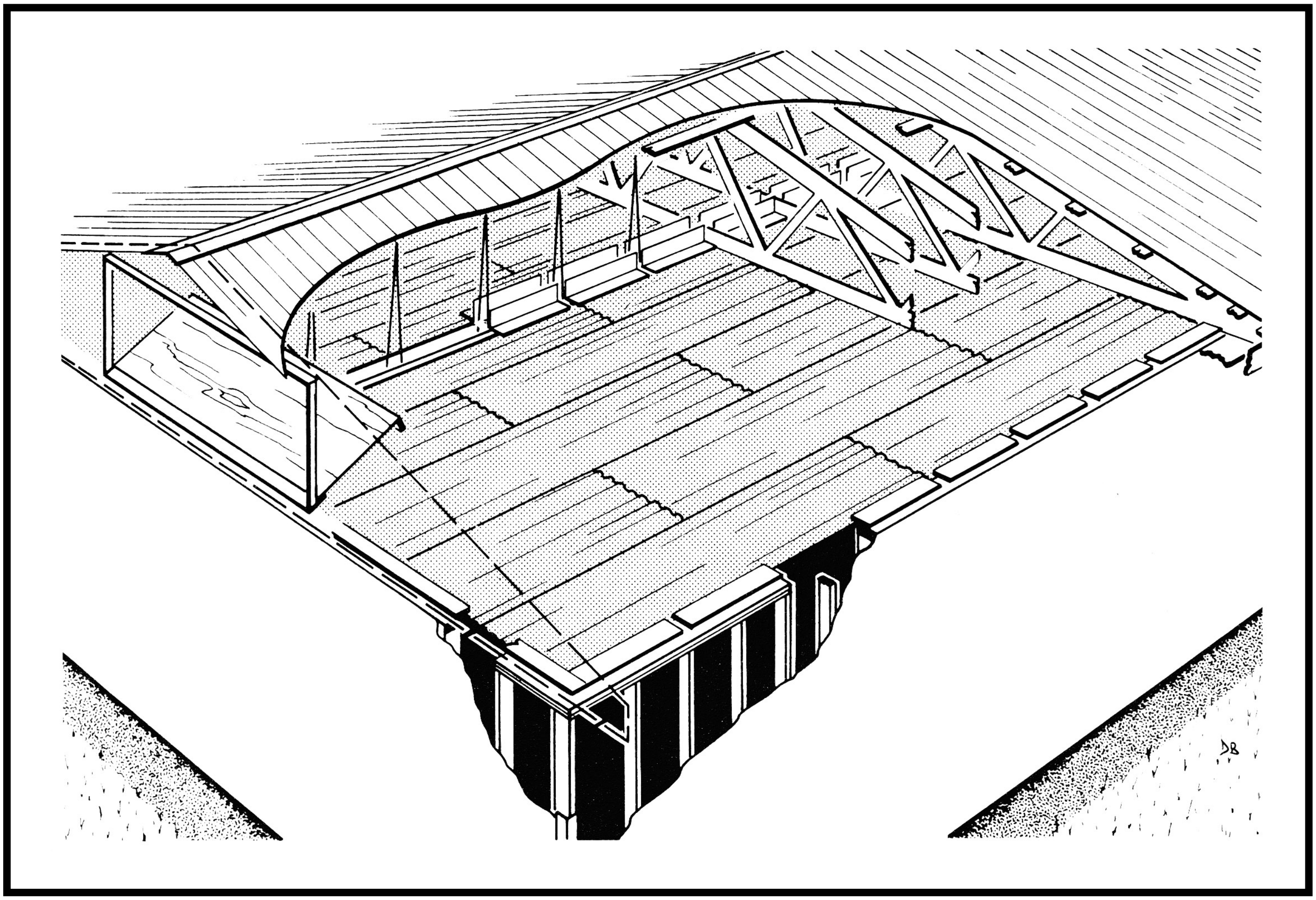
STEEL CEILING DIAPHRAGM WITH CENTER AIR INLET



