FEDERATION EUROPEENNE DE LA MANUTENTION
● Product Group Intralogistic Systems
● Product Group Racking & Shelving

FEM
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Storage systems with rail dependent storage and retrieval equipment – Interfaces

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Index

		Page
	Introduction and Aims	2
1	Scope	4
2	Definitions	4
3	Documents referred to	6
4	CE marking of the system (Declaration of conformity)	8
5	Concrete floor slab	8
6	Dynamic effects on components of the storage system	18
7	Floor rail, End buffer and Upper guide rail	22
8	Vibration of the rack	26
9	Unit load (Specified load)	27
10	Rack structure	31
11	Fire safety	43
12	Operation conditions	44
ANNEX A:	Example of load combinations with quasi-static forces…	46
ANNEX B:	Guidance for the determination of the design number of load cycles…	53
ANNEX C:	Overview of seismic design data	54
ANNEX D:	Contribution of UL weights in a rack compartment…	55

Continued page .2. to 63

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For references see end of document

Introduction and Aims

This document shall be a guideline for all parties involved in the provision of the storage system (e.g. customer, system designer, warehouse designer, logistic consultants, suppliers of sub-systems like S/R Machines, conveyor systems and racking). It informs about general properties, interfaces, behaviour under load and time dependant effects like creep that may be relevant for the planning, contracting and final performance of material handling systems It does not claim to be complete.

The persons or companies responsible for the total design of a warehouse has to consider a multiplicity of possibilities, limitations and requirements of the various combinations of elements. Each potential component has its specific behaviour, advantages / limitations and inter-component interfaces.
It is important to know which end conditions and data to be specified are relevant. The intention is that the final system should:

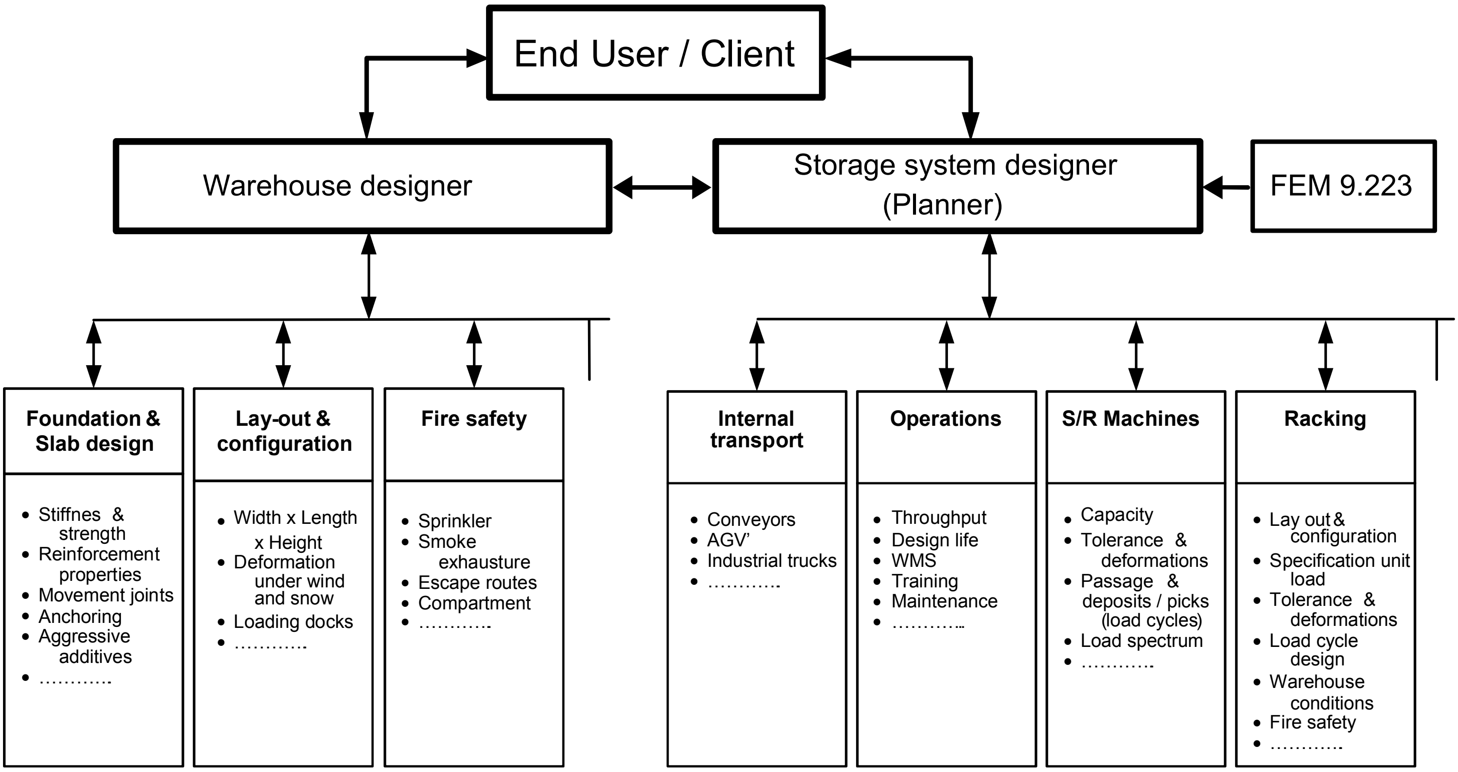
- be within budget;
- be within the time schedule agreed;
- comply with rules and legislation;
- show a logistic performance as originally intended.

