

ORDINANCE NO. 5891

**AN ORDINANCE AMENDING CHAPTER 10-5, B.R.C. 1981, CONCERNING
ALTERNATIVE BUILDING
MATERIALS, INCLUDING ADOBE AND STRAW BALE CONSTRUCTION AND
RECYCLED LUMBER.**

BE IT ORDAINED BY THE CITY COUNCIL OF THE CITY OF BOULDER, COLORADO:

Section 1. Section 10-5-2, B.R.C. 1981, is amended by the addition of a new subsection (bb) to read:

(bb) New chapter 98 are added to the Building Code to read:

CHAPTER 98 - Baled Straw Structures

SECTION 9801 - PURPOSE

The purpose of this chapter is to establish minimum prescriptive standards of safety for the construction of structures which use baled straw as a load bearing or non-load bearing material.

SECTION 9802 - SCOPE

The use of baled straw shall be limited to buildings of Group R, Division 3 and Group U occupancies of no more than one story in height, with a maximum roof span of thirty-two feet between bearing walls, unless design and structural calculations are submitted by a registered architect or a professional engineer licensed to practice in the state and approved by the building official.

SECTION 9803 – DEFINITIONS. For the purpose of this chapter, certain terms are defined as follows:

STRAW is the dry stems of cereal grains left after the seed heads have been removed.

BALES are rectangular compressed blocks of straw, bound by strings or wire.

FLAKES are slabs of straw removed from an untied bale. Flakes are used to fill small gaps between the ends of stacked bales.

LAID FLAT refers to stacking bales so that the sides with the largest cross-sectional area are horizontal and the longest dimension of this area is parallel with the wall plane.

LAID ON-EDGE refers to stacking bales so that the sides with the largest cross-sectional area are vertical and the longest dimension of this area is horizontal and parallel with the wall plane.

SECTION 9804 - MATERIALS

9804.1 Specifications for Bales.

9804.1.1 Type of Straw. Bales of various types Of straw, including, but not limited to, rye, barley, oats, wheat, rice, and similar plants, shall be acceptable if they meet the minimum requirements for density, shape, moisture content, and ties.

9804.1.2 Shape. Bales shall be rectangular in shape.

9804.1.3 Dimensions. Bales used within a continuous wall shall be of consistent height and width to ensure even distribution of loads within wall systems.

9804.1.4 Ties. Bales shall be bound with ties of either polypropylene string or baling wire. Bales with broken or loose ties shall not be used unless the broken or loose ties are replaced with ties which restore the original degrees of compaction of the bale.

9804.1.5 Moisture Content. Moisture content of bales, at time of installation, shall not exceed twenty percent of the total weight of the bale. Moisture content of bales shall be determined by one of the following:

9804.1.5.1 Field Method. A suitable moisture meter, designed for use with baled straw or hay, and equipped with a probe of sufficient length to reach the center of the bale, shall be used to determine the average moisture content of five bales randomly selected from each five hundred bales or fraction thereof.

9804.1.5.2 Laboratory Method. A total of five samples, taken from the center of each of five bales randomly selected from each of five hundred bales or fraction thereof to be used, shall be tested for moisture content by a recognized testing lab.

9804.1.6 Density. Bales shall have a minimum calculated dry density of seven pounds per cubic foot. The calculated dry density shall be determined after reducing the actual bale weight by the weight of the moisture content as determined in Section 9804.1.5. The calculated dry density shall be determined by dividing the calculated dry weight of the bale by the volume of the bale.

9804.1.7 Custom Size Bales. Where custom-made partial bales are used, they shall be of the same density, same string or wire tension, and, where possible, use the same number of ties as the standard size bales.

SECTION 9805 - CONSTRUCTION AND GENERAL REQUIREMENTS

9805.1 General. Bale walls, when laid flat and covered with plaster, drywall or stucco shall be deemed to have the equivalent fire resistive rating as wood frame construction with the same wall finishing System.

9805.2 Storage. All bale and loose hay shall be stored in accordance with Uniform Fire Code Article 28. Bales and loose hay shall be properly protected- from moisture- while being transported, stored, and during construction.

9805.3 Wall Thickness. Nominal minimum bale wall thickness shall be fourteen inches.

9805.4 Wall Height. Bale walls shall not exceed one story in height and the bale portion shall not exceed a height to width ratio of 5.6:1 (for example, the maximum height for the bale portion of a twenty-three inch thick wall would be ten feet eight inches), unless the structure is designed by a registered architect or a professional engineer licensed by the state to practice as such, and approved by the building official.

Exception: In the non-load bearing exterior end walls of structures with gable or shed roofs, an approved continuous assembly shall be required at the roof bearing assembly level.

9805.5 Unsupported Wall Length. The ratio of unsupported wall length to thickness, for bale walls, shall not exceed 13:1 (for a twenty-three inch thick wall, the maximum unsupported length allowed is twenty-five feet), unless the structure is designed by a registered architect or a professional engineer licensed by the state to practice as such, and approved by the building official.

