# CALIFORNIA HEALTH AND SAFETY CODE

# Guidelines for Straw-Bale Structures

CALIFORNIA CODES
HEALTH AND SAFETY CODE
SECTION 18944.30-18944.33

18944.30. The Legislature finds and declares all of the following:

(a) There is an urgent need for low-cost, energy-efficient housing in California.
(b) The cost of conventional lumber-framed housing has risen due to a shortage of construction-grade lumber.
(c) Straw is an annually renewable source of cellulose that can be used as an energy-efficient substitute for stud-framed wall construction.
(d) The state has mandated that the burning of rice straw be greatly reduced.
(e) As a result of the mandated burning reduction, growers are experimenting with alternative straw management practices. Various methods of straw incorporation into the soil are the most widely used alternatives. The two most common methods are nonflood incorporation and winter flood incorporation. Economically viable off-farm uses for rice straw are not yet available.
(f) Winter flooding of rice fields encourages the natural decomposition of rice straw and provides valuable waterfowl habitat. According to the Central Valley Habitat Joint Venture component of the North American Waterfowl Management Plan, in California's Central Valley, over 400,000 acres of enhanced agricultural lands are needed to restore the depleted migratory waterfowl populations of the Pacific flyway. Flooded rice fields are a key and integral part of the successful restoration of historic waterfowl and shorebird populations.
(g) Winter flooding of rice fields provides significant waterfowl habitat benefits and should be especially encouraged in areas where there is minimal potential to impact salmon as a result of surface water diversions.
(h) An economically viable market for rice straw bales could result from the use of rice straw bales in housing construction.

(i) Practicing architects and engineers have determined that the statutory guidelines established by Chapter 941 of the Statutes of 1995 contain specific requirements that they believe are either unnecessary or detrimental. Some of the requirements are considered costly and severely restrict the development of straw-bale housing.
(j) Statutory guidelines for the use of straw-bale housing would significantly benefit energy conservation, natural resources, low-cost housing, agriculture, and fisheries in California.
(k) Tests and experience with straw-bale construction demonstrate that it is a strong, durable, and thermally superior building system that deserves a larger role in modern construction.

18944.31. (a) Notwithstanding any other provision of law, the guidelines established by this chapter shall apply to the construction of all structures that use baled straw as a loadbearing or nonloadbearing material within any city or county that adopted the guidelines established by Chapter 941 of the Statutes of 1995 prior to January 1, 2002. This requirement shall not preclude the city or county from making changes or modifications to the guidelines pursuant to subdivision (b). Notwithstanding any other provision of law, the guidelines established by this chapter shall not become operative in a city or county that has not adopted the guidelines prior to January 1, 2002, unless and until the legislative body of the city or county makes an express finding that the application of these guidelines within the city or county is reasonably necessary because of local conditions and the city or county files a copy of that finding with the department.
(b) A city or county may, by ordinance or regulation, make any changes or modifications in the guidelines contained in this chapter as it determines are reasonably necessary because of local conditions, provided the city or county files a copy of the changes or modifications and the express findings for the changes or modifications with the department. No change or modification of that type shall become effective or operative for any purpose until the finding and the change or modification has been filed with the department.
(c) Nothing in this chapter shall be construed as increasing or decreasing the authority to approve or disapprove of alternative construction methods pursuant to the State Housing Law, Part 1.5 (commencing with Section 17910) or the California Building Standards Code, Title 24 of the California Code of Regulations.
(d) It is the intent of the Legislature that the statutory

guidelines of this chapter serve as an interim measure pending the evaluation of straw bales as a construction material through the normal processes used for the testing and listing of building materials, the determination of construction standards, and the adoption of those materials and construction standards into the California Building Standards Code.

18944.32. Nothing in this chapter shall be construed as an exemption from Chapter 3 (commencing with Section 5500) of, or Chapter 7 (commencing with Section 6700) of, Division 3 of the Business and Professions Code relative to preparation of plans, drawings, specifications, or calculations under the direct supervision of a licensed architect or civil engineer, for the construction of structures that deviate from the conventional framing requirements for wood-frame construction.

18944.33. For the purposes of this chapter, the following terms are defined as follows:
(a) "Bales" means rectangular compressed blocks of straw, bound by strings or wire.
(b) "Department" means the Department of Housing and Community Development.
(c) "Flakes" means slabs of straw removed from an untied bale. Flakes are used to fill small gaps between the ends of stacked bales.

(d) "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.
(e) "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.
(f) "Loadbearing" refers to plastered straw-bale walls that bear the dead and live loads of the roof and any upper floor.
(g) "Nonloadbearing" refers to plastered straw-bale walls that bear only their own weight, such as infill panels within some type of post and beam structure.
(h) "Plaster" means lime, gypsum, lime cement, or cement plasters, as defined by the California Building Standards Code, or earthen plaster with fiber reinforcing.
(i) "Straw" means the dry stems of cereal grains left after the

seed heads have been substantially removed.

