FEM RACKING AND SHELVING PRODUCT GROUP

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To inform all parties involved in storage about the latest developments and about their moral and legal responsibilities and how to comply with these.

LATEST DEVELOPMENTS IN THE HARMONIZATION OF THE DESIGN AND USE OF STORAGE EQUIPMENT

Storage equipment, like pallet racking, drive-in racking, single and multi-tier shelving and mezzanines, are produced all over Europe. The market does not know national borders. The warehouses in which they are built have grown bigger and higher. Racking structures are realized from appr.6 m to 25 m and as clad racks up to appr. 45 m. They have become serious load bearing structures. Harmonized and standardized design rules are therefore essential. A pan-European approach has been initiated and realized by the European Racking Federation / FEM-Product Group Racking & Shelving (ERF/FEM R&S). It is not only about storage equipment, but the equipment interfacing with its logistic environment : storage systems!

In the last years a specific activity has been developed by ERF/FEM R&S in European CEN environment.CEN/TC 344 "Steel Static Storage Systems" started its work in 2002 with 4 work items: "Pallet Racking - Design Principles", "Pallet Racking – Tolerances, Deformations and Clearances", "Storage Equipment - Project Specification", "Storage Equipment - Application and Maintenance" . With as first drafts the FEM Code's already published in these fields. Currently for each of the work items EN Standards have been published officially.

Kees Tilburgs, Technical Chairman ERF/FEM R&S
Stefano Calzolari, Chairman CEN/TC 344

What is FEM and ERF / FEM - R&S

The Fédération Européenne de la Manutention (FEM) is the European Federation of Materials Handling Associations and was formed in 1953 (www.fem/eur.com).
FEM today has 13 National Associations as members in the EU, Switzerland and Turkey and is the largest Mechanical Engineering Sector in the EU.
FEM organizes its work in the following Product Groups :

Industrial Trucks
Cranes & Lifting Equipment
Mobile Elevating Equipment
Elevating Equipment
Conveyors
Intralogistics
Racking & Shelving

The FEM Product Group "Racking & Shelving" was established in 1970 as Section X of FEM and today operates as the European Racking Federation (ERF). ERF's philosophy and that of its member Associations and companies has always been to promote awareness of :

- the complexity of Racking and Shelving structures with regard to the mechanical properties of its typical components as well as its overall global behaviour ;
- the interfacing safety responsibilities of suppliers, users and operators (Figure 1) of Racking and Shelving equipment : one has to work between in general very heavy unit loads stored and retrieved at high working heights (upper most storage level at quite some meters above the operators heads);
- the need for harmonized design standards for Racking and Shelving structures. Only in that case there can be a level playing field in the context of the need to be cost-effective in a highly competitive market.

Fig. 1 Pallet rack operated by a reach truck (up to appr. 12,5 m)

Fig. 2 Drive-in racking operated by a reach truck with side shift

Initiatiative by ERF / FEM R&S

A first attempt to have a European Code of Practice in place was already in the beginning of the eighties as a main goal of a research program funded by the European Community. Reference to [1]. Unfortunately this first milestone was not adopted by the national associations of racking and shelving manufacturers at that time. The time was not yet ripe for a European approach. This changed in the nineties because the market rapidly was “europëising” and “globalizing”.

Therefore with regard to the above described philosophy, ERF/FEM R&S decided to fund the development of appropriate FEM Codes of Practice over many years culminating in 2000 with the publication of (see also Table 1) :

FEM 10.2.02 – Design of Static Steel Pallet Racking
FEM 10.2.03 – Specifiers Guidelines
FEM 10.2.04 – Users Code
FEM 10.2.05 – Guidelines for working safely with lift trucks in pallet racking installations (Draft)
FEM 10.2.06 – Design of Static Steel Shelving
FEM 10.3.01 – Pallet racking : Tolerances, Deformations and Clearances.