9805.6 Allowable Loads. The allowable vertical load (live and dead load) on the top of load bearing bale walls shall not exceed four hundred pounds per square foot, based on walls with bales laid flat, and the resultant load shall act at the center of the wall. Bale structures shall be designed to withstand all vertical and horizontal loads as specified in Chapter 16.

9805.7 Footings and Foundations. All footings and foundations shall be designed as required by Chapter 18, and shall bear the seal and signature of a professional engineer registered in the State of Colorado when required by Section 106.3.2. Foundations shall be sized to accommodate the thickness of the bale wall and the load created by the wall and roof live and dead loads. Foundation (stem) walls which support bale walls shall extend to an elevation of not less than six inches above adjacent ground at all points.

9805.8 WALL AND ROOF BEARING ASSEMBLY ANCHORAGE.

9805.8.1 General. Vertical rebar with a minimum diameter of one-half inch shall be embedded in the foundation a minimum depth of six inches, and shall extend above foundation a minimum of twelve inches. The vertical bars shall be located along the centerline of the bale wall, spaced not more than two feet apart. A vertical bar shall also be located within one foot of any opening or corner, except at locations occupied by anchor bolts.

9805.8.2 Intersecting Walls. Walls of other materials intersecting bale walls shall be attached to the bale wall by means of one or more of the following methods or an acceptable equivalent:

1. Wooden dowels at least five-eighths inch in diameter of sufficient length to provide twelve inches of penetration into the bale, driven through holes bored in the abutting stud, and spaced to provide one dowel connection per bale.

2. Pointed wooden stakes, at least twelve inches in length and one and one-half inch by three and one-half inches at the exposed end, fully driven into each course of bales, as anchorage points.

3. Bolted or threaded rod connection of the abutting wall, through the bale wall, to a steel nut and steel or plywood plate washer, a minimum of six inches square and a minimum thickness of three-sixteenth inch for steel and one-half inch for plywood, in at least three locations.

9805.8.3 Anchor Bolts. All exterior and load bearing bale walls shall be anchored to the foundation by one-half inch diameter steel anchor bolts embedded at least seven inches in the foundation at intervals of four feet or less. A minimum of two anchor bolts per wall shall be provided with one bolt located within twenty-four inches of each end of each wall. Sections of one-half inch diameter threaded rod shall be connected to the anchor bolts, and to each other, by means of threaded coupling nuts and shall extend through the roof bearing assembly and be fastened with a steel washer and nut bale walls and roof bearing assemblies may be anchored to the foundation by means of other methods which are adequate to resist uplift forces resulting from the design wind load and approved by the building official. There shall be a minimum of two points of anchorage per wall, spaced not more than four feet apart, with one located within twenty-four inches of each end of each wall.

The dead load of the roof and ceiling systems will produce vertical compression of the bales. Regardless of the anchoring system used to attach the roof bearing assembly to the foundation, prior to installation of wall finish materials, bolts or straps shall be re-tightened to compensate for this compression.

9805.8.4 Moisture Protection. All weather-exposed bale walls shall be protected from water damage. An approved building moisture barrier shall be used to protect at least the bottom course of bales, but not more than the lower one-third of the vertical exterior wall surface, in order to allow natural transpiration of moisture from the bales. The moisture barrier shall have its upper edge inserted at least six inches into the horizontal joint between two courses of bales, and shall extend at least three inches below the top of the foundation. Bale walls shall have special moisture protection provided at all window sills. Unless protected by a roof, the tops of walls shall also be protected. This moisture protection shall consist of a waterproof membrane, such as asphalt impregnated felt paper, polyethylene sheeting, or other acceptable moisture barrier, installed in such manner as to prevent water from entering the wall system at window sills or at the tops of walls.

9805.8.5 Moisture Barrier. A moisture barrier shall be used between the top of the foundation and the bottom of the bale wall to prevent moisture from migrating through the foundation into the bottom course of bales. This barrier shall consist of one of the following:

1. cementitious waterproof coating;

2. type 30 asphalt felt over asphalt emulsion;

3. sheet metal flashing, sealed at joints;

4. other approved building moisture barrier. All penetrations through the moisture barrier, as well as all joints in the barrier, must be sealed with asphalt, caulking or an approved sealant.

9805.8.6 Stacking and Pinning. Bales in all exterior and load-bearing walls shall be laid flat and stacked in running bond with each bale overlapping the two bales beneath it. Bales in non load bearing interior walls may be laid either flat or on-edge and stacked in running bond. Overlaps shall be a minimum of twelve inches. Gaps between the ends of bales which are less than six inches in width can be filled by a tightly fitted untied flake.

The first course of bales shall be laid by impaling the bales on the vertical bars or threaded rods, extending from the foundation. When the fourth course has been laid, #4 rebar pins, or an acceptable equivalent, long enough to extend through all four courses, shall be driven down through the bales, two in each bale, located so that they do not pass within six inches of, or through the space between the ends of any two bales. The layout of these pins shall approximate the layout of the vertical bars extending from the foundation. As each subsequent course is laid, two such pins, long enough to extend through the course being laid and the three courses immediately below it, shall be driven down through each bale. This pinning method shall be continued to the top of the wall. In walls seven or eight courses high, pinning at the fifth course may be eliminated.

