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Guidelines for the application of LAC-components in structures

Richtlinien für die Anwendung von LAC-Bauteilen in Bauwerken

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1 INTRODUCTION, SCOPE

This document provides guidelines for the application of reinforced LAC[1] components according to EN 1520 in building structures and covers the following types of structural components:

- loadbearing wall components (solid);
- roof components (solid, hollow core and multilayer);
- floor components (solid, hollow core and multilayer);
- linear components (beams and piers)

and the following types of non-structural components:

- non-loadbearing wall components (partition walls);
- cladding components.

LAC components are industrially manufactured individual parts. A combined action of these parts requires usually the aid of non LAC materials (e.g. reinforcement, metal plates, fixings, anchorages, adhesives, mortar, concrete).

The application covers aspects of:

- material properties;
- design of joints;
- design with components;
- means of anchorage or fixtures;
- construction and workmanship.

The design rules for the LAC components are defined in EN 1520, annex A (Design by calculation) and EN 1520, annex B (Design by testing).

2 BASIS OF DESIGN

2.1 FUNDAMENTAL REQUIREMENTS

The layout of the structure and the interaction between the structural members should be such as to ensure a robust and stable behaviour.

As a rule the necessary interaction between LAC components is obtained by tying the structure together using horizontal (e.g. peripheral and internal) and, for example, vertical ties.

In addition to the limit states requirements, the design (especially of connections) should consider making assembly and maintenance easy and reliable.

Fixing devices should be treated with an anti-corrosion-protection where they are exposed to an aggressive environment. The anti-corrosion-protection should be verified by an approved test method or in accordance with an EN-standard. If they are not corrosion-protected in an aggressive environment, they should be inspectable and replaceable.

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[1] LAC: Lightweight aggregate concrete with open structure; Definition see EN 1520 "Prefabricated reinforced components of lightweight aggregate concrete with open structure"

2.2 DEFINITIONS AND CLASSIFICATIONS

2.2.1 Limit states and design situations

LAC components should, apart from the requirements in the ultimate and serviceability limit states of the finished structure, withstand all relevant actions occurring in transient situations.

Typical transient design situations for LAC components are:

- manufacture, handling, storage;
- transport;
- erection.

LAC components should be designed to ensure safe erection during relevant construction situations.

2.2.2 Actions

Where relevant, the effects of dynamic actions (including seismic actions) should be taken into account.

The consideration of dynamic action effects may be necessary for slender components, in particular during transient design situations.

In the absence of a more rigorous analysis, dynamic action effect may be taken into account by multiplying the relevant static effects by an appropriate factor.

2.3 PARTIAL SAFETY FACTORS FOR MATERIALS

Unless stated otherwise the partial safety factors for materials for the persistent and transient design situations are given in the relevant Eurocodes. Lower values may be used during transportation and erection.

2.4 ANALYSIS

2.4.1 General provisions

The analysis of a structure should be based on assumptions compatible with the structural layout. The changes in the static scheme occurring at different stages of construction as well as actual detailing of the structure, should also be considered.

The analysis of structures using LAC components should account for:

- the behaviour of the individual components, in subsequent functional phases (including transient situations);

- the behaviour of the structural system with particular regard of actual deformability, strength, and fatigue resistance of connections;

- the uncertainties influencing restraints and force transmission between components, that may depend on deviations in geometry and in the positioning of bearings;

- Horizontal restraint supplied by friction due to the weight of any supported components may be used for essentially static loads if the bearing arrangement excludes the possibility of incremental accumulation of irreversible slides caused by uneven behaviour under alternate actions (as cyclic thermal effect on the contact edges of simply supported components).

In any case the effects of the horizontal actions are to be considered in the design calculations with respect to the resistance of the structure and the integrity of the joint, providing, if needed, proper bearing devices.