Furthermore having achieved this real milestone within the industry, ERF/FEM R&S then decided it would be appropriate to convert these Manufacturers (Industry) Code's of Practice into formal European EN Standards and accordingly funded the creation of CEN TC 344 "Steel Static Storage Systems" in 2002 to undertake such work. CEN stands for "Comité Européen de Normalisation". It was felt such a development would add credibility to the industry's basic philosophy to promote safety in design and use as well as the structural engineering complexity of Racking and Shelving structures.

The main difference between a Standard and a Manufacturers Code is the involvement of in principle all parties involved. In case of storage systems for instance :

- manufacturers;
- users and their consultants;
- governmental bodies, like the office for health and safety and building authorities;
- science (universities, special R&D institutes);
- contractors.

What is so special about Racking and Shelving structures?

The main purpose to have storage equipment like Racking and Shelving is to have an optimal use of the warehouse volume, for those many situations where the stored unit loads have to be approached for picking activities as individual units. Simple and cheap block stacking of e.g. pallets or containers is in those cases not appropriate.

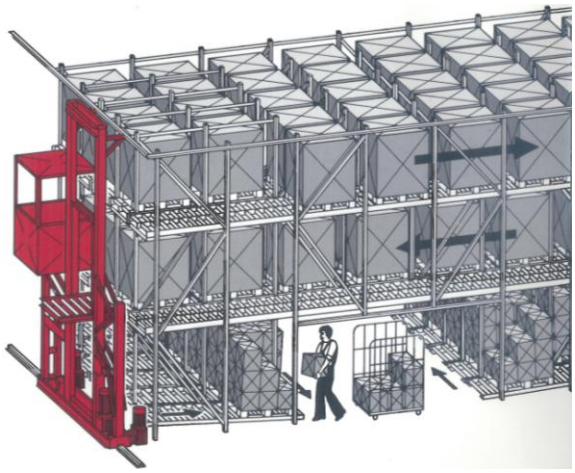


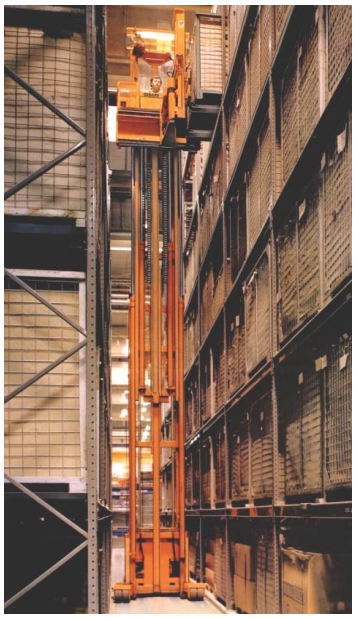
Fig. 3 Schematic view of an advanced dynamic storage

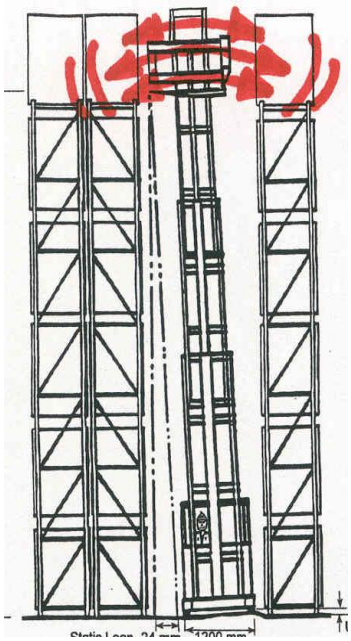
Fig. 4 Example of a cantilever racking

There are a variety of racking types. The most important are:
- Adjustable pallet racking (Figure 1), and variations like double deep racking, dynamic storage (Figure 3) and shuttle racking.
- Drive-in racking (Figure 2).
- Cantilever racking (Figure 4).

All such racking is intended for the storage of relatively large and heavy unit loads and is therefore operated by using mechanical handling equipment (MHE) like reach trucks, very-narrow aisle (VNA) trucks (Figure 5) or stacker cranes (Figure 6).
The adjustable pallet racking (APR) is the most common one, with an increasing storage height of appr. 6 m to appr. 9 m today. However with “high lifting” reach trucks till appr. 12,5 m (see Figure 1), with VNA trucks to operate till appr. 15 m and up to appr. 30 m (free standing) and up to appr. 45 m (clad rack structure) when operated by fully automated stacker cranes.
Shelving systems are in general manually operated. Single tier systems (without any flooring) but also regularly used as a multi-tier system (see Figure 7), with heights up to 10 m (4 floor levels are present).