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STEEL CEILING DIAPHRAGM WITH CENTER AIR INLET

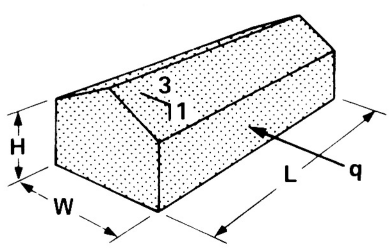
CPS
PLAN M-9373 REVISED: 82:06

Wind blowing across a typical rectangular, gable-roof farm building produces forces that tend to overturn the walls and lift the roof. The uplift forces on roofs are best resisted by secure attachment of roofing to trusses, trusses to walls, and walls to foundations; the overturning forces acting on the walls must be handled in other ways.

Where buildings are clad inside with wide panel materials such as plywood or galvanized steel, horizontal wind effects can be most economically handled by the 'diaphragm' action of the ceiling working together with the endwall and sidewall cladding. This leaflet and corresponding Plan M-9373 give details of how to use a ceiling of galvanized steel to wind-brace a stud wall farm building.

For effective diaphragm action, each panel of ceiling and wall cladding must be connected on all four edges to adjacent framing and cladding. The plan gives details for all the cladding and connections necessary to make an effective diaphragm wind bracing system, in combination with a double air inlet along the centerline of the ceiling.

DESIGN Wind pressures for locations in Canada, and the rules for determining wind forces applicable to various typical building shapes, are found in the Supplement to the National Building Code of Canada, 1980. For 'low human occupancy' farm buildings as defined in the Canadian Farm Building Code, 1977, use the 1/10 hourly wind pressures as tabled in the Supplement.



For rectangular farm buildings with stud walls and gable truss roofs as above, the maximum hourly wind pressure based on shear and fastenings of the steel ceiling is:

$$q = 2.22 \frac{SW}{HL}$$

where

- q = 1/10 hourly wind pressure, kN/m^2
- S = ceiling shear, kN/m
- W = ceiling span, m
- L = ceiling (or room) length, m
- H = stud wall height, m

The ceiling shear strength S may be limited by either the shear strength of the ceiling panels (ribbed galvanized steel) or by the fasteners. This design is based on special sheet metal roofing screws 4 x 19 mm (No. 8 x ¾ in) developed especially for rapid driving with an electric or pneumatic screwgun. Diamond-rib siding steel 0.3 mm thick (30 gauge, before galvanizing) is stiff enough to span up to 1.2 m between trusses when used as a ceiling.

Research has shown that the safe shear strength S of steel ceiling panels when screwed to the trusses at 150 mm spacing (beside each rib) and stitch-screwed together at the lapped edge ribs is:

stitch-screw spacing, mm	ceiling shear, S kN/m of span
100	3.77
150	3.0
200	2.25
300	1.5

With the center air inlet slot effectively dividing the ceiling into two halves, special steps are required to resist ceiling bending due to wind. A tension force T can develop at either edge of the ceiling slot; therefore the 38 x 89 mm wood members at the edges of the slot must be end-connected to make them act as continuous tension members for the entire length of the room. The plan shows special end splices made from 4 x 102 mm spiral nails and 0.95 mm (20 gauge) steel strapping, allowing a double shear load of 1.13 kN per nail. The tension force T (kN) can be calculated from the following formula:

$$T = \frac{0.1125\,qHL^2 - 9.64\,W + 25}{W - 0.45}$$

EXAMPLE PROBLEM For a gable-roofed farm livestock building 10.8 x 36 m with a ceiling center air inlet-slot and with stud walls 3.0 m high, check the ceiling screw spacings and the edge-beam requirements for winds at Swift Current, Saskatchewan (1/10 hourly wind pressure $q = 0.46\ kN/m^2$).

