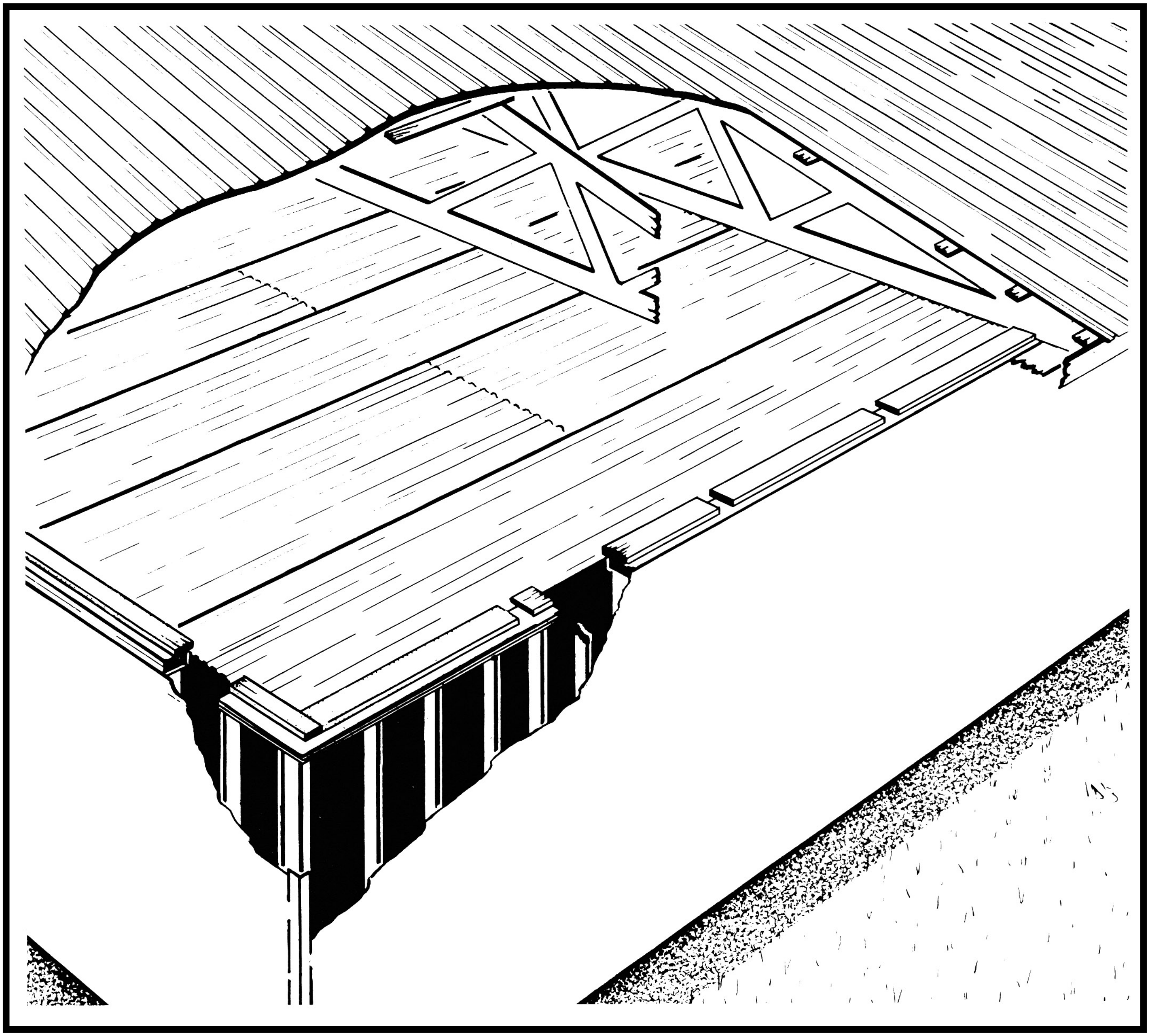
STEEL CEILING DIAPHRAGM WITH AIR INLETS BOTH SIDES



DEVELOPED BY CANADA PLAN SERVICE

305 – 15

STEEL CEILING DIAPHRAGM WITH AIR INLETS BOTH SIDES

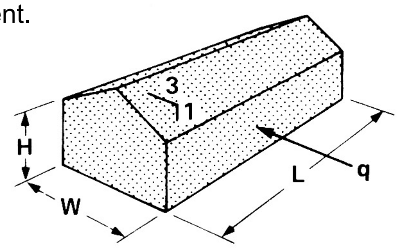
CPS
PLAN 9372 REVISED: 82:06

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 305-15 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 side air inlets along two sides of a room.