Racking and Shelving are serious load bearing structures, in general relatively much more heavily loaded than for instance the floors of office buildings. Safe structural design and a correct modeling of the actual physical behavior of such extraordinary steel structures with non-traditional components for determining reliably the load bearing capacity, is therefore of the utmost importance. As well as safe operation conditions which do allow to neglect potential collisions by MHE in the structural design (see below: “Racking is not lift truck – proof”).





(a) (b)

Fig. 5 Pallet rack operated by a Very Narrow Aisle truck

a. "Man-up" operation
b. Dynamic effects when simultaneously driving and lifting

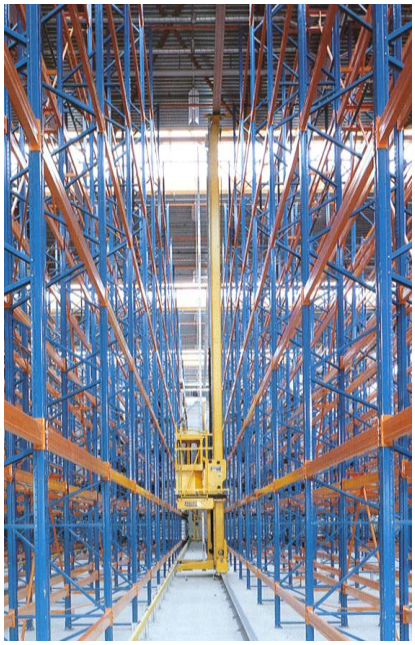


Fig. 6 Pallet rack operated by a stacker crane

Most racking and shelving have in common that they have to be adjustable to enable easy change of configuration in case the dimensions and/or weights of the unit loads are changing during the operational life. Or in case a heavier reach truck is needed with a larger 90^0 degree turning radius (see Figure 8 and [2] + [3]). And they have to be cost-effective in the logistic chain as well. This has resulted in a special type of steel structure with specific components and mechanical behavior, different from the traditional hot rolled sections and beam to column connections, such as :

- Cold formed sections and components : thin gauged and in general open, with local, distortional and torsional buckling behavior (see Figures 9 and 10).
- Continuous perforated columns, which are called “uprights”.
- Non-standard connections such as “hooked-in” or “clipped-in”, with semi-rigid behavior (see Figure 11).

It is evident from the above that the structural design principles and methods as they have been developed for the traditional steel structures, are not giving all the answers for the designers of Racking and Shelving. Therefore in addition to for instance the structural Eurocode’s (e.g. [4] – [6]), additional design rules needed to be developed, partly different for each type of racking. ERF/FEM R&S has taken the initiative needed (see e.g. Tables 1 and 2).