CALIFORNIA HEALTH AND SAFETY CODE
SECTION 18944.35

18944.35. (a) Bales shall be rectangular in shape.
(b) Bales used within a continuous wall shall be of consistent height and width to ensure even distribution of loads within wall systems.
(c) 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 degree of compaction of the bale.
(d) The moisture content of bales, at the time of installation, shall not exceed 20 percent of the total weight of the bale. Moisture content of bales shall be determined through the use of a suitable moisture meter, designed for use with baled rice straw or hay, equipped with a probe of sufficient length to reach the center of the bale, and used to determine the average moisture content of five bales randomly selected from the bales to be used.
(e) Bales in loadbearing walls shall have a minimum calculated dry density of 7.0 pounds per cubic foot. The calculated dry density shall be determined after reducing the actual bale weight by the weight of the moisture content.
(f) 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.
(g) Bales of various types of straw, including wheat, rice, rye, barley, oats, and similar plants, shall be acceptable if they meet the minimum requirements of this chapter for density, shape, moisture content, and ties.

CALIFORNIA HEALTH AND SAFETY CODE
SECTION 18944.40-18944.41

18944.40. (a) Straw-bale walls, when 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.

(b) Minimum bale wall thickness shall be 13 inches.
(c) Buildings with loadbearing bale walls shall not exceed one story in height without substantiating calculations and design by a civil engineer or architect licensed by the state, and the bale portion of the loadbearing walls shall not exceed a height-to-width ratio of 5.6:1 (for example, the maximum height for a wall that is 23 inches thick would be 10 feet 8 inches).
(d) The ratio of unsupported wall length to thickness, for loadbearing walls, shall not exceed 15.7:1 (for example, for a wall that is 23 inches thick, the maximum unsupported length allowed is 30 feet).
(e) The allowable vertical load (live and dead load) on top of loadbearing bale walls plastered with cement or lime cement plaster on both sides shall not exceed 800 pounds per linear foot, and the resultant load shall act at the center of the wall. Straw-bale structures shall be designed to withstand all vertical and horizontal loads, and the resulting overturning and base shear, as specified in the latest edition of the California Building Standards Code. Straw-bale walls plastered with cement or lime cement plaster on both sides shall be capable of resisting in-plane lateral forces from wind or earthquake of 360 pounds per linear foot.
(f) Foundations shall be designed in accordance with the California Building Standards Code to accommodate the load created by the bale wall plus superimposed live and dead loads. Supports for bale walls shall extend to an elevation of at least six inches above adjacent ground at all points, and at least one inch above floor surfaces.
(g) (1) Bale walls shall be anchored to supports to resist lateral forces, as approved by the civil engineer or architect. This may be accomplished with one-half inch reinforcing bars embedded in the foundation and penetrating the bales by at least 12 inches, located along the center line of the bale wall, spaced not more than two feet apart. Other methods as determined by the engineer or architect may also be used.
(2) Nonbale walls abutting bale walls shall be attached by means of one or more of the following methods or by means of an acceptable equivalent:
(A) Wooden dowels of 5/8 inch minimum diameter and of sufficient length to provide 12 inches of penetration into the bale, driven through holes bored in the abutting wall stud, and spaced to provide one dowel connection per bale.
(B) Pointed wooden stakes, a minimum of 12 inches in length and 11/2 inches by 31/2 inches at the exposed end, fully driven into each

course of bales, as anchorage points.
(C) 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 6 inches square and a minimum thickness of 3/16 of an inch for steel and 1/2 inch for plywood, in a minimum of three locations.
(3) (A) Bale walls and roof bearing assemblies shall be anchored to the foundation where necessary, as determined by the civil engineer or architect, by means of methods that are adequate to resist uplift forces resulting from the design wind load. There shall be a minimum of two points of anchorage per wall, spaced not more than 6 feet apart, with one located within 36 inches of each end of each wall.
(B) With loadbearing bale walls, the dead load of the roof and ceiling systems will produce vertical compression of the walls. Regardless of the anchoring system used to attach the roof bearing assembly to the foundation, prior to installation of wall finish materials, the nuts, straps, or cables shall be retightened to compensate for this compression.
(h) (1) 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 so as to come into contact with the bottom course of bales. This barrier shall consist of one of the following:
(A) Cementitious waterproof coating.
(B) Type 30 asphalt felt over an asphalt emulsion.
(C) Sheet metal flashing, sealed at joints.
(D) Another building moisture barrier, as approved by the building official.
(2) All penetrations through the moisture barrier, as well as all joints in the barrier, shall be sealed with asphalt, caulking, or an approved sealant.
(3) There shall also be a drainage plane between the straw and the top of the foundation, such as a one inch layer of pea gravel.
(i) (1) For nonloadbearing walls, bales may be laid either flat or on edge. Bales in loadbearing bale walls shall be laid flat and be stacked in a running bond, where possible, with each bale overlapping the two bales beneath it. Overlaps shall be a minimum of 12 inches. Gaps between the ends of bales which are less than 6 inches in width may be filled by an untied flake inserted snugly into the gap.