Try a steel ceiling with stitch-screws spaced at 200 mm. Therefore:

S = 2.25 kN/m, and

$$q = 2.22 \frac{SW}{HL} = \frac{2.22(2.25)(10.8)}{(3.0)(36)} = 0.50\ kN/m^2$$

This is greater than $0.46\ kN/m^2$, and therefore safe for Swift Current.

Design the inlet edge beam tension splice. Tension force at design wind is:

$$T = \frac{0.1125(0.46)(3.0)(36)^2 - 9.64(10.8) + 25}{(10.8 - 0.45)} = 11.8\ kN$$

Number of 4 x 102 mm spiral nails for each half of each tension splice is 11.8 kN/(1.13 kN/nail) = 10.4; therefore use 11 nails.

A table of allowable wind pressures and nailing requirements for buildings with stud walls 2.4 m high is included on the plan. Use the above formulas for cases not covered by the plan.

Note also that shear and bending forces developed in the diaphragm ceiling and roof must be carried to the foundation by the four walls. The ceiling-to-wall and wall-to-foundation connections as well as the walls themselves must be at least as strong as the ceiling. Walls built according to Plan M-9324, Insulated Stud Frame Walls, would be adequate as long as endwall door openings do not exceed 1/3 of the building width, W.

CENTER AIR INLET The plan also gives details of how to build a baffled center slot air inlet that can be quickly adjusted to accommodate weather changes and corresponding changes in ventilation rate. For proper function of the air inlet slots, the baffles must be held straight and true to give uniform openings (both sides and from end to end). For cool and cold weather operation the air openings should be adjusted to give at least 4 m/s velocity (corresponding to a static pressure drop of 13 Pa through the slots). For hot weather it is often better to increase the openings in relation to the exhaust fan capacity to give about 2 m/s (corresponding to 3 Pa).

For the inlet control in the attic, use 3 mm (or bigger) galvanized steel aircraft control cable, leading through 50 mm marine steerer pulleys at all cable turns, to a boat-winch located near a doorway into the room being ventilated.

Pairs of nylon cords at least 2 mm diameter and spaced at 1.2 m are the most suitable for suspending the baffle. Tying knots to adjust the cord is not satisfactory; a better way to secure and adjust the cords is to thread small Marr electrical connectors onto the steel cable to clamp the ‘control’ end of each nylon cord. Use a second Marr connector as an adjustable stopper clamped to the ‘baffle’ end of each cord, and adjust all cords to give a straight, uniform slot openings when almost closed.

Do not use cheaper cords of cotton, polypropylene or baler twine; these will wear out and develop too much friction where they bend and slide through the screw-eyes in the attic.

USING THE ATTIC AS A FRESH AIR PLENUM The center air inlet draws fresh air from the attic space above. This is a good way to provide fresh winter air unaffected by cold winds, as it enters the attic through bird-proof, snow-resistant screened slots all around the eaves. In summer, demand for ventilation air increases almost tenfold; to supply this extra air the plan shows a large tilt-in door in each gable, made from a full sheet of plywood. These doors are sloped outwards when opened; this is to stop wind-blown rain from penetrating the attic and wetting ceiling insulation. Close only the windward door during severe summer rainstorms, and close both doors during winter to exclude snow. A rope and pulley system is suggested so that the doors can be easily operated to suit changes in weather.

In hot sunny weather, a dark-painted or weathered galvanized metal roof will trap enough solar radiation to overheat the attic at least 2 to 3 ^{o}C in spite of rapid air change in the attic. Therefore, use a metal roof painted *white* (or bright aluminum). If you must use plain galvanized steel or other dark roofing, add insulation such as 12 mm fiberboard or plywood between the roofing and the roof framing. Another good alternative is *white* asphalt shingles over continuous wood decking.

In winter, warm moist air from the barn interior must not be allowed to rise through the ceiling slots and into the cold attic space. To prevent this, make sure the inlet slots are correctly adjusted (see above), and set the ventilation fan controls so that at least one fan is always exhausting from the warm room below the ceiling.