Only full-length bales shall be used at corners of load bearing walls, unless exceptions are designed by a professional engineer licensed by the state to practice as such. and approved by the building official.

Vertical #4 rebar pins, or an acceptable alternative, shall be located within one foot of all comers or door openings.

Staples, made of #3 or larger rebar formed in a "U" shape, at least eighteen inches long with two six inch legs, shall be used at all corners of every course, driven with one leg into the top of each abutting comer bale. In lieu of staples, comer bides may be tied together by a method approved by building official.

9805.8.6.1 Alternative Pinning Method. When the third course has been laid, vertical #4 rebar pins, or an acceptable equivalent, long enough to extend through all three courses, shall be driven down through the bales, two in each bale, located so that they do not pass within six inches of, or through, the space between the ends of any two bales. The layout of these rebar pins shall approximate the layout of the rebar pins extending from the foundation. As each subsequent course is laid, two such pins, long enough to extend through that course and the two courses immediately below it, shall be driven down through each bale. This pinning method shall be continued to the top of the wall.

9805.8.7 Roof and Roof Bearing Assembly. Load-bearing bale walls shall have a roof bearing assembly at the top of the wall to bear the roof load and to provide a means of connecting the roof structure to the foundation. The roof bearing assembly shall be continuous along the tops of structural walls. Roofs shall be designed, constructed, and anchored as required by Chapters 15, 16, 23, and other appropriate chapters of this code.

An acceptable roof bearing assembly option consisting of two double two inch by six inch, or larger, horizontal top plates, one located at the inner edge of the wall and the other at the outer edge. Connecting the two doubled top plates and located horizontally and perpendicular to the length of the wall shall be two inch by six inch cross members spaced no more than forty-eight inches center to center, and as required to align with the threaded rods extending from the anchor bolts in the foundation. The double two inch by six inch top plates shall be face nailed with 16d nails staggered at sixteen inches on center, with laps and intersections face nailed with four 16d nails. The cross members shall be face nailed to the top plates with four 16d nails at each end. Corner connections shall include overlaps nailed as above or an acceptable equivalent such as plywood gussets or metal plates. Alternatives to this roof bearing assembly option must provide equal or greater vertical rigidity and provide horizontal rigidity equivalent to a continuous double two inch by six inch top plate and approved by the building official.

9805.8.8 Openings and Lintels. All openings in load-bearing bale walls shall be a minimum of one full bale length from any outside corner, unless designed by a registered architect or a professional engineer licensed by the state to practice as such, and approved by the building official.

9805.8.8.1 Openings. Openings in exterior bale walls shall not exceed fifty percent of the total wall area, based on interior dimensions, where the wall is providing resistance to lateral loads, unless the structure is designed by a registered architect or a professional engineer licensed by the state to practice as such, and approved by the building official.

9805.8.8.2 Lintels. Wall and/or roof load present above any opening shall be carried, or transferred to the bales below by one of the following:

1. a structural frame,
2. a lintel (such as an angle-iron cradle, wooden beam, wooden box beam). Lintels shall be a least twice as long as the opening is wide and extend at least twenty-four inches beyond either side of the opening. Lintels shall be centered over openings, and shall not exceed the load limitations of Section 9805.6.

9805.8.9 Wall Finishes. Interior and exterior surfaces of bale walls shall be protected from mechanical damage, flame, animals, and prolonged exposure to water. Bale walls adjacent to bath and shower enclosures shall be protected by a moisture barrier.

Cement stucco shall be installed as required by Chapter 25 of the Uniform Building Code.

Where bales abut other materials the plaster/stucco shall be reinforced with galvanized expanded metal lath, or an acceptable equivalent, extending a minimum of six inches onto the bales.

Earthen and lime-based plasters may be applied directly onto the exterior and interior surface of bale walls without reinforcement, except where applied over materials other than straw. Weather exposed earthen plasters shall be stabilized using a method approved by the building official.

Lime based plasters may be applied directly onto the exterior surface of bale walls without reinforcement, except where applied over materials other than straw.

9805.8.10 Electrical. All wiring within or on bale walls shall meet all provisions of the National Electrical Code adopted by this jurisdiction. Type NM or UF cable may be used, or wiring may be run in metallic or non-metallic conduit systems. Electrical boxes shall be securely attached to wooden stakes driven a minimum of twelve inches into the bales, or an acceptable equivalent.

9805.8.11 Plumbing. Water pipes within bale walls shall be encased in a continuous pipe sleeve to prevent leakage within the wall. Where water pipes are mounted on bale walls, they shall be isolated from the bales by a moisture barrier. Gas piping shall not be encased within bale walls without prior approval the building official.

9805.8.12 Insulation. All straw bale buildings shall be constructed to comply with the adopted energy code.

Exception: A vapor barrier shall not be installed over the exterior walls.

Flat laid walls shall have an assumed R-value of 2.4 per inch of thickness.