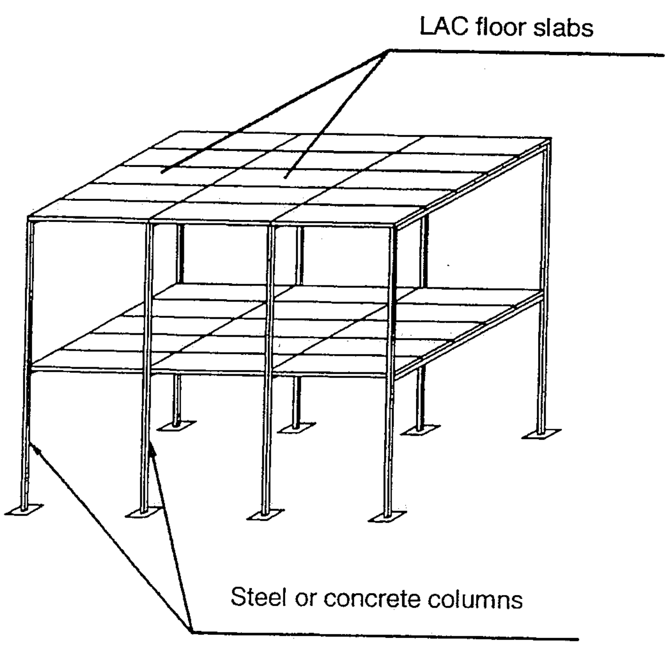
2.4.2 Idealisation of the structure

Using LAC components the following structural systems are commonly used to ensure the overall stability. These and other systems may act alone or together:

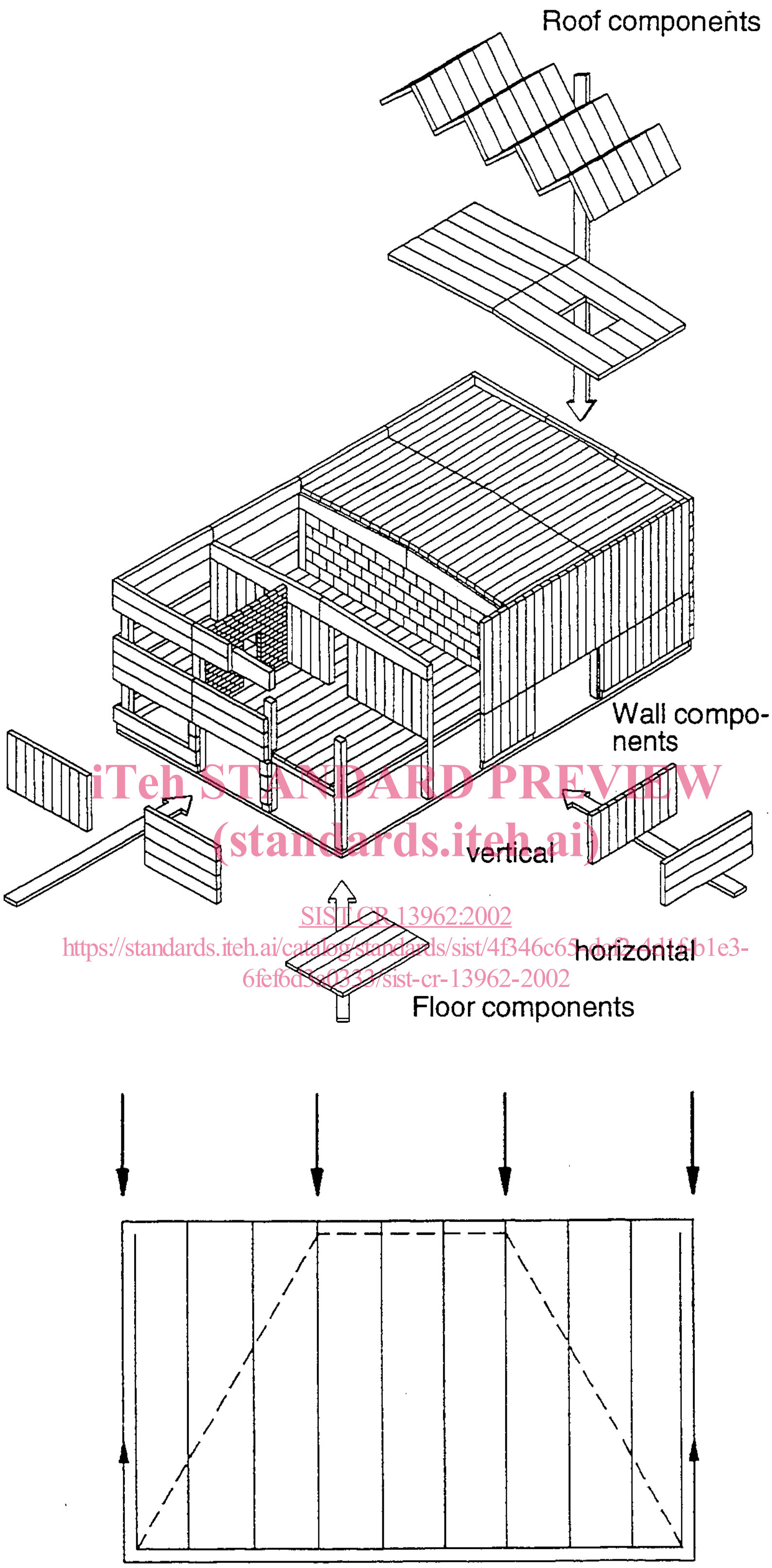
a) Framed structure (figure 1a), composed of LAC floor, roof or wall components and beams and columns of other materials. They may be designed either as cantilevering continuous columns (mainly for low rise buildings) or partly or wholly as a continuous framework. The framed structure is usually a concrete, steel or timber structure.