(2) Bale wall assemblies shall be held securely together by rebar pins driven through bale centers as described in this chapter, or

equivalent methods as approved by the civil engineer or architect.
(3) The first course of bales shall be laid by impaling the bales on the rebar verticals and threaded rods, if any, extending from the foundation. When the fourth course has been laid, vertical #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 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 pins, long enough to extend through that course 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.
(4) Alternative pinning method to the method described in paragraph (3): 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 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 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.
(5) Only full-length bales shall be used at corners of loadbearing bale walls.
(6) Vertical #4 rebar pins, or an acceptable alternative, shall be located within one foot of all corners or door openings.
(7) Staples, made of #3 or larger rebar formed into a "U" shape, a minimum of 18 inches long with two 6-inch legs, shall be used at all corners of every course, driven with one leg into the top of each abutting corner bale.
(j) (1) All loadbearing bale walls shall have a roof bearing assembly at the top of the walls to bear the roof load and to provide the means of connecting the roof structure to the foundation. The roof bearing assembly shall be continuous along the tops of loadbearing bale walls.
(2) An acceptable roof bearing assembly option shall consist of two double 2-inch by 6-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

2-inch by 6-inch cross members, spaced no more than 72 inches center to center, and as required to align with the threaded rods extending from the anchor bolts in the foundation. The double 2-inch by 6-inch top plates shall be face-nailed with 16d nails staggered at 16-inch o.c., with laps and intersections face-nailed with four 16d nails. The crossmembers 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 shall provide equal or greater vertical rigidity and provide horizontal rigidity equivalent to a continuous double 2 by 4 top plate.

(3) The connection of roof framing members to the roof plate shall comply with the appropriate sections of the California Building Standards Code.

(k) All openings in loadbearing bale walls shall be a minimum of one full bale length from any outside corner, unless exceptions are approved by an engineer or architect licensed by the state to practice. Wall or roof load present above any opening shall be carried, or transferred, to the bales below by one of the following:

(1) A frame, such as a structural window or door frame.

(2) A lintel, such as an angle-iron cradle, wooden beam, or wooden box beam. Lintels shall be at least twice as long as the opening is wide and extend a minimum of 24 inches beyond either side of the opening. Lintels shall be centered over openings.

(3) A roof bearing assembly designed to act as a rigid beam over the opening.

(l) (1) All weather-exposed bale walls shall be protected from water damage. No vapor impermeable barrier may be used on bale walls, and the civil engineer or architect may design the bale walls without any membrane barriers between straw and plaster, except as specified in this section, in order to allow natural transpiration of moisture from the bales and to secure a structural bond between plaster and straw.

(2) Bale walls shall have special moisture protection provided at all horizontal surfaces exposed to the weather. This moisture protection shall be installed in a manner that will prevent water from entering the wall system.

(m) (1) 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.

(2) Cement stucco shall be reinforced with galvanized woven wire stucco netting or an equivalent, as approved by the building official. The reinforcement shall be secured by attachment through the wall at a maximum spacing of 24 inches horizontally and 16 inches vertically, unless substantiated otherwise by a civil engineer or architect.
(3) Where bales abut other materials, the plaster or stucco shall be reinforced with galvanized expanded metal lath, or an acceptable equivalent, extending a minimum of 6 inches onto the bales.
(4) Earthen and lime-based plasters may be applied directly onto bale walls without reinforcement, except where applied over materials other than straw.
(n) (1) All wiring within or on bale walls shall meet all provisions of the California Electrical Code. Type "NM" or "UF" cable may be used, or wiring may be run in metallic or nonmetallic conduit systems.
(2) Electrical boxes shall be securely attached to wooden stakes driven a minimum of 12 inches into the bales, or an acceptable equivalent.
(o) Water or gas pipes within bale walls shall be encased in a continuous pipe sleeve to prevent leakage within the wall. Where pipes are mounted on bale walls, they shall be isolated from the bales by a moisture barrier.
(p) Bales shall be protected from rain and other moisture infiltration at all times until protected by the roof of the structure.

18944.41. Sections 18944.30, 18944.31, 18944.33, 18944.35, and 18944.40 shall become inoperative when building standards become effective after approval by the California Building Standards Commission pursuant to Chapter 4 (commencing with Section 18935) that permit the construction of structures that use baled straw as a loadbearing or nonloadbearing material and that are safe to the public.