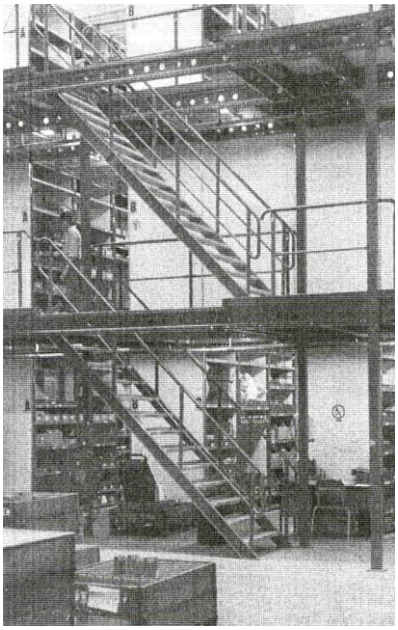


Fig. 7 A multi-tier shelving system

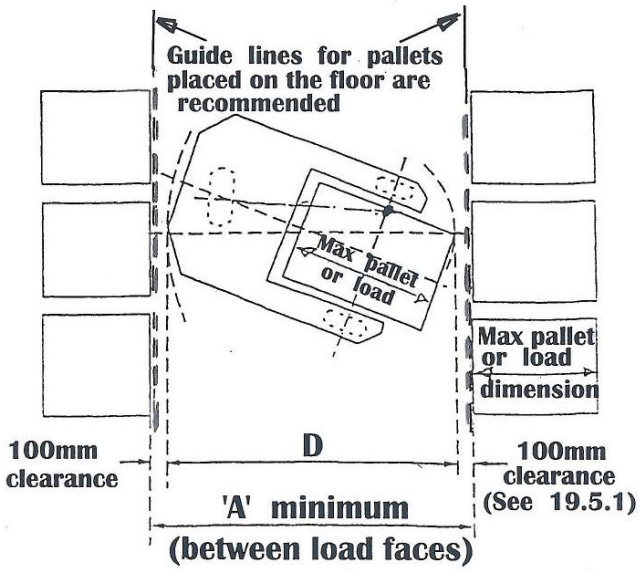


Fig. 8 Minimum required operating rack aisle in case of a 90° turning reach truck

Fig. 9 Torsional buckling of an upright (left sided)

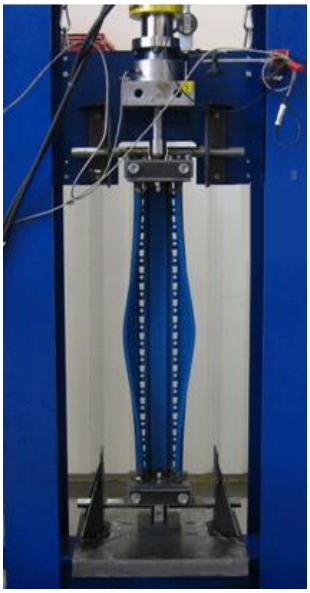


Fig. 10 Distortional buckling of an upright

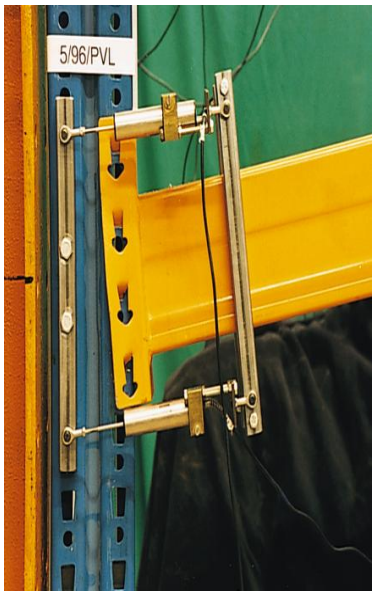


Fig. 11 Test on a hook-in connection

Intended use and actions

For the warehouse building, offices etc. the loads acting on the structure and changing with time have been monitored and measured over many, many years thus making statistical evaluations possible. This has resulted in National and European standards specifying for instance floor, roof, wind and seismic loads. But for Racking and Shelving the typical actions for a specific project are not known, but have to be specified per project and daily operation has to be monitored and controlled by the warehouse management to be not in conflict with the design. The most known specific actions for storage racks are :

- Maximum weight of each “family” of unit loads to be stored.
- Placement loads due to picking and depositing activities.
- Forces induced by rack supported and/or guided stacker cranes.
- Loads on floors directly supported by the racking or shelving caused for instance by workers for order picking activities, conveyor systems, storage of goods and/or mechanical handling equipment (industrial trucks) such as pallet trucks.

It was therefore needed to give guidance to specifiers of the project-related design starting points and to the users to operate daily in accordance with such specifications, to enable safe structural design based upon safe use conditions. Such as sufficient manoeuvrability for lift trucks operated by skilled workers to ensure a sufficient small chance on lift truck collisions.
This resulted in the Code’s of Practice FEM 10.2.03 and FEM 10.2.04 (see Table 1).