This is a complex process in which contractual responsibility for the building, building services and storage system may be split between a number of parties. It is an interactive process where end-user, designer of the warehouse and the designer of the storage system (system designer) are interfacing (see Flow Chart).
The design of the storage system needs to consider the properties of the UL s relevant for transport, conveying, storage and retrieval. This along with fire safety, environmental conditions, specification of the warehouse-building, required capacity, throughput etc. will determine the choice of warehouse management system (WMS), conveyer, S/R Machine and storage equipment.
Once completed there will be test runs to demonstrate compliance.

This code is intended to provide sufficient information on the issues involved in the design of the storage system so that timely decisions can be taken, thereby reducing the risk of conflicts during the process of realisation.
One should realise that the logistic situation in most warehouses today has been changed over the last decade:

- 24h economy;
- Much higher running speeds;
- Higher accelerations and decelerations;
- More complex systems.

The overall intention of this code is to help in removing uncertainties between the contracting parties and to add more detailed information to FEM 9.223.
This FEM Code of Practice is prepared by a joint Working Group of the FEM Product Group Intralogistic Systems (IS) and the FEM Product Group Racking and Shelving (R&S).



LOGISTIC WAREHOUSE DESIGN INFORMATION FLOW
(It shows a typical example, but responsibilities can change / be spread and it does not give contractual relationships)

1 Scope

This Code of Practice gives in addition to EN 15629 guidelines and background information about the specification of interfaces between sub-systems of rail dependent storage & retrieval systems and is relevant for the functionality and safe operation of the system.
For interfaces with regard to “tolerances, deformations and clearances” refer to EN 15620 / FEM 9.831 – Part 1 and FEM 9.832.

This Code of Practice specifies the position, obligations and responsibilities of parties involved.

There are storage systems like e.g. small part shuttle storage systems for which this code is not specifically meant for. However principles and approaches given in this Code might give guidance for specifying the interfaces of such storage systems.

NOTE: Also for industrial truck operated storage systems certain subjects considered in this Code might give useful guidance, additional to EN 15629.

2 Definitions

For terms and definitions of steel static storage systems in general: see EN 15878. Some which are important for this Code are repeated.

Accidental action (EN 1990)
action, usually of short duration but of significant magnitude, that is un likely to occur on a given structure during the design working life.

NOTE: In practical terms, a load case with an accidental action is analysed with a load factor of 1.0 and with the possibility of residual deformations after unloading.

Accidental design situation (EN 1990)
design situation involving exceptional conditions of the structure or its exposure, including fire, explosion, impact on local failure or an earth quake

Accidental load
is an example of an accidental action.

