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Lett-Tak – diaphragm behaviour

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General

Lett-Tak elements in a roof structure may, through interaction with a well designed wall stability system, act as a stiffening diaphragm. A diaphragm is part of the main load bearing structure and is just as important for the stability of the building as columns, beams and bracings (see e.g. the Swedish book by Torsten Höglund: *Stabilisering genom skivverkan*, SBI Publikation 190).

Calculation of adequate fastening of the roof is part of the delivery, including fastening

- at the supports,
- in the longitudinal joints between the elements and
- between the elements and the edge beams parallel to the element span direction.

How the Lett-Tak diaphragm works

The main function of the roof elements in a diaphragm is normally the transfer of shear forces, in Lett-Tak this function is held by the plywood plate. The surrounding structure (i.e. support beams and edge beams) acts as compression and tensions flanges in the diaphragm, see figure:

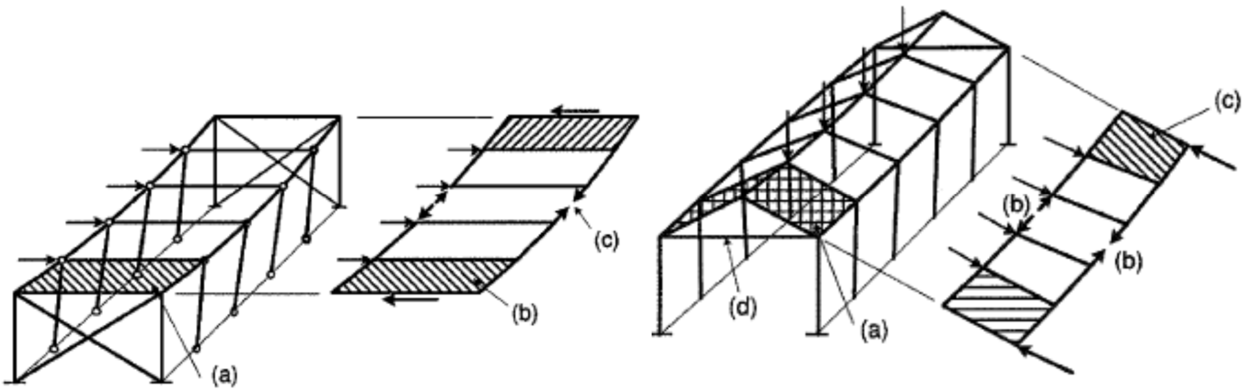

Figure 1: *Diaphragm function representative for Lett-Tak (NS-EN 1993-1-3, Figure 10.12 and 10.13)*

Edge beams including support beams therefore must be continuous and, by the responsible consultant engineer, designed to carry the compression and tension forces from the diaphragm moments.

Lett-Tak is a relatively soft diaphragm with respect to shear, and is modelled as a simply supported diaphragm during simplified calculations. Its light weight and relatively soft diaphragm behaviour may influence the overall structural behaviour of the building. The responsible consultant engineer therefore must ensure that Lett-Tak as a part of the complete stability system fulfils the intended function both with respect to force transfer and (in-plane) deformations.

Current requirements for deliveries that include Lett-Tak diaphragm function

The diaphragm design shear flow capacity is determined by the capacity of the fasteners connecting the element to the support- and edge beams and connecting elements to each other, and varies from 17 – 23 kN/m depending on element type (thinner elements have higher capacity) and support beam material. Presence of axial diaphragm forces will reduce the amount of shear flow that can be transferred by the fasteners. The overall stability system must be designed such that the design shear flow in the diaphragm nowhere exceeds this capacity.

The responsible consultant engineer must, when considering and carrying out calculations on building structural stability, take into account the material properties representative for the Lett-Tak diaphragm.

Representative material properties for Lett-Tak must form the basis for the considerations and calculations carried out by the responsible consultant engineer. The diaphragm has an equivalent in-plane shear stiffness varying between GA_{ekv}= 350 N/mm² · $t_{plywood}$ (diaphragms with mechanical fasteners that have low utilisation) to GA_{ekv}= 200 N/mm² · $t_{plywood}$ (diaphragms with highly utilised mechanical fasteners). See further the section on design for seismic loading.

The responsible consultant engineer must in time supply all assumptions and drawings needed for the diaphragm analysis. This includes:

- Drawings showing the diaphragm geometry both in plan and elevation.
- Drawings that clearly show where the forces are to be transferred to surrounding structure or to the ground.
- All relevant loads from wind as well as any stabilisation loads from lateral deflection of support beam top chord in compression.
- All loads acting on the roof, both direct and indirect through surrounding structure.
- Precise information regarding any special loads, e.g. seismic loads (separate section), is required.
- Contact data for the person(s) responsible for the stability of the building.

If the information needed to carry out the necessary static analyses of the diaphragm is not received or not clearly stated in the received information, or if the layout of the stability system is particularly complicated, Lett-Tak Systemer A/S reserve the right to charge additional costs for consultancy costs according to the time elapsed.

Conditions that may complicate the diaphragm analyses

The level of complexity and need for documentation increases considerably for diaphragms that

- are not rectangular,
- have non-standard elements (e.g. with large cut-outs , stepped shapes, variable steel profile length within elements etc.),
- have discontinuous edge beams or diaphragm flanges,
- have elements with different span directions in smaller or larger areas,
- are to transfer particular concentrated loads or
- have irregular support conditions, e.g. several smaller support in varying directions.

These factors all complicate both the analyses and documentation.

Special requirements when subject to seismic loading

1. The load details that are supplied from the customer to Lett-Tak Systemer as design basis must be established based on representative material properties for Lett-Tak. Where load effects on a building from seismic loading are to be considered by use of e.g. a finite element model, a diaphragm built up from Lett-Tak elements may be considered to have the following material properties:

Equivalent diaphragm shear stiffness[a)]:	GA_{eq}= 200 N/mm² · $t_{plywood}$
Axial stiffness parallel to span dir.[b)]:	$EA_{0,eq}$ = 100 000 N/mm
Axial stiffness normal to span dir.[c)]:	$EA_{90,eq}$ = 40 000 N/mm
Bending stiffness parallel to span dir. [d)]:	EI_0 – depends on element type (see NBI Teknisk Godkjenning 2215, tab. 4, column *Bøyestivhet ved strekk i underkant*, can be found in our home page)
Bending stiffness normal to span dir.[d)]:	EI_{90} = 0,7 · 10^6 Nmm²/mm

a) Equivalent diaphragm stiffness represents the reduced plywood in-plane stiffness taking into account the slip in the mechanical connections in the joints and at the supports. $t_{plywood}$ is the thickness of the top (plywood) flange of the Lett-Tak element (15 – 19 mm).
b) Equivalent axial stiffness parallel to span direction represents the element axial stiffness corrected for eccentric force transfer at the supports.
c) Equivalent axial stiffness normal to span direction represents the plywood axial stiffness corrected for the slip in the mechanical connections between the elements.
d) Bending stiffness represents the plywood stiffness normal to the span direction and the stiffness of the complete element parallel to the span direction.

2. For rectangular buildings with bracing or shear walls inn all four walls, the design basis can be given as total force in both axis directions at roof level. Lett-Tak will perform simplified calculations of shear flow.

   For buildings having a larger degree of complexity the design basis must be presented as calculated extreme values for design shear flow for the complete roof, e.g. as contour plots, all relevant load combinations taken into account. Further, an overview over the shear force transfer between roof and wall bracing is necessary. The maximum allowable value for shear flow given previously is valid also for seismic loading.

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