pieces are service class 2. The design stress values used in structural calculations for these strength classes are summarized in table 1.

To meet the requirements of quality and strength class, visual strength grading standard UNE 56544 was used. Although the species used is redwood pine, Pinus sylvestris L., these strength classes requirements are achieved to visual grades ME2 and ME1, as defined in the standard for redwood pine, laricio pine and maritime pine (C22).

6. Wood preservation

All timber pieces are treated by immersion in a water-soluble salt preservative in a high pressure vacuum system. This preservation treatment has anti-fungal and anti-insect properties, and is effective against termites.

Wood preservative should be registered in official establishments and should be authorized for use in bovine cattle infrastructures.

The effectiveness of the treatment used should be enough to assure protection in risk class 4 (UNE-EN 335), corresponding to timber in permanent contact with the ground or non-salt water.

In general, wood has natural resistance against acid or corrosive atmospheres, so it is not considered to require any special treatment due to contact with cattle excrement.

6. Assembly and costs

Due to prefabrication it is possible in the case of the larger folds to assembly them in five days, using a team of five workers.

Table 1. Mechanical properties of timber (UNE-EN 338)
(strength and stiffness properties in N/mm²; density in kg/m³)

Strength class	Characteristic Strength		Modulus of elasticity		Density	
	Bending	compression	Mean	characteristic	mean	characteristic
C18	18	18	9,000	6,000	380	320
C22	22	20	10,000	6,700	410	340

The basic cattle fold consists of 12 modules which delimit a total area of 1,000 m², of which 600 m² are covered. The total cost including stone cladding is 56,000 euros. The first of these cattle folds to be built is shown in figures 16 to 22.

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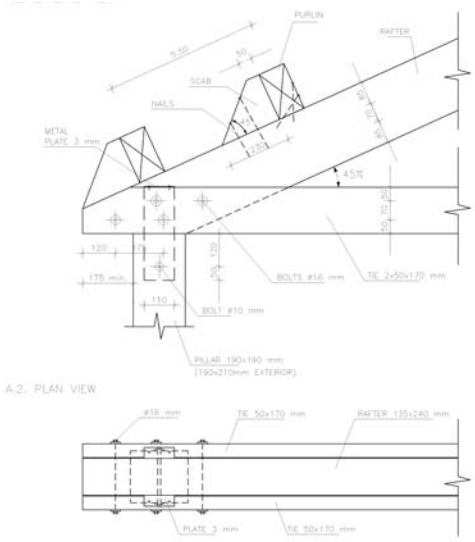