Racking is not lift truck-proof
It should be noted that the loads due to placement and retrieval as specified in the FEM Code’s reflect the likely result of good practice. This means that a possible accidental action as a collision by a lift truck is not considered in the structural design, as it is for the warehouse building columns where industrial truck traffic will take place. The reason for not including an accidental collision force is the substantial impact compared to the practices and designs of racking in the past and of today. And therefore also on the costs per unit load (e.g. pallet) location. The ERF Technical Committee, responsible for the ERF/FEM Code’s, and the CEN/TC 344 (see below) has adopted the neglection of possible industrial truck impact, only under the compelling pre-condition that the following is in place:

- Operators are trained and instructed to work in the rack environment concerned.
- Sufficient manoeuvrability for such operators is in place by the presence of e.g. sufficient rack aisle width (see e.g. Figure 8) and compartment dimensions.
- Freestanding protectors at all corners of rack aisles and passage ways.
- The appointment of a person responsible for storage equipment safety (PRSES).
- Regular systematic inspections for collision damage and immediate off-loading in case of damage with “Red” risk level.
- Regular systematic inspection of actual use not being in conflict with the user manual.
- A damage investigation procedure to ascertain potential causes with the intention to eliminate if not substantial reduction of the possibility of reoccurring.

Most calamities with racking in general fork lift truck collisions are involved as well (Figures 12 and 13).

Fig 12. Example of a the result of a progressive collapse

Fig. 13 In case of injuries or a casualty authorities are involved as well

EN Standards

Adjustable pallet racking (APR) is the most frequently used pallet rack type (appr. 80% of realized storage capacity). For APR all relevant FEM Code's of Practice were in place in 2002 : structural design, layout and configuration design, project specification and safe use (FEM 10.2.02, 10.2.03, 10.2.04 and 10.3.01). This was a true landmark : after 20 years of talking and discussing finally the European Racking and Shelving industry had achieved an impressive level of harmonization on very important issues. All principally dealing with the safety of rack operators at work and of the sometimes very costly stored products.
At the same time there was the awareness of substantially increasing through puts in warehouses and developments taken place with regard to legally defined responsibilities. It was felt to be crucial that the ERF/FEM Code's should be widely recognized and accepted by all parties involved in developing, realizing and operating storage equipment as part of the storage system. As said, this was only possible via an official standardization process : "Code's of Practice" had to become European "EN-Standards" via the route of CEN : Installation of a European standardisation committee (CEN/TC 344 – Steel static storage systems), of national so called "mirror committees" under the responsibility of the National Standardisation Bodies (eg AFNOR, BSI, DIN, NBN, NF, NEN, UNI etc.) and the installation of CEN/TC 344 working groups (WG's).

ERF/FEM R&S took the initiative and strongly supported this route to EN-Standards. The FEM Industry Code's of Practice became the first draft as a starting point for the WG's. Experts from the Racking and Shelving industry together with other experts took part in the WG's and national mirror committees. An important number of standards are recently published and a review is given in Table 1. Table 2 shows which other FEM Codes are already published or being developed. In principle it is the intention of ERF/FEM R&S to propose each FEM Code as a first draft for an EN Standard after a "try-out" period of applying the Code in daily practice.

TABLE 1 : REVIEW OF STANDARDS IN THE EN - SERIES "STEEL STATIC STORAGE SYSTEMS"

First draft (*)	**EN Standard**	**Published**
FEM 10.2.02	EN 15 512 : Adjustable pallet racking systems - Principles for structural design	March 2009
FEM 10.3.01	EN 15 620 : Adjustable pallet racking - Tolerances, deformations and clearances	October 2008
FEM 10.2.03	EN 15 629 : Specification of storage equipment	November 2008
FEM 10.2.04	EN 15 635 : Application and maintenance of storage equipment	November 2008
–	pr EN 15 878 : Terms and definitions	December 2008