b) Loadbearing wall or panel structures (figure 1b) which are composed entirely or partly of LAC components. These are characterised by a stiff in-plane behaviour (loadbearing walls) and hinged connections perpendicular to the plane direction (cross slabs). Bearing wall structures may be stiffened in lateral direction by means of precast lateral walls or precast portal frames.

c) Floor or roof diaphragms (figure 1c). Prefabricated floor and roof systems are often used in structures to transfer the horizontal forces, acting on the structure, towards the braced vertical components (cantilevered columns, central cores or shear walls). The floor or roof may be designed as a stiff member able to transfer and to distribute horizontal forces.



a)



b)

c)

Figure 1 (continued): Different types of structures

2.4.3 Structural analysis of slabs and floors using LAC components

The main structural requirements of floor are vertical loadbearing capacity, transverse load distribution and diaphragm distribution of horizontal actions.

The prefabricated LAC components are normally designed as simply supported structures.

In case of higher life loads, with the possibility of punching or of in-plane-load situations, the application of topping concrete may be necessary. For the distribution of floor loads there should in this situation be a bond between the topping concrete and the LAC-components (e.g. by anchorage of the structural reinforcement of the topping concrete with the reinforcement in the joints between the LAC components; see also clause 5.1.5).

Longitudinal joints between LAC components can be designed to transfer the in-plane and out-of-plane shear forces from one component to the other.

The in-plane shear forces can be transferred by distribution along joint interfaces (by means of concrete or mortar) or by concentrated shear connectors. In-plane shear may also be transmitted by relying on the roughness of the surfaces with appropriate shear design according to section 4.

Out-of-plane shear should be transmitted by keys or grooves. This restraint may produce opening forces which can be transferred by means of ties, between components or at their ends in their supports.

Possible combination of horizontal and vertical shear should be considered in the design of the connections.

The transfer of both vertical and horizontal shear forces can be realised in different ways by:

- concreted or grouted joints;
- thin layer mortar joints or glued joints;
- welded or bolted connections;
- reinforced topping on the floor.

In the first case the joint faces of the LAC components should be shaped appropriately in order to make shear transfer possible by friction or interlocking effects. Minimum joint width and minimum joint opening in the top of the floor should be designed considering the actual type of grout and grouting method.

The strength of the joint fill, the quality of the fill, the size of the joint and the joint filling operation may affect the shear capacity and should be considered in the design and detailing.

Transverse load distribution between adjacent floor components under action of live loads across the joints should be ensured by appropriate shear transferring connections. The shear capacity should be determined by calculation or by testing.

The distribution of concentrated loads can be determined either by means of analytical methods or on the basis of test results.

When the connections are not designed for bending moments, they may be assumed to act as shear transferring hinges only.

