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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 suited wall stability system, provide the shear resistance function of 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. It is crucial that the diaphragm properties are considered when the global stability system is designed.

The delivery includes

- to provide diaphragm shear resistance, upwards limited to the capacity of the roof elements
- transfer of diaphragm shear forces to edge and support beams
- calculation of adequate fastening to the relevant surrounding structural elements and internally between the elements

The delivery does not include

- structural resistance for the moment part of the diaphragm (i.e. axial forces in edge and support beams as well as in additional load distributing members connected to vertical stability members that are located away from the diaphragm edges)
- transfer of diaphragm shear forces exceeding the capacity of the diaphragm
- transfer of forces exceeding the capacity of the roof and fasteners
- delivery or design of other structural elements such as e.g. additional steel beams etc.

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 provided 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 1. Consequently, they must be continuous and, by the responsible consultant engineer, designed to carry the compression and tension forces from the diaphragm moments.

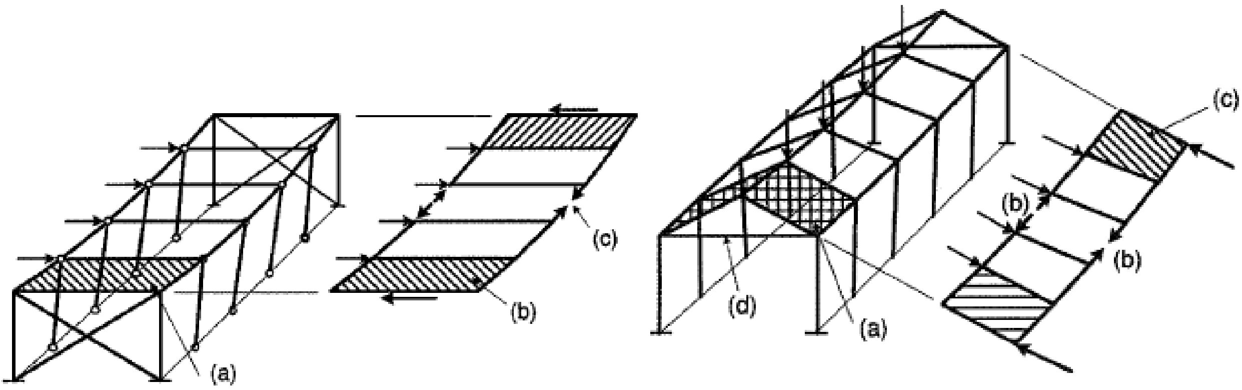

Figure 1: *Diaphragm function representative for Lett-Tak (NS-EN 1993-1-3, Figure 10.12 and 10.13)*

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, e.g. how forces are distributed within the global stability system.

Vertical stability members with a limited horizontal extension, e.g. lift shafts or concrete walls, will normally have to be extended in the diaphragm plane using beams in order to prevent exceedance of the diaphragm shear flow capacity. Such beams must be continuous. They will provide diaphragm moment resistance and must be designed by the responsible consultant engineer as a part of the global stability analysis.

The responsible consultant engineer must ensure that Lett-Tak as a part of the overall stability system fulfils the intended function both with respect to shear 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. It varies from 17 to 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, including the interface towards other structural members, nowhere exceeds this capacity.

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 showing clearly where 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 directly and indirectly through surrounding structure.
- Precise information regarding any special loads, e.g. seismic loads (separate section), is required.
- The loads must be presented with their characteristic values.
- 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 AS (LTS) 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

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 Systemer AS will perform simplified calculations of shear flow.

For buildings with a more complex stability system the shear flow will depend on the location, extent and stiffness of the other structural stability parts. In such cases the design basis must be presented as calculated extreme values for design shear flow for the complete roof, e.g. as contour plots from finite element analyses, all relevant load combinations taken into account. Further, an overview over the shear force transfer between roof and the other members in the global stability system. The maximum allowable value for shear flow given previously (17 – 23 kN/m dependent on element type) is valid also for seismic loading.

The Lett-Tak diaphragm and finite element analyses (FE-analyses)

The Lett-Tak diaphragm is a relatively soft diaphragm with respect to shear force and should not be compared to e.g. hollow core slabs. Consequently, FE-analyses of structures that include Lett-Tak elements should be carried out based on representative material properties for Lett-Tak. A diaphragm consisting of 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:

Steel profile type	EI_0 [kNm²/m]
210 mm	5 100 – 7 000
310 mm	9 500 – 13 000
360 mm	12 300 – 17 800
440 mm	24 000 – 30 000

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 the effect of slip and 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.

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