(*) The FEM Code's with their Commentary are still available

TABLE 2 : REVIEW OF FEM CODE'S OF PRACTICE

PUBLISHED, STILL WORKING ON OR INTENDED TO WORK ON

FEM Code	Title	Published **)
FEM 10.2.05 Draft	Guidelines for working safely with lift trucks in pallet racking installations	October 1999 (Final: 2013)
FEM 10.2.06	The design of hand loaded static steel shelving systems	April 2001
FEM 10.2.07	The design of drive-in and drive-through racking	(Mid 2011)
FEM 10.2.08	Recommendations for the design of static steel pallet racks under seismic conditions	(Mid 2011)
FEM 10.2.09	The design of cantilever racking	(End 2011)
FEM 10.2.10 (9.841 *))	Rail dependent storage and retrieval systems – Interfaces	(Mid 2011)
FEM 10.2.11 (9.842 *))	Rail dependent storage and retrieval systems – Consideration of kinetic energy action due to a faulty operation in cross-aisle direction, in compliance with EN 528 – Part 1: Pallet racking	(Mid 2011)
FEM 10.3.01-1 (9.831-1*))	Basis of calculations for storage and retrieval machines – Tolerances, deformations and clearances in the storage system – Part 1: General, Single deep and Double deep Pallet racking	(Mid 2011)

*) Drafted in liaison with the FEM Product Group "Intra-logistic Systems". Their document numbering starts with "9"

**) Dates between brackets are target dates

Highlighting the EN Standards

EN 15512

- Safety philosophy and design principles such as required, monitored and controlled operational conditions in use.
- Specific loads and load combinations.
- Effect of tolerances and imperfections.
- Modeling of the structural behavior under load considering e.g. the connection to the building floor, specific component behavior, configuration and detailing.
- Calculation rules.
- Standardized test set ups and test evaluation where design need to be assisted by testing.

EN 15620

- Classification of pallet racking.
- Warehouse floor tolerances at hand-over and deformations under load.
- Warehouse building tolerances and deformations.
- Rack tolerances and deformations under load, depending on the way of operation : reach truck, very-narrow-aisle (VNA) truck or stacker crane.
- Guidance to the consideration of VNA truck tolerances and deformations (Figure 5).
- Stacker crane tolerances and deformation : reference also to FEM 9.831-1 / FEM 10.3.01-1.
- Maximum overall dimensions of the unit load, inclusively the effect of expected imperfections of the palletized goods like fanning, bulging or overhanging.
- Minimum required dimensions of rack compartments, distance between double runs, operating aisle width : minimum required clearances to enable sufficient manoeuvrability for safe unit load handling and depositing for trained and instructed operators in order to avoid collisions by the mechanical handling equipment.

- Review of responsibilities of specifiers, suppliers and users to safeguard safe use conditions in accordance with the design.
- Warehouse floor design in accordance with loads induced by racking or shelving and with deformation properties in accordance with the requirements of the storage system.
- Warehouse floor properties with regard to flatness, concrete grade, anchoring, cut-out shrinkage joints, horizontal movement joints.
- Relevant properties of the unit loads to be stored, e.g. pallet type and quality (Figure 14), maximum overall dimensions (Figure 15), asymmetric load?, is a reduced design upright frame load allowed?

Fig. 14 Pallet of far too bad quality

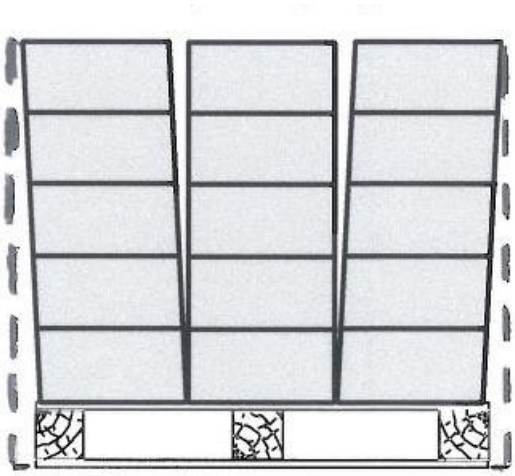


Fig. 15 Example of unit load dimensions larger than the pallet area : "Fanning"

- Actions from pick floors (walkways) and/or raised floors (Figure 16) supported by the racking or shelving : m^2 – load locally and overall, wheel loads from pallet trucks, maximum velocity of the pallet trucks.
- Requirements for pallet back stops. Buffering back stops (“depositing help”) is strongly not recommended because they encourage misuse.
- Seismic site conditions in case of an earth quake area.
- End conditions relevant for layout, configuration and cross section dimensions of the racking (see also EN 15620).
- Free-standing upright protectors.
- Environmental conditions, like temperature, humidity, corrosion aggressivity, good lighting.
- Fire safety requirements, if any.