Floors and roofs made of LAC components can act as diaphragms for transferring horizontal forces to the braced vertical components when the following conditions are satisfied:

- The completed floor or roof is analysed under realistic assumptions on the deformability of the bracing members, the LAC components and the connections.
- The components are connected and the completed floor or roof is provided with a tying system so that lateral force transfer is possible by arch, truss or vierendeel action.
- The stiffening (e.g. tying) system is able to resist all tensile forces to be derived from the in-plane actions (bending, shear, tension).
- Corners and openings in the diaphragm should be properly detailed so that the continuity of the tying system is not disturbed.
- Force transfer capacity is provided to the bracing vertical components in order to realise the necessary interaction. Possible stress concentrations at the joints should be considered in detailing.

2.4.4 Structural analysis for bracing walls

The structural requirements on overall integrity and robustness of the structure should be met by tying the wall system together by tie reinforcement at each floor intersection or by similar arrangements and, where necessary, by vertical ties.

Walls and framed systems are stiffened at each floor level by floors acting as horizontal diaphragms.

The diaphragm effect can be ensured by:

- individual shear connectors;
- grouted joints;
- peripheral ties;
- other suitable means.

The walls may support the floor directly or the walls may be in-fill panels between columns and beams. In both cases the stability of the structure against horizontal actions is ensured by the structural response of the wall-floor system.

2.4.5 Movements joints

Changes in the temperature of the structure or the moisture content in the LAC will lead to strains in the LAC structure.

The shrinkage strain of the component may be estimated on the basis of EN 1520.

The thermal strain can be estimated on the basis of the declared thermal expansion factor and the expected temperature variation at the structures location

The thermal strain and the shrinkage strains will lead to tensile stresses in the components and the joints when the other structural parts restrict the movement of the components.

All movement joints should be assumed to be cracked in the structural design.

The tensile stresses in the component and in the joints can be reduced by using movement joints at suitable positions.

The maximum distance between the movement joints will depend on the shrinkage of the LAC component and on the environment in which the LAC component is to be used.

3 MATERIAL PROPERTIES

3.1 LAC

The material properties for the design of LAC components are defined in EN 1520.

3.2 CONCRETE

Strength classes of concrete are defined in EN 206. The maximum strength class to be taken into account for topping concrete and filling concrete for use in joints is C 30/37.

3.3 MORTAR

The minimum strength of mortar used in joints for structural purposes should not be less than 10 N/mm^2.

Bond of mortar should be assured by using a compatible mix.

Repair mortar should be used in accordance with the suppliers recommendations.

3.4 REINFORCEMENT OF JOINTS

Structural reinforcement should be in accordance with the provisions of EN.

Sufficient protection against corrosion of the reinforcement in the joints should be provided by adequate mortar or concrete cover or by corrosion protective treatment.

3.5 CONNECTION MATERIALS

3.5.1 General

It is distinguished between:

- connections between LAC-components;
- connections for fixing of LAC-components to the structure (for transmission of tensile and shear forces).

3.5.2 Fundamental requirements

Connection materials should be stable and durable for the defined lifetime of the construction. Chemical and physical compatibility should be checked. If necessary, materials should be protected against chemical and physical influences, e.g. fire.

3.5.3 Support requirements

The strength and deformation performances of the bearings should be in accordance with the design criteria.

3.5.4 Metal fastenings

This clause is applicable to permanent metal fastenings which are used for LAC cladding components and which are not so enclosed as to exclude exposure to air when the components have been erected.

Metals to be used for fastenings should belong to one of the following categories:

(i) If exposed to air, but not inspectable or replaceable

- austenitic stainless steels or steel with durable corrosion protection;

(ii) If exposed to air, but inspectable or replaceable

- hot dip galvanised steels, or
- galvanised or plated, screw threaded parts protected with two layers of epoxy paint,

or

- non-ferro-materials (for example aluminium) and ferro-materials with corrosion protection if required.

If the material is to be welded, annealed or hot-formed, special precautions should be taken with regard to the most suitable material.

4 DESIGN OF JOINTS

4.1 GENERAL

Connections should be designed to resist all action effects implicit in the assumptions made in analysing the structure as a whole and in designing the individual members to be joined. The design should ensure that:

- the joint is able to accommodate the relative displacements needed to mobilise its resistance;
- the joint is able to resist all action-effects resulting from the assumptions made in the analysis of the structures as a whole, as well as those resulting from the analysis of individual members;
- the strength and deformability of the joints assure a robust and stable behaviour of the structure as a whole.