Figure 10 Módulo tipo. Detalle del pilar

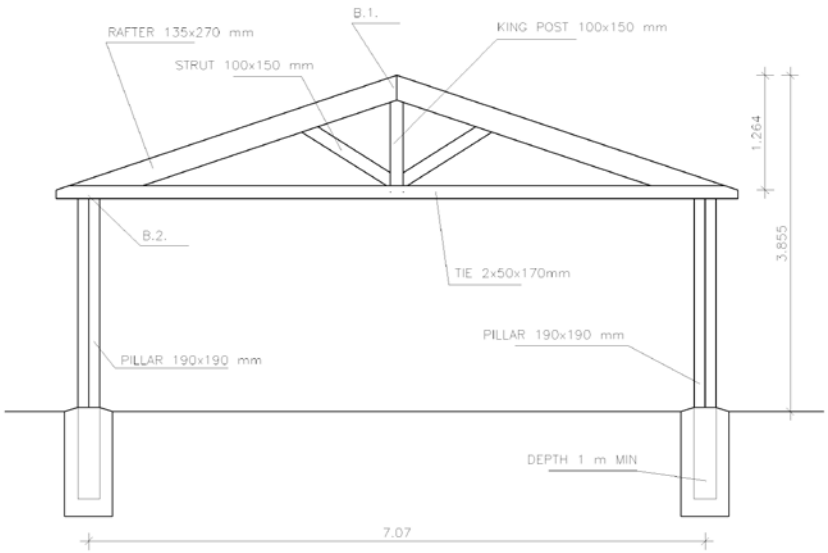

Figure 11. Corner module

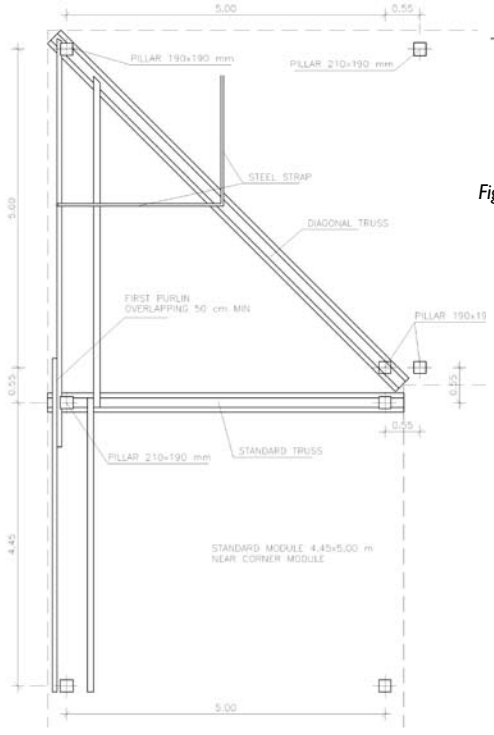

Figure 12. Corner module. Plan

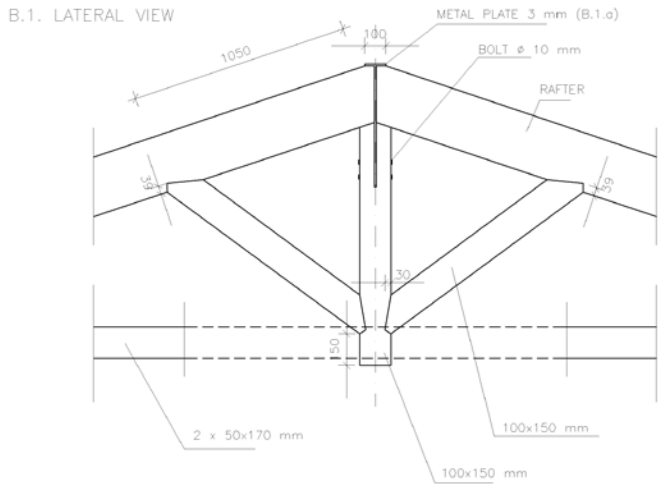

Figure 13. Corner module. Details

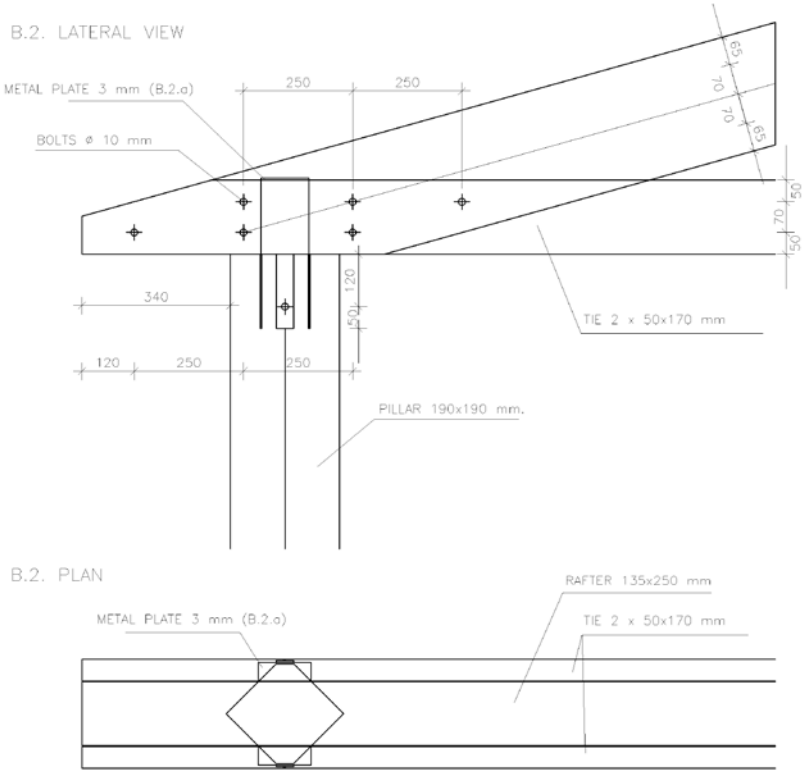

Figure 14. Corner module. Details

loads).

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UNE-EN 335-1. Durability of wood and wood-based products. Definition of hazard classes of biological attack. Part 1: General.

UNE-EN 335-2. Durability of wood and wood-based products. Definition of hazard classes of biological attack. Part 2: Application to solid wood.

UNE-EN 338. 1995. Structural timber Strength classes.

UNE-EN 19951-1. Eurocode 5. Design of timber structures. Part 1-1: General. Common rules and rules for buildings

Figure 16. Exterior view of building with stone cladding

Figure 19. Standard module and truss with bracing

Figure 17. Exterior view of building

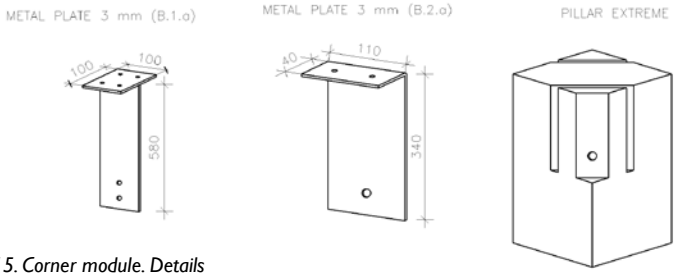

Figure 15. Corner module. Details

Figure 20. Standard module next to corner module

Figure 18. Interior of finished cattle fold

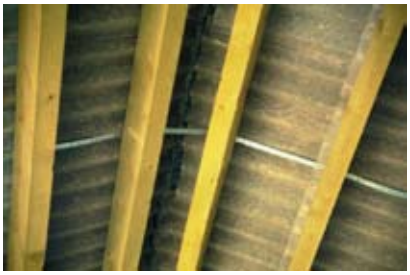

Figure 21. Diagonal truss of corner module

Figure 22. Purlins and steel strap