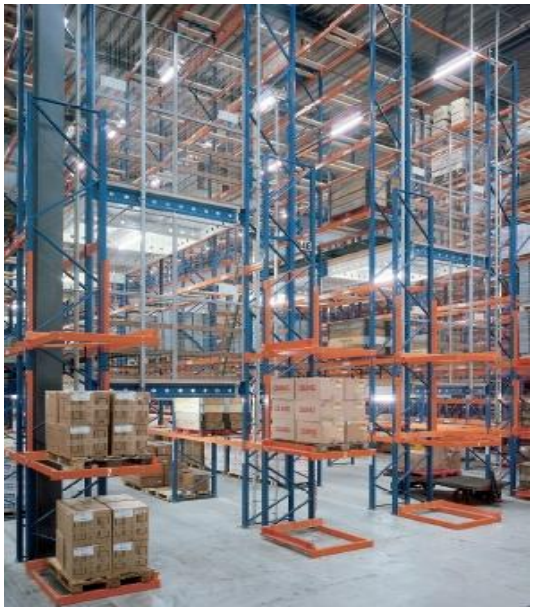


Fig. 16 VNA truck racking also supporting raised floors for order picking

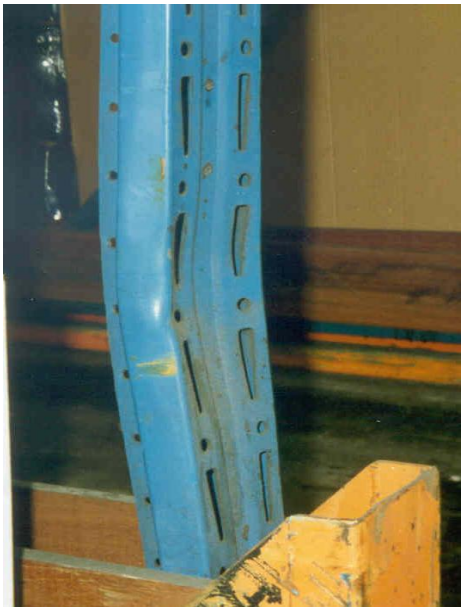


Fig. 17 Not allowed ("Red") damage. Immediate off-loading required

EN 15 635

- Review of responsibilities of racking and shelving suppliers and of users.
- Review of design data to be provided by the user.
- Installation requirements, if done by the user himself.
- Consequences of alterations during use.
- Appointment of a person responsible for storage equipment safety (PRSES) ; Training and instruction.
- Load warning notices.
- Actual use to be monitored and controlled to be not in conflict with the design specifications.
- Consequences of collision damage and immediate reporting when observed.
- Regular systematic inspections and reporting by the PRSES, to enable damage control and maintaining of safe use conditions. As well as expert inspections by a competent third person yearly or as often as needed to be determined by the PRSES, independently from the warehouse management.
- Rules for the measurement and classification of damage to uprights and upright frame bracing, with the requirement of prompt remedial actions. For instance immediately off-loading and isolation from future use until repair, in case of “Red risk” level (see e.g. Figure 17, far above “red risk”).