Buffer back stop
a component used as an aid to deposit a UL in the correct position in the racking

Design working life (EN 1990)
assumed period for which a structure or part of it is to be used for its intended purpose with anticipated maintenance but without major repair being necessary.

Dynamic action (EN 1990)
action that causes significant acceleration of the structure or structural members.

Load cycle / Loading event (EN 1993 -1-9)
a defined loading sequence applied to the structure and giving rise to a stress history, which is normally repeated a defined number of times in the life of the structure.

Load handling device (LHD)
part of the machine for carrying the specified loads.

Movement joint
a structural joint in a concrete slab which allows a slab part to shrink (sometimes also to expand) or to allow movements due to ground settlements or earthquakes, independently from adjacent parts.

Pick up and deposit (P&D) station
structure in an operating aisle used as an interface between different types of mechanical handling equipment.

System designer (SD) / Planner (FEM 9.223)
the person or institution responsible for the overall design and functionality of the system, this can be the logistic consultant or the general contractor or the client himself and shall be defined on a project by project basis.

NOTE: For more information and responsibilities see FEM 9.223.

Quasi – rigid
not fully rigid, but allowed to be considered as fully rigid.

Quasi - static action (EN 1990)
dynamic action represented by an equivalent static action (action that does not cause significant acceleration of the structure or structural members) in a static model.

NOTE: Inertia effects due to e.g. accelerating or turning, effects caused by imperfections like tolerances and / or deformations of the running surface and such are accounted for, e.g. by a multiplication factor β_{dyn}.

Safety back stop (EN 15629)
component used to prevent unintentional UL movement or accidental collision of a moving object with other ULs or equipment when the UL is placed or removed from its storage location.

Type (a) safety device, which protects against unintentional load movement within the racking and prevents ULs from protruding into or falling into an operating aisle or falling into an area accessible to people, when a UL is placed in or removed from the storage compartment.

Type (b) safety device to prevent accidental damage, usually placed in the back of a storage location, by preventing the accidental collision of a UL (e.g. pallet with load) or of the telescopic fork tips with other equipment, such as sprinklers, when a .UL is placed in the storage compartment.

NOTE 1: Type (a) is the type where EN 528 speaks of (physical) back stop

NOTE 2: In this Code, as well as in FEM 9.842 - 1/ 10.2.11, the term “safety back stop” is used instead of “back stop” to make a difference with a “buffer back stop”.

NOTE 3: The horizontal clearance between a UL adjacent to a safety backstop should be sufficient to prevent any colliding during daily depositing operations. See also EN 528: 2008, Clause. 5.10.1.

Serviceability limit state (SLS)
state that correspond to conditions beyond which specified service requirements for a structure or structural member, such as beam deflection or horizontal sway deformation, are no longer met.

Specified load
load with specified characteristics (e.g. mass, dimensions with their tolerances, pallet or container, quality, packaging, etc.) which the machine has been designed to carry and the storage system has been designed to operate.

Storage and retrieval machine (S/R Machine)
machines, restricted to the rails on which they travel and handling ULs for the storage & retrieval in respectively from racking or shelving equipment.

Ultimate limit state (ULS)
state that is associated with collapse or with other similar forms of structural failure

Unit load (UL)
see specified load

Warehouse management system (WMS)

3 Documents referred to

The following referenced documents are indispensible for the application of this document. For dated references only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13857	Safety of machinery – Safety distances to prevent hazard zones being reached by upper and lower limbs
EN ISO 12100-2	Safety of machinery – Basic concepts, general principles for design – part 2 Technical principles
EN ISO 14122-2	Safety of machinery – Permanent means of access to machinery – Part 2: Working platforms and walkways
EN 528	Rail dependent storage and retrieval equipment – Safety requirements.
EN 1990	Eurocode – Basis of structural design
EN 1090-2	Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures
EN 1993-1-9	Design of steel structures – Fatigue strength of steel structures
EN 15512	Steel static storage systems – Adjustable pallet racking – Principles for structural design.
EN 15620	Steel static storage systems – Adjustable pallet racking – Tolerances, deformations and clearances.
EN 15629	Steel static storage systems – The specification of storage systems
EN 15635	Steel static storage systems – The application and maintenance of storage equipment
EN 15878	Steel static storage systems – Terms and definitions
ETAG No 001	Guideline for European Technical Approval of Metal Anchors for Use in Concrete
FEM 9.223	Basic data and criteria for the construction of automated high bay warehouses with distribution systems