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, 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 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 buckling shear strength of the ribbed galvanized steel, or by the tearing of steel at the fasteners driven around the perimeter of each sheet. The customary steel thickness and profile for ceilings is 0.3 mm (30 gauge, before galvanizing), diamond rib, with the ribs spaced at approximately 150 mm. This profile gives good longitudinal stiffness for ceilings supported by trusses spaced at up to 1200 mm. Joints between adjacent steel panels should be lapped one full rib at the side and at least 75 mm at the ends, so order the sheets cut 4875 mm long for trusses spaced at 1200 mm (four truss spaces plus 75 mm lap).

Ceiling screws should be slightly shorted than the depth of the steel ribs, otherwise the screws will punch holes in the polyethylene vapor barrier sandwiched between steel and trusses. Using special self-drilling roofing screws 4.2 x 19 mm (No. 8 x 3/4"), the ceiling strength is:

screw spacing to trusses (beside each rib) mm	stitch-screw spacing at lapped ribs mm	ceiling shear strength S kN/m
150	150	2.71
150	200	2.25
150	300	1.50

With continuous slot side air inlets along both long walls as shown in this plan, it is not practical to use the long walls as parts of the "beam" system to resist ceiling bending. Therefore, the plan shows a special edge-beam at both long edges of the ceiling. This edge-beam must of course be constructed before the side air inlet baffles are installed. The edge-beam is made from 38 x 89 x 4800 mm wood pieces connected end-to-end for the full length of the ceiling. End connections every 4.8 m must be fastened to resist a net tension force P (in kN):

$$P = \frac{0.1125\, qHL^2 - 0.964\, W + 25}{W - 0.7}$$

The plan gives a splice detail for these end connections and a table in the plan gives the number of nails for each half connection. Use the above equation for situations not covered in the plan.

EXAMPLE PROBLEM For a gable-roofed farm building 10.8 x 30 m with stud walls 3.6 m high, find the diaphragm ceiling screw spacings and the edge-beam connection details for a location near Swift Current, Saskatchewan (1/10 hourly wind pressure q = 0.46 kN/m^2). The building will have continuous side air inlets at both long walls, which reduces the effective ceiling span W to 10.8 – 0.7 = 10.1 m.

Try stitch-screws spaced at 200 mm. This gives an allowable ceiling shear strength S = 2.25 kN/m, and the maximum allowable wind force is:

$$q = 2.22\frac{SW}{HL} = \frac{2.22(2.25)(10.1)}{(3.6)(30)} = 0.47$$

Since q = 0.47 is slightly greater than 0.46 (1/10 hourly wind pressure for Swift Current), a stitch-screw spacing of 200 mm is safe.

Design the edge-beam connections to handle that part of the ceiling bending force P not resisted by the steel, as follows:

$$P = \frac{0.1125\ qHL^2 - 9.64\ W + 25}{W - 0.7}$$

$$= \frac{.1125(0.46)(3.6)(900) - 9.64(10.8) + 25}{W - 0.7}$$

$$= 8.77\ kN$$

The plan shows a special splice detail using a galvanized steel splicing strap and 4.5 x 102 mm spiral nails loaded in double shear, giving a design load of 1.13 kN/nail. Therefore, the number of nails required in each half of the connection is:

$$\frac{P\ (kN)}{1.13\ (kN/nail)} = \frac{8.77}{1.13} = 7.66, \text{ or 8 nails}$$

A table on the plan sheet gives the design wind force q and the number of nails to resist net plate force P for various ceiling lengths L and widths W, all for the common stud wall height of 2.4 m. For other dimensions not covered by the table, calculate as above.

Note also that shear forces developed in the diaphragm ceiling must be carried to the foundations by the end 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 306-52 Insulated Stud Frame Walls, would be adequate as long as endwall door openings do not exceed 1/3 of the building width, W.

SIDE AIR INLETS The plan also gives details of how to combine the ceiling diaphragm with baffled slot air inlets that can be quickly adjusted with a boatwinch and cable system to accommodate weather changes. For proper function of the air inlet, it must be made straight and true to make a uniform slot opening. As a rule of thumb, the air opening should be adjusted to give an air velocity of at least 4 m/s in cold weather, and 2 to 3 m/s in hot weather.

For the control, use 3 mm galvanized steel cable or 5 mm plastic-covered marine steering cable; plastic rope has too much “stretch” for this application. At all cable turns use marine-quality pulleys (50 mm nylon marine steerer pulleys with stainless steel parts are best).

Nylon cord (such as heavy mason’s chalk-line) spaced 1.2 m o.c. is the most suitable for suspending the baffle. Tying knots in 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 clamp to the “baffle” end of each cord, and adjust all cords to give a straight, uniform slot opening when almost closed.