Responsibilities of Specifiers, Suppliers and Users

The way racking and shelving structures are used in daily practice and the actions imposed on the racking or shelving due to such operations, depends largely on the actual working conditions. The actual level of structural safety depends therefore also on the management system in place. This system should ensure that actual use will not be in conflict with the design and by this to ensure that the minimum level of required structural safety will always be present. This dependence of the "human factor" is specific for racking and shelving compared and different to "normal" load bearing structures as for instance offices or the warehouse building the racking or shelving is installed in. Therefore the EN 15629 and EN 15635 had to and does specify responsibilities of all involved to safeguard safe working conditions at all times: specifiers of the relevant project data and requirements to comply with, suppliers of the storage equipment and the end-users. Figure 18 gives a flowchart from which it becomes clear that the final responsibility lies with the client / end-user: to comply with legislation, to take care of the safety of his workers and his stored goods and to be sure that it is a well spent investment. See also ERF Info Bulletin No 1 ([7]).

An additional responsibility for pallet rack suppliers in Germany and the Netherlands is compliance with their national A-Deviations as specified in Annex I of EN 15512.

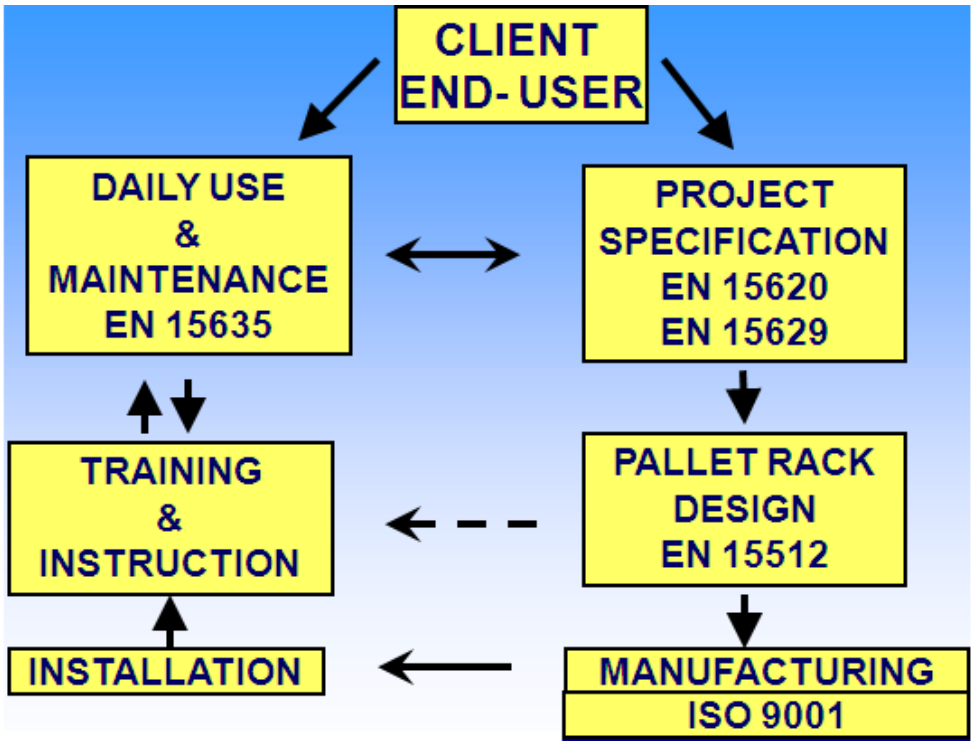


Fig. 18 Scheme showing the important role of the client / end-user in the interactive design towards safe operation

References

[1] EUR Report 7612, European draft recommendations for pallet rack, drive-in and drive-through rack design, Commission of the European Communities, 1983

[2] FEM 4.005, Industrial trucks – 90 stacking aisle width, final draft 1.2005

[3] EN 15 620, Steel static storage systems – Adjustable pallet racking – Tolerances, deformations and clearances

[4] EN 1991-1-1, Eurocode 1: Actions on structures – Part 1-1: General actions – Densities, self weight, imposed loads for buildings

[5] EN 1993-1-1, Eurocode 3: Design of steel structures – Part 1.1: General rules and rules for buildings

[6] EN 1993-1-3, Eurocode 3: Design of steel structures – Part 1. 3: General rules – Supplementary rules for cold-formed members and sheeting

[7] ERF Info 01, Responsibilities of suppliers and users of pallet racking, September 2009