FEM 9.831-1 Basis of calculations for storage and retrieval machines – Tolerances, deformations and clearances in the storage system – Part.1: General, Single and Double deep pallet racking

FEM 9.832 Basis of calculations for storage and retrieval machines – Tolerances, deformation and clearances in automatic small parts warehouses (not silo design)

FEM 9.842-1
FEM 10.2.11-1 Rail dependent storage and retrieval systems - Consideration of kinetic energy action due to a faulty operation in compliance with EN 528 – Part 1: General, single and double deep pallet racking.

FEM 10.2.08 Recommendations for the design of static steel pallet racks under seismic conditions

FEM 10.2.13 Principles for the fatigue design of crane racking components – Best practice (*to be published in 2011/2012)*

4 CE marking of the system (Declaration of conformity)

It shall be agreed in the contracting stage between the system designer, client and / or the end user, who is responsible for the "declaration of conformity" for the system.
The system is the combination of several sub-systems such as storage systems, conveyor systems and involved parts of them, which shall be determined and contractually agreed in the scope of supply.

5 Concrete floor slab

5.1 General

(1)
The foundation on which the S/R Machines are supported and which has to carry the concentrated loads from the storage equipment (racking), shall be sufficiently stiff and strong to ensure operational safety and structural safety of all components of the storage system. The foundation consists of:
- a subsoil, with improved load bearing properties as necessary;
- piling, when necessary ;concrete floor slab.

NOTE: In general a non-concrete floor structure will not be sufficiently stiff and strong.

(2)
The structural behaviour of a concrete floor slab under load depends upon a number of factors:
- the concrete grade;
- the support conditions;
- the loading conditions (e.g. magnitude; uniformly distributed or concentrated; pattern loading; load duration);
- the reinforcement;
- the possible presence of movement joints.

(3)
The floor slab may be considered to be quasi-rigid and the floor slab deflections may be neglected if it satisfies the requirements of EN15620 / FEM 9.831 Part 1 or FEM 9.832 (as appropriate). If the floor slab is not quasi-rigid then slab deflections must be taken into account as given in 5.3.6.

NOTE 1: The deflection requirements specified in EN15620/FEM 9.831 Part 1 and FEM 9.832 are demanding. Accurate prediction of the behaviour (deflection) of the concrete slab and of the supporting soil is difficult and inexact and the client should expect that higher cost will ensue if contractual guarantees are demanded.

NOTE 2: It is important that a sufficient site/soil investigation is carried out in the planning stage of the project, particularly if a high variation in soil properties might be expected.

5.2 Support conditions

(1)
The support condition affects the deformation of the floor slab under load.
The following two principle alternatives can be distinguished:

a. Ground bearing: a floor slab directly supported by the sub soil.
b. Suspended floor: a floor slab not directly and not continuously supported by the subsoil but supported by structural elements such as piles, beams, columns.

(2)
For type (a) slabs the geotechnical engineer and slab designer shall at least consider the following:

- Uneven settlements due to possible inhomogeneous subsoil properties over the floor slab area.
  - The difference in settlements of the soil that is not loaded compared to the soil beneath the slab that is loaded (see Figure 1).
- Spreading effect of concentrated rack loads due to the relative stiffness of the slab to sub soil.
  - The non-linear relationship of settlements with time.

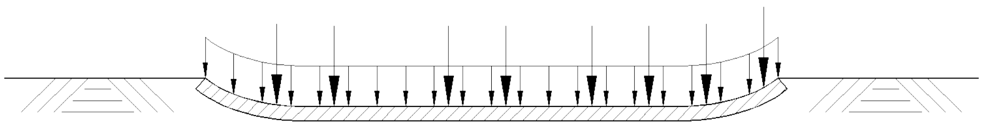


Figure 1: Example of the deformation of a ground bearing floor slab, due to stiffening effects of the surrounding sub soil.

(3)
For type (b) slabs the geotechnical engineer and floor slab designer shall at least consider the following:

- Uneven settlements of the piling or columns due to possible inhomogeneous sub soil properties over the pile positions.
  - Bending of the beams supporting the slab, if any.
  - Bending of the floor slab itself (see Figure 2).

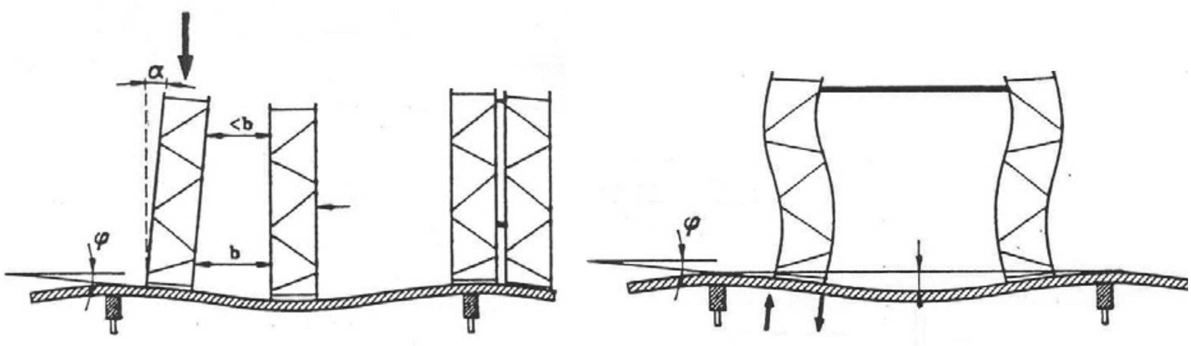


Figure 2: In case of a suspended floor slab, the floor deformations might not be in accordance with the "quasi-rigid" requirements

5.3 Loading conditions

5.3.1 Rack loads, in house structure

(1)
The supplier of the rack structure shall specify to the SD the rack loads on the floor slab in the serviceability limit state (SLS) as well as in the ultimate limit state (ULS) which is at factored loads, according to EN 15512. The rated (considering the different factors for dead load and variable loads) partial safety factor used in the ULS shall be specified. The way of presentation shall be sufficiently differentiated for consideration by the concrete designer (see e.g. Figure 3).

The rack supplier shall indicate when these loads are still not final.

NOTE : The rack loads have to be specified in the SLS as well in the ULS because in general there will be a non linear behaviour with increasing loads acting on the rack (second order effect). In particular relevant for the punching shear check at concentrated upright loads.

(2)
Unless advised otherwise the rack supplier shall specify the rack loads assuming a quasi-rigid floor slab (see 5.1 (3) and 5.3.6).

(3)
The concentrated loads at the rack uprights and at the anchorages of bracing systems shall be determined from the self weight and all variable actions concerned.
Examples of variable actions to be considered are:

- Value(s) for the weight of the ULs to be used in the design.
- Horizontal guide forces in the cross aisle (Z-) direction and traction drive (moving) forces in down aisle (X-) direction (if any) at the upper guide rail.
- Loads on order picking floors supported by the racking which may include live load reductions in accordance with National standards and not being in conflict with actual use during the design life (reference to EN 15512) :
  - local maximum (uniformly distributed load and/or loads from mechanical handling equipment);
  - uniformly distributed load over the entre rack aisle length;
  - effect of more floor levels involved, if any.
- Loads from installations attached to the racking, e.g. sprinkler.
- Horizontal force on a safety back stop, if any.
- Horizontal force on an end buffer connected to an upper guide rail or rack supported “floor” rail, if any.
- Seismic actions, if any. Reference to FEM 10.2.08.

For the specification of the concentrated loads, see 5.3.2 (3).

(4)
The rack supplier shall specify the additional loading due to the installation activity (e.g. wheel loads of lorries or special equipment), if any.

(5)
The end user in cooperation with the SD shall communicate with the floor slab designer and rack designer whether or not pattern loading (due to different maximum pallet loads for certain storage areas, e.g. logistic ABC – Zones) over the rack volume has to be considered and how it is defined.